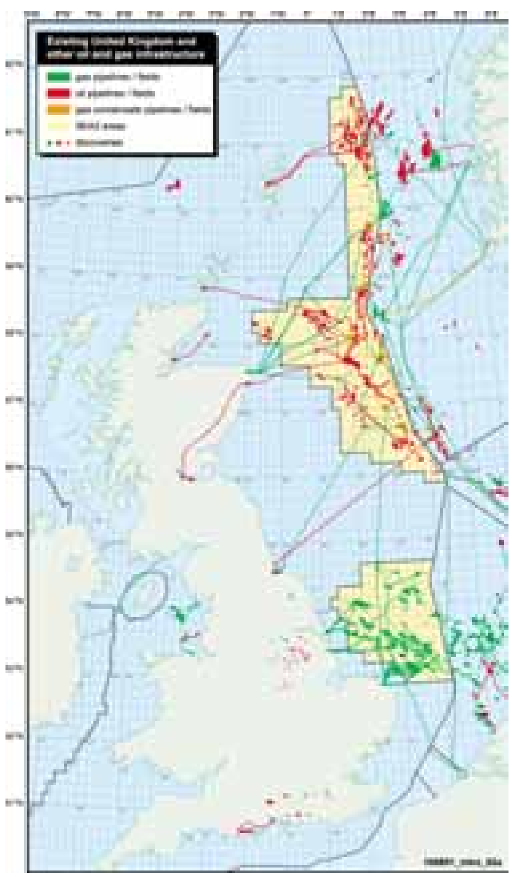
Report to the
Department of Trade and Industry

Strategic Environmental Assessment of the Mature Areas of the Offshore North Sea SEA 2



Consultation Document

September 2001

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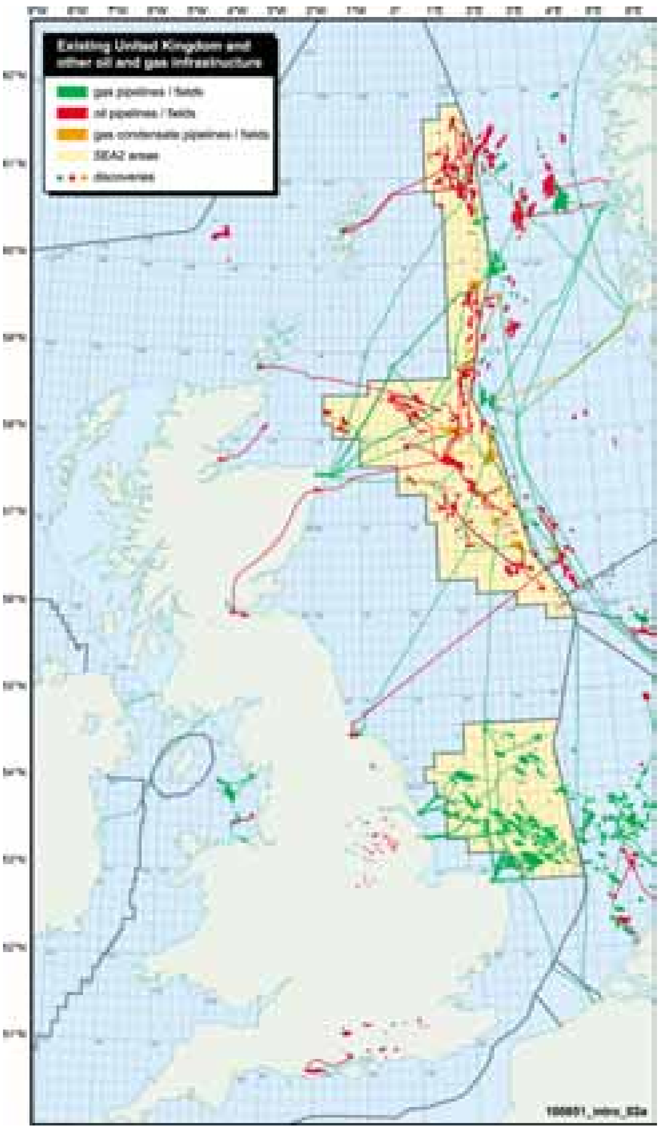
NON-TECHNICAL SUMMARY

Introduction

The UK Department of Trade and Industry (DTI) is conducting a sectoral Strategic Environmental Assessment (SEA) of the implications of licensing parts of the North Sea for oil and gas exploration and production (see Figure 1).

Figure 1 – SEA 2 Areas (shaded in yellow)



This SEA (SEA 2) is the second in a series planned by the DTI, which will in stages, address the whole of UK waters. The first DTI SEA was conducted in 2000 prior to a 19th Round of offshore licensing and covered areas to the northwest of Scotland. SEA 2 is being undertaken in line with the newly adopted European SEA Directive (2001/42/EC) with the aim of considering environmental protection and sustainable development objectives in decisions relating to oil and gas licensing in the North Sea. For the purposes of oil and gas licensing, UK waters are divided into quadrants (1° of latitude by 1° of longitude) with each quadrant further divided into 30 blocks.

The SEA 2 area includes the majority of the UK's existing North Sea oil and gas fields. All bar three of the blocks potentially available have been licensed one or more times previously and subsequently relinquished. Many of the blocks included in the yellow shaded SEA 2 areas are currently under licence.

The proposed action considered by this SEA is the offer of Production Licences for blocks in part(s) of the UK sector of the North Sea through a 20th Round of offshore licensing. The alternatives to the proposed licensing are not to offer any blocks, to license a restricted area, or to stagger the timing of activity in the area.

A required part of an SEA under the SEA Directive is consultation with the public, environmental authorities and other bodies, together with such neighbouring states as may be potentially affected. To facilitate consultation, this assessment document is available in a number of different formats and media. For details see the SEA website (www.habitats-directive.org) or contact the SEA Coordinator (Ms Christine Weare, DTI Oil and Gas

Directorate, 86-88 Atholl House, Guild Street, Aberdeen, AB11 6AR). The formal public consultation phase extends for ninety days from the date of publication.

The process used to conduct this SEA draws on earlier studies commissioned by the UK Government, the European Commission and other organisations, together with previous assessments of potential oil and gas licensing elsewhere. In addition, the experience gained and lessons learned from the first DTI SEA have been used to refine the process. Improvements made have included involving stakeholders in the scoping stage of the SEA (through a dialogue session), and the establishment of a Steering Group drawn from a range of stakeholders, to provide technical and general advice to facilitate the DTI SEA process. The Steering Group also participated in a workshop to identify which oil and gas industry activities might potentially result in significant effects. The DTI commissioned a number of desk-top studies covering a range of topics together with field surveys of specific seabed features of potential conservation interest. The studies and survey information have been used in the preparation of this document.

The potential occurrence of hydrocarbon reserves is assessed through seismic survey. However, the location of commercial hydrocarbon reserves can only be confirmed by drilling a well, and for the North Sea the success ratio is about 1 in 5 (that is five wells drilled to discover one field). Consequently, there is uncertainty in predicting the scale and precise location of hydrocarbon related activities which could follow the proposed licensing. In order to conduct the SEA, possible development and activity scenarios have been prepared for consultation purposes by the DTI based on the geology and results of past exploration. These involve up to 21 exploration wells and the development of up to five new producing fields, most probably subsea wells tied back to adjacent, existing oil and gas fields. Only large finds could justify development by stand alone facilities. This activity would represent a small proportion of total oil and gas exploration and production in the UK, which for existing licensed areas in the North Sea, is projected to involve around 200 to 500 exploration/appraisal wells and up to 90 field developments over the next 10 years. The actual scale of activity is dependant on a variety of factors and in particular, oil/gas prices and tax regime.

The North Sea Environment

Water depths and seafloor

The North Sea is a large shallow sea with a surface area of around 750,000km^2. Water depths gradually deepen from south to north and the main topographic features are the Dogger Bank, marking a division between the southern and central North Sea, the Fladen/Witch Ground, a large muddy depression between the central and northern North Sea, and the Norwegian Trough, a deep water channel extending from the mouth of the Baltic Sea to the Norwegian Sea.

Tides and currents

Tidal currents in offshore waters decrease in velocity from south to north. The chief water movements are influxes of Atlantic water through the Fair Isle Channel (between Orkney and Shetland) and to the east of Shetland, and a major outflow through the Norwegian Trough. Water circulation in the North Sea is anticlockwise, with an eddy forming over the Fladen Ground. The water column of the southern North Sea remains mixed throughout the year while to the north it becomes layered (stratified) in summer, which effectively isolates surface and near bottom waters until autumn gales break down the stratification.

Seabed sediments

Seabed sediments over the majority of the North Sea are sand or mud, or a mixture of the two. Typically, sandier sediments are found in the south and in coastal waters, with muddy sediments present in the deeper areas of the central and northern North Sea. Pockmarks (shallow seabed depressions formed from the seepage of gas) are found in muddy areas of the North Sea in particular the Fladen and Witch Grounds. Most pockmarks are relict features but a few continue to leak natural gas and may contain carbonate rocks which provide a habitat for encrusting and other surface living seabed animals.

Seabed animals

The seabed fauna of the North Sea varies mainly according to sediment type and water temperature range. The fauna is diverse, but the SEA 2 areas do not appear to contain any species of particular conservation concern. The DTI commissioned a survey of habitats of potential conservation interest within the SEA 2 areas. These habitats are defined by the EU Habitats Directive, and in those relevant to the SEA 2 areas are *sandbanks in shallow water* and *submarine structures made by leaking gases*. Preliminary results from the survey did not reveal the presence of any outstanding animal species or communities. However, within the SEA 2 areas it is possible that some sandbanks or submarine structures made by leaking gases may be designated as conservation sites in the future as representative examples of those habitats.

Food web

The North Sea is a very productive area with a "food web" linking the plankton (the source of much of the initial productivity) with fish, birds, marine mammals, other water column animals and the fauna of the seabed.

Seabirds

The North Sea and its coastline support many internationally important numbers of seabirds. Seabird vulnerability to surface pollution varies throughout the year with peaks in late summer, following breeding when the birds disperse into the North Sea, and during the winter months with the arrival of over wintering birds. In general, seabird vulnerability is highest in inshore waters.

Marine mammals

The waters of the North Sea support a wide variety of marine mammals, with internationally important numbers of grey and common seals. A wide range of cetaceans has been sighted in the North Sea, the most common being the harbour porpoise, minke whale and white beaked dolphin. Bottlenose dolphins from the nearshore population of the Moray Firth are rarely seen far offshore.

Fish and fisheries

Many different types of fish are found in the North Sea with diversity being higher in the central and northern North Sea and in inshore waters. The North Sea is one of the world's most important fishing grounds. There are extensive fisheries for herring and mackerel in addition to shellfisheries for Norway lobster, crab and scallop and industrial fisheries for sandeel and Norway pout. The central and northern North Sea support a mixed demersal (seabed) fishery for cod, haddock and whiting, with plaice and sole targeted in the south.

Contamination

The North Sea is predominantly surrounded by densely populated land with extensive industry and agriculture. River runoff, atmospheric fallout and the past dumping of wastes at sea has resulted in widespread contamination of the marine system with a wide range of chemicals and nutrients. These contamination levels are typically very low but in some (usually coastal) areas concentrations can be high enough to result in marked biological effects. The discharge of oil based drill muds and rock cuttings from oil and gas well drilling has resulted in numerous piles of cuttings on the seabed in the northern and central SEA 2 areas which are localised hotspots of contamination. Such discharges have now ceased in the North Sea and the main source of contaminants from oil industry activities is produced water from existing activities in the SEA 2 areas.

Other users

In addition to the oil and gas industry and commercial fisheries, the other major user of offshore areas is shipping – and the North Sea (particularly the southern part) contains some of the busiest shipping lanes in the world.

Surrounding coasts

The North Sea coastline has many sites of conservation, economic and human interest. In total there are 135 sites designated for their bird life. Large stretches of the coastline are popular tourist destinations, due to their coastal landscape, cultural heritage, wildlife and opportunities for water-based activities. There are no offshore (beyond 12 nautical miles from shore) conservation sites designated at present, although a process is underway to identify potential sites under the EU Habitats Directive.

Assessment

Introduction

An assessment of the possible implications of oil and gas activity in the SEA 2 areas was conducted and the findings are discussed in detail in Section 10 of the main report. A summary of the key oilfield activities and associated potential sources of effect is shown on the facing page (Figure 2). While all sources of emissions, discharges and disturbance could potentially contribute to local, regional and global effects, the following were identified as key issues requiring further consideration in the SEA.

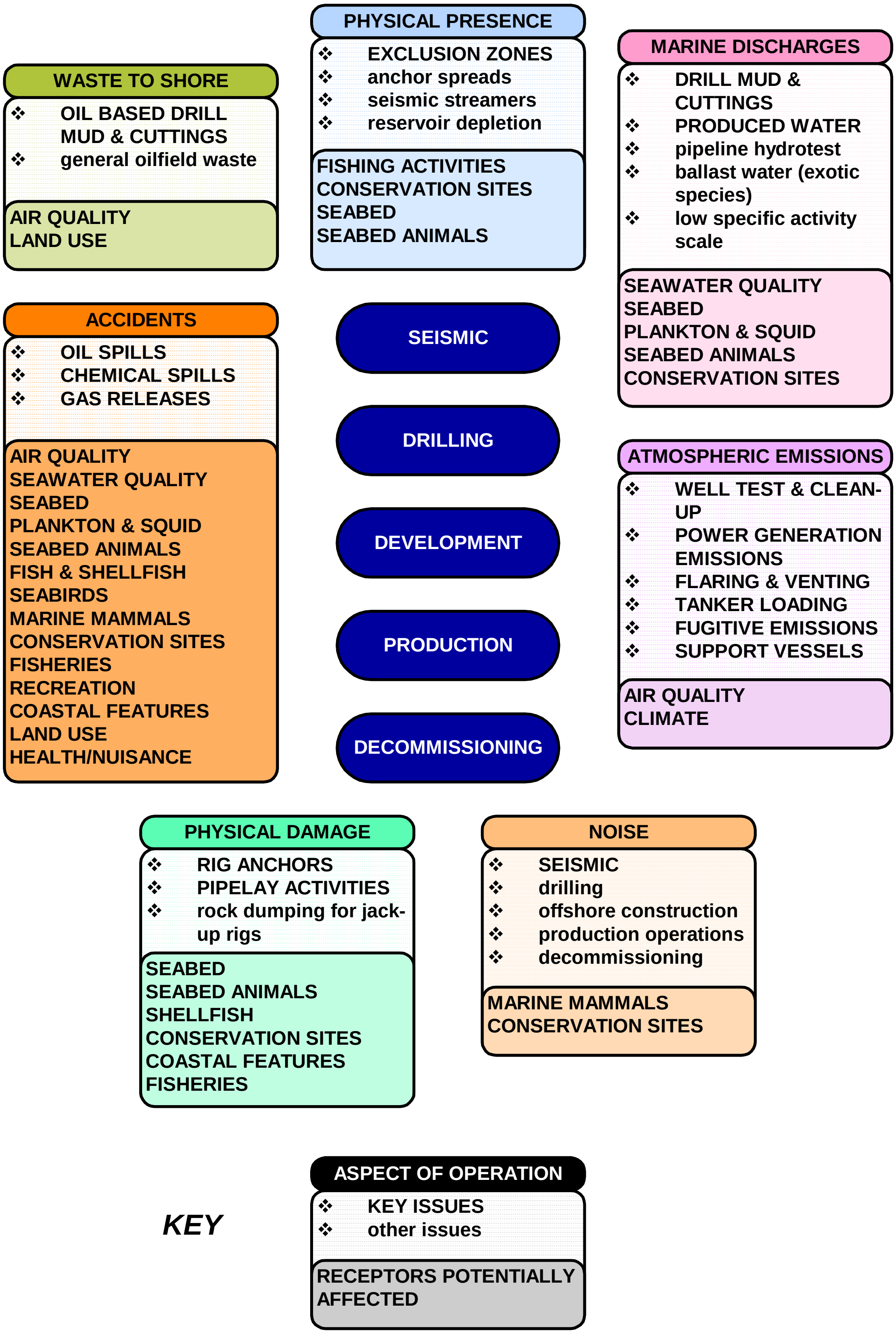
Noise

While seismic surveys could potentially affect minke whale, harbour porpoise, and white-beaked dolphin, it is considered unlikely that physical damage or significant behavioural disturbance of marine mammals will result from activities following the 20th Round licensing or those in existing licensed areas.

Physical damage

The predicted scale of physical disturbance of the seabed, resulting from activity scenarios for potential SEA 2 licensed areas, is very small in comparison with the total area of the North Sea. Recovery of affected seabed is expected to be rapid and it is concluded that the potential incremental and cumulative effects of physical disturbance are not likely to be significant.

Figure 2. – Summary of key oilfield activities and associated potential sources of environmental effect



Physical presence

Exclusion from large areas of sea by the presence of rigs or installations could result in effects on commercial fishing, as could the presence of snagging hazards associated with pipelines or debris. However, the small scale of such effects from SEA 2 licensing indicates that the number of exclusion zones that may be established is unlikely to cause significant economic impacts. The oil industry and UK fishing industry consultation, liaison and compensation mechanisms, should serve to mitigate any conflicts.

Discharges

Concerns over produced water discharges include the cumulative effects of oil and the possible biological effects of residual chemicals. However, incremental contributions from newly licensed SEA 2 blocks would be minimal (predicted 2.4% of total North Sea discharges of produced water), or negligible if produced water is reinjected, which is the disposal method of choice for new developments.

Discharges of water based muds and cuttings in the North Sea have been shown to disperse rapidly with minimal ecological effects. Dispersion mechanisms could, in theory, lead to localised accumulation for example in pockmark basins and sandbank areas (in the central and southern North Sea respectively) although this is considered unlikely to be detectable.

Atmospheric Emissions

Potential environmental effects of acid gas and greenhouse emissions are, respectively, regional and global in nature. Local environmental effects of atmospheric emissions are not expected to be significant in view of the high atmospheric dispersion associated with offshore locations. Incremental contribution to regional and global effects will not be significant.

Significant combustion emissions from oil or gas flaring are not expected from potential developments in the SEA 2 licence areas, in view of regulatory controls and commercial considerations. Similarly, combustion emissions from power generation would only be a minor contribution to oil industry, other industry or national totals. Overall, peak annual emissions from production in newly licensed SEA 2 blocks are estimated as 2.4% of current (2000) emission levels from offshore oil and gas fields and associated onshore terminals.

Wastes to shore

Oil based muds are needed to drill through some of the rock types found in the SEA 2 areas. Rock cuttings contaminated with oil based mud are no longer discharged to sea and either reinjected into underground rock formations or shipped to land to undergo treatment prior to onshore disposal. The environmental management of treatment and disposal of such cuttings, both onshore and offshore, is strictly controlled. The incremental volumes of cuttings associated with 20th Licensing round activities will be small in the context of overall waste disposals from offshore.

Accidental events

The incremental risk of oil spills associated with exploration and development in the SEA 2 areas is low, particularly in the southern gas fields. Seabirds offshore are vulnerable to even small spills, particularly in late summer and autumn when many auks are flightless. In the event of a large spill of persistent oil, coastal oiling could occur on the adjacent North Sea coastline. However, risk assessments have been carried out for existing activities in SEA 2 areas and contingency measures put in place which mitigate risks to tolerable levels.

The persistence and biological effects of most chemicals used in the oil and gas industry are equivalent to or lower than those of oil, and similar risk assessment conclusions will therefore apply to chemical spills.

The environmental and safety consequences of accidental gas releases depend both on scale, and on whether release gas ignites. The major constituent of natural gas is the greenhouse gas methane, and gas releases on all scales will therefore contribute to global climatic effects. Any foreseeable contribution of methane, including a sustained gas blowout, to global emissions will be negligible.

Cumulative effects

Cumulative effects from activities resulting from the proposed 20th Round licensing, have the potential to act additively with those from other oil and gas activity (including both existing activities and new activities in existing licensed areas). Synergistic effects are the potential effects of activities which act additively with those of other human activities (eg fishing and crude oil transport). Cumulative effects in the sense of overlapping "footprints" of detectable contamination or biological effect were considered to be either limited (physical presence, noise, physical damage, emissions, discharges), or unlikely (accidental events). No synergistic effects were identified that were considered to be potentially significant.

Transboundary effects

SEA 2 areas adjoin the continental shelf areas under the jurisdiction of Norway, Denmark, Germany and the Netherlands. Prevailing winds and the residual water circulation of the North Sea will result in the transboundary transport of discharges to water (including particulates) and atmospheric emissions.

The environmental effects of underwater noise, produced water, drilling discharges, atmospheric emissions and oil spills may be able to be detected physically or chemically in the marine environments of adjacent states, particularly from activities undertaken in SEA 2 areas close to international boundaries. The scale and consequences of environmental effects in adjacent state territories will be comparable to those in UK territorial waters.

Socio-economic effects

Economic modelling indicates that if oil and gas prices remain at their current levels then more than 67.9 million extra cubic metres of oil (424 million barrels) and 22.4 billion extra cubic metres of gas (790 billion cubic feet) may be extracted as a result of 20th round licensing. These volumes would be less if the prices were lower. Over a ten year period almost £925 million more may be spent on development and £881 million more on operating costs than would be the case without relicensing of the SEA 2 areas.

Forecasted tax revenues to the UK Government are up to £797 million over a 20 year period. However, if the oil price drops significantly, under the current tax regime Government revenues from the 20th round are likely to be negative when tax relief for exploration and appraisal activities is given.

The forecast activity could result in a peak of 8,977 total extra jobs in the UK by 2009, of which 858 are estimated to be direct and the remainder in support services and industry.

Wider policy objectives

No significant effect of activities following the proposed 20th Licence Round are predicted on UK Government or other wider policy and commitments; specifically

- Energy Policy
- Common Fisheries Policy
- Commitments under the EU Urban Waste-Water and Water Framework Directives
- National Waste Strategy
- Kyoto Agreement
- MARPOL
- OSPAR
- Natura 2000 and RAMSAR programmes
- UN Convention on Biological Diversity and UK Action Plans

Conclusions

Synergistic effects of exploration and production activities with those of other activities in the area are not predicted. A number of potential sources of effects could conceivably be detectable across national boundaries with other European states; however, only oil spills are regarded as having the potential to result in significant negative environmental effects.

The DTI as licensing authority and offshore environmental regulator has at its disposal a range of powerful permit based legislation and other environmental control mechanisms, which provide a sound basis for the regulation of future oil and gas activities in the North Sea. Project-specific permitting allows due attention to be given to the protection of environmental sensitivities (eg seasonal seabird vulnerability, and actual or potential conservation sites), other users of the sea and other marine resources. These permits can and do where necessary specify timing, spatial and activity constraints relevant to the sensitivities of the area. No specific additional controls were identified as being essential. A number of gaps in information and understanding relevant to potential environmental sensitivities have also been identified, and may be addressed most efficiently through continuation of ongoing co-operative industry and government programmes including broad scale environmental monitoring.

The overall conclusion of the SEA is that there are no overriding reasons to preclude the consideration of further oil and gas licensing within the SEA 2 areas.

1 INTRODUCTION AND BACKGROUND

1.1 Introduction

Strategic Environmental Assessment is a process of appraisal through which environmental protection and sustainable development may be considered, and factored into national and local decisions regarding government (and other) plans and programmes.

This document reports on an assessment of the environmental implications of licensing for oil and gas exploration and production parts of the UK offshore North Sea (see Figure 1.1 which shows the area within which unlicensed Blocks will be considered for licensing) as part of a Strategic Environmental Assessment process.

Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment (hereafter called the SEA Directive) entered into force on July 21 2001. Member States are required to comply with the Directive before 21 July 2004.

The stated objective of the Directive is *"to provide for a high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation and adoption of plans and programmes with a view to promoting sustainable development, by ensuring that, in accordance with this Directive, an environmental assessment is carried out of certain plans and programmes which are likely to have significant effects on the environment."*

The United Kingdom is also a signatory to the *"Convention on access to information, public participation in decision-making and access to justice in environmental matters"* (hereafter called the Aarhus Convention) which is expected to enter into force at the end of October 2001.

Article 1 of the Aarhus Convention states that *"In order to contribute to the protection of the right of every person of present and future generations to live in an environment adequate to his or her health and well-being, each Party shall guarantee the rights of access to information, public participation in decision-making, and access to justice".*

A required part of an SEA is consultation with the public, environmental authorities and other bodies, together with such neighbouring states as may be potentially affected. The SEA is documented in this volume (available in a variety of media) for use in consultation. A range of commissioned studies and reports support the SEA – see Section 1.5.

1.2 Licensing context and SEA sequence

Exploration and production in the oil and gas industry is regulated primarily through a licensing system – see Section 3 for more information. Production Licences grant exclusive rights to the holders to "search and bore for, and get, petroleum" in specific areas. The first offshore (seaward) UKCS Licensing Round took place in 1964 – see Section 3. Seaward licensing rounds have been held roughly every two years. In January 2000, there were 109 oil fields, 87 gas fields and 16 condensate fields in production offshore on the UKCS.

The licensing system is managed by the DTI Oil and Gas Directorate's Exploration and Licensing Branch. Prior to the adoption of the SEA Directive, the Department of Trade and Industry (DTI) had taken a policy decision to set in train a process to allow the intent of the SEA Directive to be met for future UKCS oil and gas licensing.

The first UK offshore Strategic Environmental Assessment (SEA 1) was conducted in preparation for the 19th Licensing Round, covering the formerly disputed area between UK and Faroese waters (an area known as the "White Zone").
The Department of Trade and Industry (DTI) is now undertaking a 2nd Strategic Environmental Assessment (SEA 2) addressing the implications of licensing for oil and gas exploration and production, some unlicensed parts of the offshore North Sea – see Figure 1.1 to the right. SEA 2 builds on the lessons learned in conducting the 1st SEA and takes into account the requirements of the SEA Directive together with those of the Aarhus Convention on public participation.

For the purpose of licensing, the UKCS is divided into quadrants of 1° of latitude by 1° of longitude (except where the coastline, "bay closing line" or a boundary line intervenes). Each quadrant is then further subdivided into 30 blocks each of 10 x 12 minutes each with an average size of 250km^2. Production licenses may be issued for single or groups of Blocks and may be offered again following relinquishment – see Section 3.

The bulk of the SEA 2 area shown above, is either already licensed, or has been licensed one or more times in the past and only three of the *ca.* 400 unlicensed blocks under current consideration have not been previously licensed. The area contains the majority of existing producing installations.

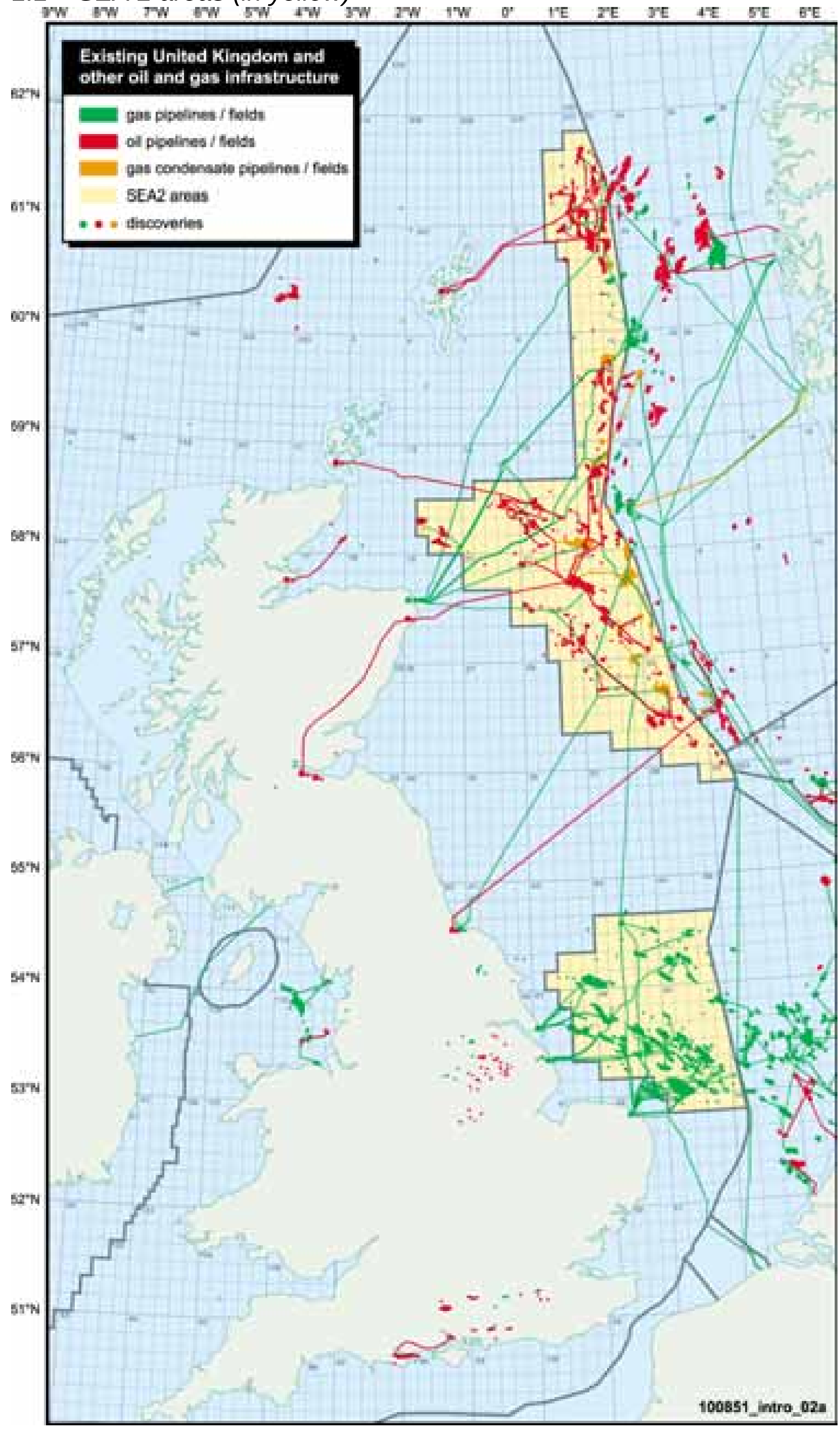
1.3 Scope and purpose of the SEA

The proposed action is to offer Production Licences covering part of the UK sector of the North Sea through a 20th Round of offshore licensing. The purpose of this SEA is to consider the environmental implications of this action and its alternatives and the potential exploration, development and production activities which could result.

The SEA aimed to consider the following:

- The environmental protection objectives, standards etc established for the area relevant to the approval and subsequent implementation of the proposed action
- Any existing environmental problems in the area which may be affected by the proposed action
- Potential activities in the area
- The main mitigatory measures and alternatives investigated
- An assessment of the likely significant environmental consequences of the proposed action and its alternatives including the potential for cumulative, synergistic and transboundary effects
- Proposed arrangements for monitoring the environmental effects of the proposed action and post decision analysis of its environmental consequences
- Difficulties encountered in compiling the information and a discussion of uncertainty of impact predictions

Figure 1.1 – SEA 2 areas (in yellow)



The assessment considers the potential environmental effects of opening the area to oil and gas exploration and production activity in terms of continued or future non-oil and gas uses, environmental contamination, biodiversity and conservation of the area. The wider policy issues of continued oil and gas production from the UKCS and sustainable development of the overall national hydrocarbon reserves are not considered since these are subjects for a different appraisal forum.

This consultation document was prepared by independent consultants Hartley Anderson Limited on behalf of the DTI with contributions from Dr Sue Gubbay (independent) and Professor Alex Kemp and Ms Linda Stephen of the Department of Economics of Aberdeen University and input from the SEA Steering Group, the DTI and Geotek Limited together with the underpinning studies summarised in the subsequent sections of this document.

1.4 Organisation of the consultation document

The consultation document comprises 12 Sections with a glossary and a non-technical summary. Figures and tables are interspersed throughout the document.

The **non-technical summary** is intended as a comprehensive stand alone summary of the SEA, its findings and conclusions.

Section 1 Introduction and Background provides both a context and guide to the main body of the report.

Section 2 Strategic Environmental Assessment Process provides an overview of the various stages and activities leading up to this public consultation phase.

Section 3 Regulatory Context summarises the requirements of the SEA Directive, the oil and gas licensing process together with an overview of the development of environmental legislation in relation to the oil and gas industry offshore.

Section 4 Activities describes the alternatives to the proposed action and the activities arising (and more fully described in a supporting document, SD_002, available on the SEA website).

Section 5 Physical and Chemical Environment describes the geology, sediments, climatic conditions and oceanography of the area, together with a consideration of the existing levels of contamination and their sources.

Section 6 Ecology addresses the biological features of the area together with their ecological importance and sensitivity to oil and gas activity.

Section 7 Potential Offshore Conservation Sites specifically considers habitats of relevance in the context of *The Offshore Petroleum Activities (Conservation of Habitats) Regulations, 2001* which recently entered into force.

Section 8 Existing Human Activity describes the commercial and other human interests and activities in the offshore area.

Section 9 Coastal Resources Potentially Relevant to the SEA 2 summarises coastal resources and conservation interests in adjacent areas.

Section 10 Consideration of the Effects of Licensing describes the method used to screen potential effects together with a more detailed consideration of those environmental interactions with the potential to cause significant effects and including cumulative, synergistic and transboundary effects. Mitigation measures are also considered.

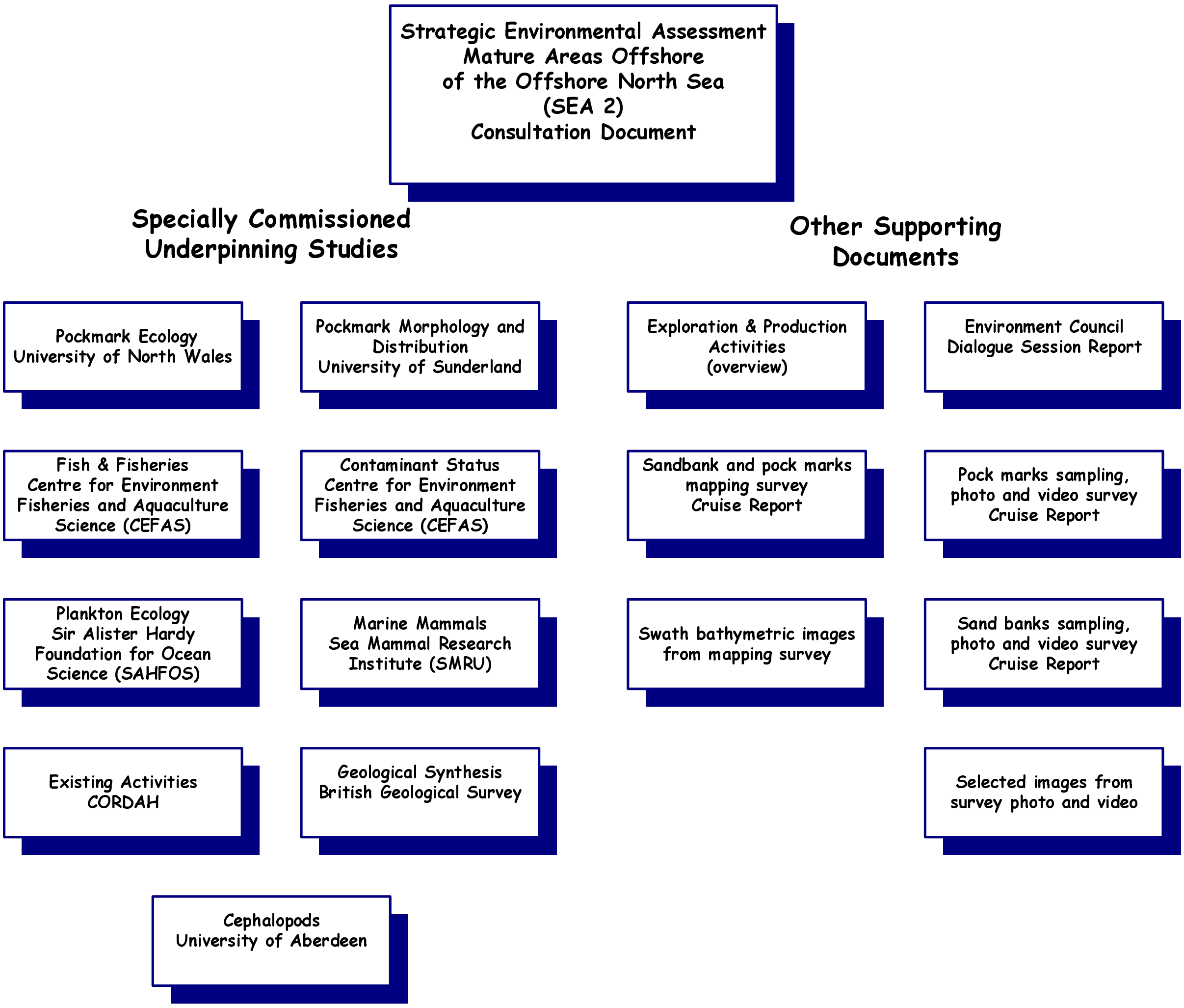
Section 11 Conclusions provides an overall conclusion regarding the likely implications of the proposed licensing and alternatives, together with recommendations for mitigation and monitoring and gaps in understanding relevant to the process.

Section 12 References lists the data sources used in the conduct of the SEA 2 and referenced in the report.

1.5 Supporting studies and documents

As part of the SEA 2 process a series of seabed surveys, independent studies and syntheses were commissioned. These reports underpin the assessment documented in this report and are available for review from the DTI's SEA website (www.habitats-directive.org) – see Figure 1.2 below.

Figure 1.2 – SEA Consultation Document, Supporting Studies and Surveys



In addition, a study of the potential socio-economic effects of further licensing within the SEA 2 areas was commissioned from the Department of Economics , Aberdeen University. This report is not available on the SEA website but the findings of the study are included in Section 10 of this consultation document as a personal communication from Professor Alex Kemp and Linda Stephen.

Links to additional information sources of potential interest or use in considering the SEA 2 consultation document are included on the SEA 2 website.

2 SEA PROCESS

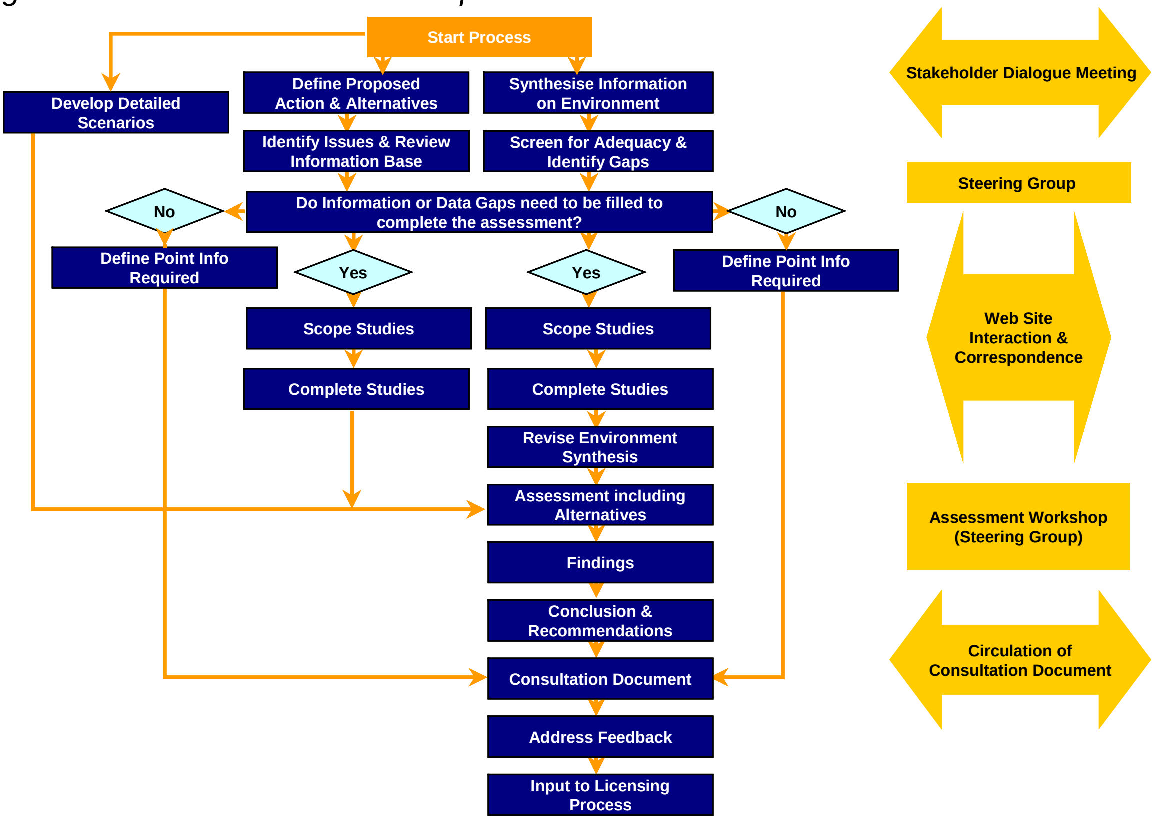
2.1 Introduction

SEA 1 was conducted during 2000 before the finalisation of the EU SEA Directive. The Consultation Document was arranged in three volumes and disseminated via the DTI's web page. Feedback received during the consultation on the first SEA and from the Stakeholder Dialogue Session has been incorporated into a revised process for SEA 2.

2.2 Overview of the SEA process

A summary of the SEA 2 process is given below in Figure 2.1.

Figure 2.1 – Overview of the SEA process



A Steering Group for the SEA process was established comprising representatives of a range of stakeholders and experts in the field of Environmental Impact Assessment, Strategic Environmental Assessment, environmental management, conservation and regulations. The idea behind the steering group was to give the DTI a broad range of opinion on the SEA process from a group of independent stakeholders. The Terms of Reference for the Steering Group are:

Objective: to provide objective technical and general advice to facilitate the DTI SEA process, to promote stakeholder involvement and to achieve timely preparation of quality documents to inform licensing decisions.

Specifically the Steering Group will:

- Input to the scoping, consultation and methodology selection for the SEA
- Critically review proposed data collection objectives, scope and methods
- Participate in the assessment phase of the SEA
- Critically review the drafts of the SEA documents
- Promote stakeholder awareness and engagement in the SEA process

The Steering Group was integral to the identification of key issues resulting from the potential licensing of the SEA 2 areas through an assessment workshop, prior to the drafting of the assessment document.

Responsibility for the publication of the assessment document rests with the DTI, and the steering group have made only a preliminary review of it. Members of the steering group, as individuals and through their organisations, may comment on the proposed licensing and the consultation materials (including this document) during the consultation phase, and are encouraging others to do likewise.

2.3 Scoping the SEA

The scoping of SEA 2 took the first DTI SEA as a starting point, including the feedback received during the consultation stage. A draft contents list and proposed approach were presented to a wide range of stakeholders at a stakeholder dialogue session (see below) and their input in terms of suggestions, issues and concerns was incorporated into a revised outline for the document. This outline was then reviewed and amended by the Steering Group.

At an early stage of scoping it became evident that there was insufficient information available to assess the importance or potential effects on shallow sandbanks and seabed pockmarks. Accordingly, a survey was planned and the scope and methodology discussed with the Steering Group. The survey took place in April and June 2001 (see Section 2.5 below).

2.4 Stakeholder dialogue session

A stakeholder dialogue session was organised and facilitated by the independent Environment Council on behalf of the DTI and held in London on 9 May 2001.

The dialogue session had two main functions. Firstly, to raise awareness of the DTI's proposals to conduct a series of SEAs covering the UK Continental Shelf (UKCS) prior to decisions on further large scale licensing and secondly, to contribute to the scoping of SEA 2.

A wide variety of potential stakeholders, drawn from UK and other regulators, government advisers, local authorities, other industry representatives, academics and NGOs were invited to the session. Delegates to the meeting were asked to contribute:

- Issues and concerns which should be addressed in the SEA including areas of the UKCS that may require special protection or consideration
- Relevant information sources and perceived gaps in understanding, both of the natural environment and the effects of oil and gas activities
- Suggestions on ways to advance the consultation process

The meeting was attended by some sixty stakeholders and included presentations on SEA 1 and the feedback received, proposals on the process to be used for SEA 2, together with discussion of the potentially significant effects of offshore oil and gas activity. A wide range of views and opinions were expressed, and advice offered, which has been considered and used in the scoping of the SEA 2 approach, document and consultation methods. A report of the meeting was produced by the Environment Council (reproduced as supporting document SD_001 on the SEA website).

2.5 Studies and surveys

Preliminary review of the availability of information to support preparation of the environment description for this assessment (Sections 5 – 9), with input from the SEA 2 Steering Group, concluded that a number of commissioned studies were required. These studies were commissioned either to provide expert reviews in areas for which synoptic review had not previously been published; where it was apparent that new data was available but not yet published; or where an expert review was judged to be necessary.

2.5.1 Studies

The following studies were commissioned:

Pockmarks in the UK Sector of the North Sea (TR_001) **-** This report reviews the distribution and character of pockmarks - shallow seabed depressions - which are common in the area of the North Sea to the north-east of Scotland known as the Fladen Ground and are potentially features which could be designated as offshore conservation sites. The report was prepared by Dr Alan Judd (University of Sunderland), an authority on seafloor pockmarks.

Biological aspects of pockmarks in the UK Sector of the North Sea (TR_002) **-** The biological aspects of pockmarks found in the North Sea are reviewed. The report was written by Professor Paul Dando (School of Ocean Sciences, University of Wales, Bangor).

Contaminant Status of the North Sea (TR_003) **-** This report draws on a wide range of data sources to provide an overview of the chemicals used in the offshore oil and gas industry, of the chemicals already in the environment and of those released into the environment from other sources. The report was prepared by scientists from the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), with additional data supplied by the Fisheries Research Services Marine Laboratory in Aberdeen.

North Sea Fish and Fisheries (TR_004) **-** This report reviews the impact of human activity on fish and fisheries in the North Sea. The report was prepared by scientists from the

Centre for Environment, Fisheries and Aquaculture Science (CEFAS) Lowestoft Laboratory with additional data supplied by the Fisheries Research Services Marine Laboratory in Aberdeen.

Overview of plankton ecology in the North Sea (TR_005) **-** This report gives an overview of the phytoplankton and zooplankton community composition in the North Sea and how this has fluctuated through the latter half of the 20th century in response to environmental change. The study is based on a unique long-term dataset of plankton abundance in the North Atlantic and the North Sea acquired by the Continuous Plankton Recorder (CPR). The report was prepared by scientists from the Sir Alister Hardy Foundation for Ocean Science (SAHFOS), which specialises in the study of plankton in the North Atlantic and the North Sea.

Marine mammals in the North Sea (TR_006) **-** This report describes distribution and abundance of marine mammals in the North Sea, their ecological importance, sensitivity to disturbance contaminations and disease, bycatch and other non-oil related management issues, and conservation framework. The report was prepared by scientists from the Sea Mammal Research Unit, Gatty Marine Laboratory, University of St Andrews.

Human activities in the North Sea (TR_007) **-** This report considers human activities in the North Sea which might have an impact on, or themselves be affected by, further oil and gas developments in the SEA 2 areas. The activities include shipping, energy (both existing oil and gas developments and renewable energy), telecommunications, military activities, waste disposal, dredging and aggregate extraction, marine archaeological sites and wrecks. The report was produced by Cordah Ltd, a multi-disciplinary environmental management consultancy.

North Sea Geology (TR_008) **-** This report presents a review of (1) the evolution of deeply-buried sediments with reference to petroleum geology and production-related seabed subsidence (2) the evolution of shallow and seabed sediments with reference to present sediment distributions and seabed features (3) the evidence for possible hydrogeological exchange across selected onshore/offshore areas and (4) the history of earthquakes and the hazard that they may pose. The report was prepared by scientists from the British Geological Survey (BGS).

Overview of Cephalopods relevant to the SEA2 Area (TR_009) **-** This report provides an overview of cephalopods – squid, octopus, cuttlefish – in the SEA 2 areas. The report was prepared by Iain Young of the Department of Zoology, University of Aberdeen, where a group specialises in cephalopod research.

The commissioned studies listed above, are available for download as pdf files from the SEA website or in paper copy from the SEA Coordinator (Ms Christine Weare), DTI Oil and Gas Directorate, 86-88 Atholl House, Guild Street, Aberdeen, AB11 6AR.

In addition, a study on the socio-economic effects of proposed SEA 2 licensing was commissioned from the Department of Economics, University of Aberdeen. The study provided forecast information on probable activity levels, capital expenditure, tax revenues and employment resulting from exploration and production in the proposed 20th Round areas which is included in the consideration of the implications of licensing in Section 10 of this document.

2.5.2 Sandbank and pockmark surveys

In order to acquire additional information regarding specific seabed features within the proposed licensing area a dedicated survey programme was commissioned by DTI. The survey specifically addressed pockmarks, and offshore shallow (< 20m) sand areas including linear sandbanks and the shallow parts of the Dogger Bank. The survey was carried out in three legs between April and June 2001, comprising a geophysical leg and biological sampling leg from *S/V Kommandor Jack* and a sampling leg over crests of the Norfolk Banks using the shallow draught vessel *R/V Vigilance.* Following high resolution swath bathymetry and shallow profiling during the geophysical leg, seabed sampling was carried out using a Van Veen grab in the sandbank and Dogger Bank areas, and a Calvert box corer in the pockmark areas. Video and stills photographs were also obtained in all three survey areas.

2.6 Further consultation process

The consultation document and supporting documents will be available for review and comment for a period of 90 days from the middle of September 2001. The documents are being made available via the SEA website or via CD or printed copy. Comments and feedback may be made via the website or via fax or letter to the contact in Section 2.5.1 above.

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3 REGULATORY CONTEXT

3.1 SEA Directive

The Treaty establishing the European Community, *"provides that Community policy on the environment is to contribute to,* inter alia*, the preservation, protection and improvement of the quality of the environment, the protection of human health and the prudent and rational utilisation of natural resources and that it is to be based on the precautionary principle."*

The Treaty also provides *"that environmental protection requirements are to be integrated into the definition of Community policies and activities, in particular with a view to promoting sustainable development."*

Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment came into force on 21 July 2001. Member States have several years to put in place the mechanisms necessary to comply with its requirements. In future, for a number of sectors all plans and programmes which set a framework for future development consent of projects listed in Annexes I and II to *Council Directive 85/337/EEC* (the EIA Directive), and all plans and programmes which have been determined to require assessment pursuant to Council *Directive 92/43/EEC* (the Habitats Directive), are likely to have significant effects on the environment, and should as a rule be made subject to systematic environmental assessment. When they determine the use of small areas at local level or are minor modifications to the above plans or programmes, they should be assessed only where Member States determine that they are likely to have significant effects on the environment.

Strategic environmental assessment is an important tool for integrating environmental considerations into the preparation and adoption of plans and programmes because it ensures that such effects of implementing plans and programmes are taken into account during their preparation and before their adoption.

The SEA Directive sets out the information to be included in the report of the Strategic Environmental Assessment:

- An outline of the contents, main objectives of the plan or programme and relationship with other relevant plans and programmes
- The relevant aspects of the current state of the environment and the likely evolution thereof without implementation of the plan or programme
- The environmental characteristics of areas likely to be significantly affected
- Any existing environmental problems which are relevant to the plan or programme including, in particular, those relating to any areas of a particular environmental importance, such as areas designated pursuant to Directives 79/409/EEC and 92/43/EEC (the Birds, and Habitats Directives)
- The environmental protection objectives, established at international, Community or Member State level, which are relevant to the plan or programme and the way those objectives and any environmental considerations have been taken into account during its preparation

- The likely significant effects on the environment, including on issues such as biodiversity, population, human health, fauna, flora, soil, water, air, climatic factors, material assets, cultural heritage including architectural and archaeological heritage, landscape and the interrelationship between the above factors
- The measures envisaged to prevent, reduce and as fully as possible offset any significant adverse effects on the environment of implementing the plan or programme
- An outline of the reasons for selecting the alternatives dealt with, and a description of how the assessment was undertaken including any difficulties (such as technical deficiencies or lack of know-how) encountered in compiling the required information
- A description of the measures envisaged concerning monitoring
- A non-technical summary of the information provided under the above headings

These effects should include secondary, cumulative, synergistic, short, medium and long-term permanent and temporary, positive and negative effects.

ANNEX II of the SEA Directive sets out the criteria for determining the likely significance of effects. These are listed below:

- The characteristics of plans and programmes, having regard, in particular, to
  - the degree to which the plan or programme sets a framework for projects and other activities, either with regard to the location, nature, size and operating conditions or by allocating resources,
  - the degree to which the plan or programme influences other plans and programmes including those in a hierarchy,
  - the relevance of the plan or programme for the integration of environmental considerations in particular with a view to promoting sustainable development,
  - environmental problems relevant to the plan or programme,
  - the relevance of the plan or programme for the implementation of Community legislation on the environment (eg plans and programmes linked to waste-management or water protection).

- Characteristics of the effects and of the area likely to be affected, having regard, in particular, to
  - the probability, duration, frequency and reversibility of the effects,
  - the cumulative nature of the effects,
  - the transboundary nature of the effects,
  - the risks to human health or the environment (eg due to accidents),
  - the magnitude and spatial extent of the effects (geographical area and size of the population likely to be affected),
  - the value and vulnerability of the area likely to be affected due to:
    - special natural characteristics or cultural heritage,
    - exceeded environmental quality standards or limit values,
    - intensive land-use,
    - the effects on areas or landscapes which have a recognised national, Community or international protection status.

3.2 Licensing

Exploration and production in the oil and gas industry is regulated primarily through a licensing system managed by the DTI Oil and Gas Directorate's Exploration and Licensing Branch. A brief overview of the offshore or “Seaward” licensing process is given below, more detail can be found on the DTI’s website at www.og.dti.gov.uk/upstream/licensing.

The various Orders made under the *Continental Shelf Act 1964* which designated areas of the UK continental shelf for hydrocarbon and mineral exploration were consolidated by the *Continental Shelf (Designation of Areas) (Consolidation) Order 2000 SI 2000 No. 3062*.

The *Petroleum Act 1998*, entered into force in 1999 and consolidated a number of provisions previously contained in five earlier pieces of primary legislation. The Act vests ownership of oil and gas within Great Britain and its territorial sea in the Crown, and gives Government rights to grant licences to explore for and exploit these resources and those on the UK Continental Shelf (UKCS). Regulations set out how applications for licences may be made, and specify the Model Clauses to be incorporated into the licences.

There are two types of Seaward Licences:

- **Exploration Licences** which are non-exclusive, permit the holder to conduct non-intrusive surveys, such as seismic or gravity and magnetic data acquisition, over any part of the UKCS not held under a Production Licence. Wells may be drilled under these licences, but must not exceed 350 metres in depth without the approval of the Secretary of State. These licences may be applied for at any time and are granted to applicants who have the technical and financial resources to undertake such work. Each licence is valid for three years, renewable at the Secretary of State’s discretion for one further term of three years. Exploration licence holders may be commercial geophysical survey contractors or Production licence Operators. A commercial contractor acquiring data over unlicensed acreage may market such data.

- **Production Licences** grant exclusive rights to holders “to search and bore for, and get, petroleum”, in the area of the licence covering a specified block or blocks. For licensing purposes the UKCS is divided into quadrants of 1° of latitude by 1° of longitude (except where the coastline, “bay closing line” or a boundary line intervenes). Each quadrant is further partitioned into 30 blocks each of 10 x 12 minutes. The average block size is about 250 square km (roughly 100 square miles). Relinquishment requirements on successive licences have created blocks subdivided into as many as six part blocks. Production Licences are usually issued in periodic “Licensing Rounds”, when the Secretary of State for Trade and Industry invites applications in respect of a number of specified blocks or other areas.

Most activities carried out under an Exploration or Production Licence require the consent of the Secretary of State and may require compliance with other legislative provisions and specific conditions attached to the consent – see below.

3.3 Control of Operations

An overview of the main environmental regulatory requirements applicable to UK offshore oil and gas activities is given below.

Petroleum Act, 1998
The Act provides the basis for granting licences to explore for and produce oil and gas. Production licences grant exclusive rights to the holders to "search and bore for, and get, petroleum" in specific blocks. Under the terms of a Production Licence, licence holders require the authorisation of the Secretary of State before installing facilities or producing hydrocarbons. A consent to flare or vent gas is also required from the DTI under the terms of the Model Clauses incorporated into Production Licences (see also the Gas Act 1986, as amended).

The Petroleum Act also requires an authorisation (Pipeline Works Authorisation) from the DTI for the use of or works for the construction of a submarine pipeline. The authorisation may include conditions for the design, route, construction and subsequent operation of the pipeline. The Pipeline Works Authorisation process has been streamlined and also includes consenting for the discharge of pipeline contents (DISCON) and placement of concrete mattresses and rock dumping (DEPCON).

Part IV of the Petroleum Act 1998 specifies the requirements for facility and pipeline abandonment.

Offshore Petroleum Production and Pipe-lines (Assessment of Environmental Effects) Regulations, 1999
The Offshore Petroleum Production and Pipe-lines (Assessment of Environmental Effects) Regulations 1999 implement the 1985 and 1997 EC Directives on the "Assessment of the effects of certain public and private projects on the environment" with regard to the offshore oil and gas industry. The regulations require an environmental impact assessment and a public consultation document, an Environmental Statement (ES) to be submitted for certain projects including new developments with expected production >500 tonnes of oil/day or 500,000 cubic metres of gas/day.

Radioactive Substances Act, 1993
Under the Radioactive Substances Act 1993 a registration certificate from the Scottish Environment Protection Agency is required to keep and use radioactive sources offshore. The certificate contains details of source type, activity and purpose. The Act also requires installations to hold an authorisation to store and dispose of radioactive waste such as low specific activity scale (LSA) which may be deposited in vessels and pipework.

The Offshore Petroleum Activities (Conservation of Habitats) Regulations, 2001
These regulations implement European Directives for the protection of habitats and species namely, Council Directive 92/43 on the conservation of natural habitats and of wild fauna and flora and Council Directive 79/409 on the conservation of wild birds in relation to oil and gas activities carried out in whole or in part on the UKCS. The DTI's Oil and Gas Directorate is the Competent Authority. The Secretary of State will, where it is considered that an activity completed under a project consent may have a significant effect on a Special Area of Conservation (SAC) or Special Protection Area (SPA), conduct an Appropriate Assessment prior to granting the consent. The regulations also require a consent in writing from the DTI prior to conducting geological surveys – this includes seismic surveys, rig site surveys and pipeline route surveys.

Prevention of Oil Pollution Act, 1971 (POPA) (as amended)
This Act and associated Regulations prohibits the discharge of oil or oily mixtures to sea from any offshore installation or pipeline. The Act provides for exemptions to be obtained to allow lawful discharge of treated produced water, sand and other operational discharges. The current standard for produced water discharges is maximum monthly average of 40mg/kg oil-in-water although this discharge standard is expected to change to 30mg/l in the future (OSPAR Recommendation 2001/1 for the Management of Produced Water from Offshore Installations).

Food and Environment Protection Act, 1985 and the Deposits in the Sea Exemptions Order, 1985
The Food and Environment Protection Act 1985 (as amended) is the mechanism through which deposits in the sea are regulated. The Deposits in the Sea Exemptions Order exempts non-oil operational discharges, including chemicals, drilling cuttings and muds, associated with the exploration and production of oil and gas from the licensing requirements of the Act.

Offshore Combustion Installations (Prevention and Control of Pollution) Regulations, 2001
These introduce Integrated Pollution Prevention and Control (IPPC) to offshore oil and gas combustion installations with a combined total rated thermal input exceeding 50 MW. Under the Regulations an IPPC Permit will be required in order to operate a qualifying offshore installation. The permit will be granted with conditions that will include provisions based on best available techniques, emission limits, and monitoring requirements. Existing installations must comply by October 2007.

Merchant Shipping (Prevention of Oil Pollution) Regulations, 1996 (as amended)
These Regulations give effect to Annex I of MARPOL 73/78 (prevention of oil pollution) in UK waters. They address oily drainage from machinery spaces on vessels and installations. The North Sea is designated a "Special Area", within which the limit for oil in discharged water from these sources is 15ppm. Vessels and installations are required to hold a valid UKOPP (UK Oil Pollution Prevention) or IOPP (International Oil Pollution Prevention Certificate). Vessels and drilling rigs are also required to hold a current, approved Shipboard Oil Pollution Emergency Plan (SOPEP) which is in accordance with guidelines issued by the Marine Environment Protection Committee of the International Maritime Organisation.

Merchant Shipping (Oil Pollution Preparedness, Response and Co-operation Convention) Regulations, 1998
The Merchant Shipping (Oil Pollution Preparedness, Response and Co-operation Convention) Regulations, 1998 came into force in May 1998 and require all existing offshore installations and oil handling facilities (eg pipelines) to have an approved oil spill contingency plan. Oil spill plans must be submitted for approval at least two months in advance of commencement of operations. The regulations apply to installations and to mobile drilling rigs while engaged in drilling operations on the UKCS. The DTI is the regulator for this legislation and have issued guidance to the regulations. Oil Spill Contingency Plans are required to follow a defined format and to include spill risk assessment. (Note: Operators are required to report all oil spills as soon as possible, regardless of size to the Coastguard, DTI and other relevant authorities according to the instructions and format included with Petroleum Operations Notice 1 (PON 1).)

Merchant Shipping (Prevention of Pollution by Garbage) Regulations, 1998
The Merchant Shipping (Prevention of Pollution by Garbage) Regulations 1998 implement Annex IV of MARPOL 73/78 and apply to all fixed and floating offshore installations

(including rigs) and their support vessels operating on the UKCS. All domestic and operational wastes, except ground food waste must be stored and taken to shore for disposal. Food ground to particles 25mm or less may be discharged overboard but only if 12 nautical miles or more offshore. Installations and vessels are required to have a Garbage Management Plan or equivalent.

Environmental Protection Act, 1990
The Environmental Protection Act 1990 and associated regulations introduced a “Duty of Care” for all controlled wastes. Waste producers are required to ensure that wastes are identified, described and labelled accurately, kept securely and safely during storage, transferred only to authorised persons and that records of transfers (waste transfer notes) are maintained for a minimum of two years. Carriers and waste handling sites require licensing. Although the Act does not apply to offshore installations, it requires operators to ensure that offshore waste is handled and disposed onshore in accordance with the Duty of Care introduced by the Act.

Special Waste Regulations, 1996 (as amended)
Additional controls are applied to more hazardous (special) types of controlled waste by the Special Waste Regulations 1996 (as amended). These Regulations require controlled wastes that are also considered to be special wastes because of their potentially harmful properties, to be correctly documented, recorded and disposed at an appropriately licensed site. Records of transfers (special waste consignment notes) are to be maintained for a minimum of three years.

Offshore Chemical Notification Scheme (OCNS)
The OCNS scheme is administered by DTI, and requires that all chemicals used on offshore installations are tested and assigned one of 5 classifications depending upon their impact on the environment (Groups A to E where A is the most harmful based on toxicity, persistence and bioaccumulation potential). A trigger level is assigned to each chemical group, specifying the maximum quantity that may be used offshore before triggering consultation with the DTI and their advisors – see below:

Group	Production Chemicals	Drilling Chemicals
A	40 tonnes	All proposed use
B	70 tonnes	3 tonnes
C	150 tonnes	15 tonnes
D	375 tonnes	350 tonnes
E	1,000 tonnes	4,750 tonnes
Z	Closed system chemicals – no discharge permitted	

The OCNS Scheme will be superseded shortly by new chemical regulations (*draft Offshore Chemicals (Pollution Prevention and Control) Regulations 2001*) which will implement the recently adopted OSPAR Decision (2000/2) and Recommendations (2000/4 and 2000/5) introducing a Harmonised Mandatory Control System for the use and reduction of the discharge of offshore chemicals. The regulations are expected to introduce a new permit system for the use and discharge of chemicals offshore and include a requirement for site specific risk assessment. A new database (currently being developed) will rank chemicals by hazard, based on a PEC:PNEC (Predicted Effect Concentration : Predicted No Effect Concentration) approach.

OSPAR Decision 2000/3 on the Use of Organic-Phase Drilling Fluids (OPF) and the Discharge of OPF-Contaminated Cuttings

OSPAR Decision 2000/3 has been in force since 16 January 2001 and applies to the use and discharge of all organic phase drilling fluids which include both oil based and synthetic based drilling fluids. No such fluids may be used without prior authorisation (normally through the PON 15/Environmental Statement process), and discharge of cuttings to sea with a concentration >1% by weight of oil based fluids on dry cuttings is prohibited. The discharge to sea of cuttings contaminated with synthetic fluids will only be authorised in exceptional circumstances.

OSPAR Recommendation 2000/1 for the Management of Produced Water from Offshore Installations

OSPAR recommendation 2000/1 has been in force since 29th June 2001. It provides for a reduction in the discharge of oil in produced water by 15% over a five year period and a lowering of the discharge concentration from each installation to 30mg/l over the same period. and applies to the use and discharge of all organic phase drilling. The recommendation also includes a presumption against the discharge to sea of produced water from new developments.

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4 ACTIVITIES

4.1 Introduction

The possible scale of exploration and development activity which could result from a 20th Round of UKCS licensing covering the “mature” areas of the North Sea (SEA 2 areas) is considered below. These implications are summarised as scenarios which are used in Section 10 as the basis for considering the potential effects of such activities.

The SEA 2 areas cover the mature areas of the North Sea, that is, those areas that have been licensed since the early days of the North Sea as an oil and gas province, and extensively explored with numerous existing fields in production and extensive export infrastructure in place. Of the blocks potentially available for licensing in the 20th Round, all except three have been licensed one or more times in previous rounds – see Figures 4.1a and b overleaf. Many of the 20th Round blocks, have been split, with a proportion of the block relinquished and the remainder still licensed - often with a developed field or undeveloped discovery within the retained portion.

4.2 Alternatives

SEA 2 is the second of a series of DTI Strategic Environmental Assessments which will, over time, address the entire UK Continental Shelf (UKCS) prior to decisions on further large scale licensing. The DTI has divided the UKCS into a number of areas with the SEA 2 area being selected as the next to consider for licensing, based on knowledge of the geological conditions together with availability of existing oil and gas infrastructure. Alternatives proposed for the development of the oil and gas resources within the proposed 20th Round areas have been identified as:

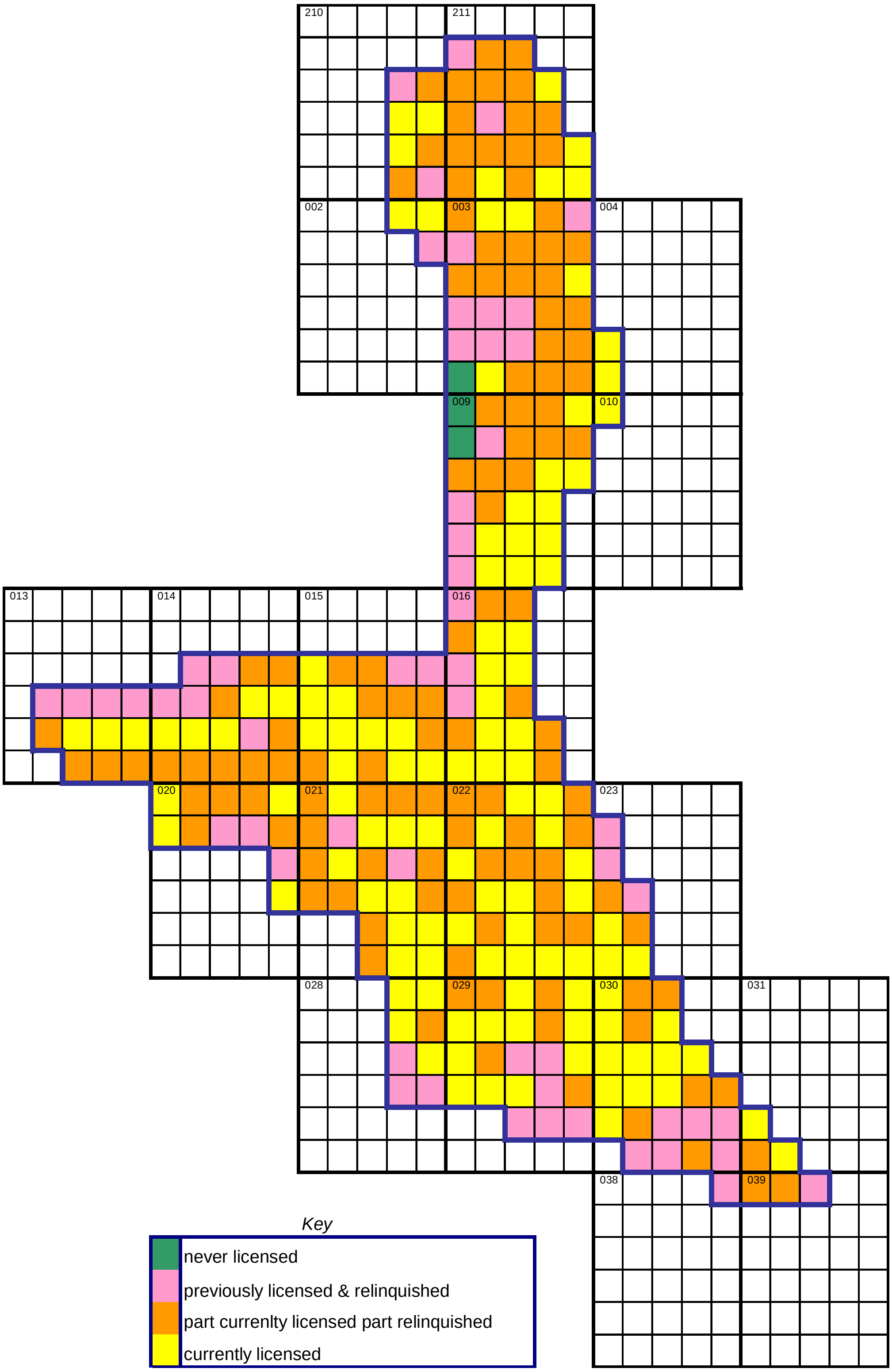
1. Not to offer any blocks for Production Licence award
2. To restrict the area licensed by offering only a proportion of the blocks nominated
3. To stagger the timing of activity in the area
4. To proceed with the licensing programme as proposed

The activities following from licensing are considered in Section 4.3 below. The implications of the alternatives are considered in Sections 10 (Consideration of the effects of licensing) and 11 (Conclusions).

4.3 Scenarios

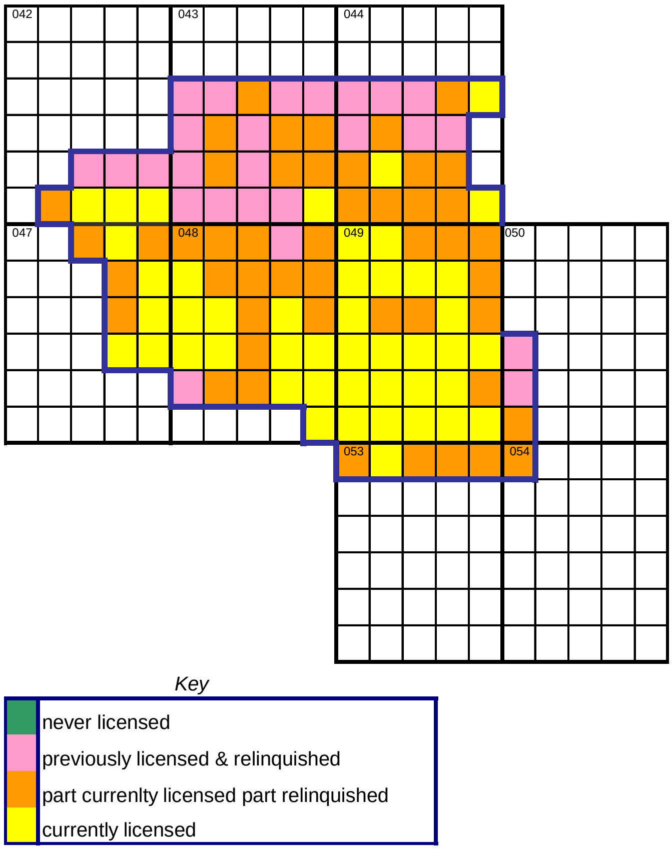
The SEA process has been conducted on the basis of exploration and development scenarios for the northern, central and southern SEA 2 areas. These scenarios include seismic, exploration drilling and production phases and must only be considered as indicative.

Figure 4.1a – Blocks in the quadrants within the northern and central North Sea SEA 2 areas, either currently licensed or potentially available for licensing



(Source: DTI 2001)

Figure 4.1b - Blocks in the quadrants within the southern North Sea SEA 2 area, either currently licensed or potentially available for licensing



(Source: DTI 2001)

Both exploration and development activity levels and timing would depend on a range of factors including the number of blocks licensed, work programme commitments made by licensees, exploration success, economic and commercial factors and Government approval of project development plans.

These forecasts of potential activity were developed by the DTI Licensing Branch. They are not based on detailed mapping, but on a broad understanding of the geology of the areas involved, anticipated applications for the blocks, currently known but undeveloped reserves which are in unlicensed blocks, and the likely exploration success rates. Predicted numbers are therefore indicative only.

4.3.1 Northern North Sea, Quadrants 210, 211, 2, 3, 4, 9 and 10

Over 60 blocks or part blocks are open and potentially available for licensing. All except three blocks have licensed one or more times previously.

Most of the acreage available lies on the margins of the Viking Graben. In these areas there is already extensive 3D seismic information, so not more than ten seismic surveys are anticipated (assuming one to each block down the western margin), but it is likely that these will be combined and carried out over larger areas, which would result in fewer surveys (an estimate of five surveys).

The number of exploration wells which will be committed to at the licence application stage is estimated at five wells in separate blocks. The anticipated timing of these wells is 3 wells in 2002, and one in both 2003 and 2004. Using a typical North Sea success ratio of 1 commercial discovery in five wells, this would suggest the discovery of a single new field. Potential developments are likely to be subsea tiebacks to existing fields with development estimated in 2006 following an appraisal well in 2003. However, on the western margin, there are known heavy oil finds which may, if further prospectivity is identified as a result of the 20th Round, generate sufficient potential for a platform hub. Thus more than one commercial discovery may result from 20th Round licensing.

4.3.2 Central North Sea, Quadrants 13 to 39

Approximately 90 blocks or part blocks are open for potential licensing. All blocks have previously been licensed.

Most of the area in the centre of the sedimentary basins is already under licence so will have already been extensively surveyed by 3D seismic. However, up to three infill seismic surveys may be required. On the margins of the area, assuming one survey per block, up to 15 surveys may be expected, but as surveys are likely to be combined this is expected to reduce the number of surveys to five.

An estimated ten exploration wells will result from 20th Round licensing, all in separate blocks. The anticipated timing of these wells is 5 wells in 2002, and 3 in 2003 and 2 in 2004. Using a typical North Sea success ratio of 1 commercial discovery in five wells, this would suggest the discovery of two new fields. Potential developments are likely to be subsea tiebacks to existing fields with development estimated in 2006 following appraisal wells in 2003 and 2004. As with the northern North Sea, as the area has been heavily explored in the past and is comparatively well known, more than two commercial discoveries may result from 20th Round licensing.

4.3.3 Southern North Sea, Quadrants 42, 43, 44, 47, 48, 49, 50, 53 and 54

Approximately 70 blocks or part blocks are open for potential licensing. All blocks have previously been licensed.

The north-western part of the area has not been covered by 3D seismic, so again assuming one survey per block, up to 18 surveys may be acquired, although this is likely to be reduced to six surveys if the areas are combined.

An estimated six exploration wells in separate blocks will result from 20th Round licensing. The anticipated timing of these wells is 3 wells in 2002, and 2 in 2003 and 1 in 2004. As the area is particularly well understood, a success ratio of 1 commercial discovery in 4 wells has been used, which suggests the discovery of two new fields. Potential developments are likely to be subsea tiebacks to existing fields with development estimated in 2004 and 2005 following appraisal wells in 2002 and 2003. As with the other SEA 2 areas, the area has been heavily explored in the past and is comparatively well known, thus more than two commercial discoveries may result from 20th Round licensing.

To place the scale of activity that might follow a 20th Round of licensing into context, the projected activity in the existing licensed acreage in the SEA 2 areas is summarised below.

This information is an important consideration in the assessment of incremental and cumulative effects.

Within the SEA 2 areas there are 90 new fields (ie fields which have not been approved yet) included in the Reserves Category in Chart 4.5 of the 2001 Brown Book (DTI 2001), which are expected to commence production between 2001 and 2010. Of these 12 are in the northern North Sea, 54 in the central North Sea and 24 in the southern North Sea (DTI, pers. comm.).

Table 4.1 - Number and type of new developments envisaged between 2001 and 2010 for the SEA 2 area

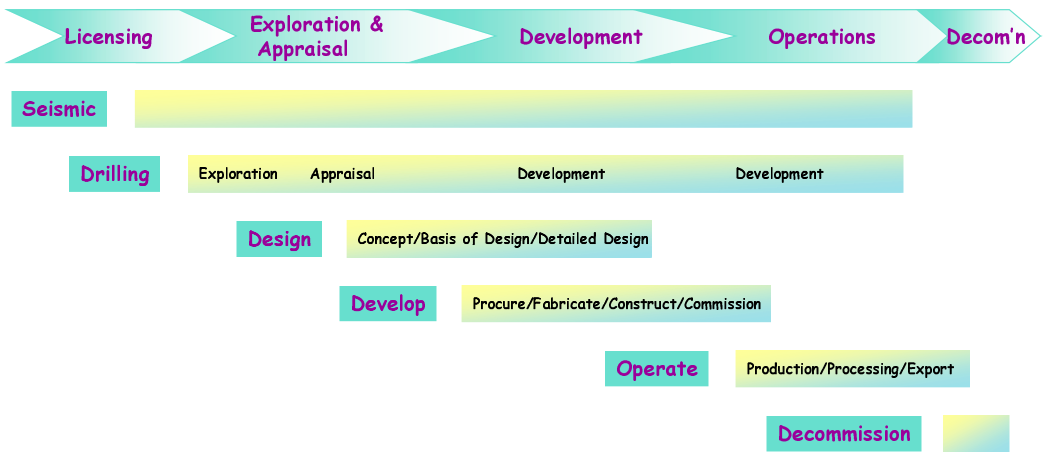
AREA	FLUID[1]	PLATFORM	FPSO/FPV[2]	SUBSEA	Totals
NNS	OIL	0	1	7	8
NNS	GAS	1	0	3	4
Subtotal		**1**	**1**	**10**	**12**
CNS	OIL	2	3	24	29
CNS	GAS	4	0	21	25
Subtotal		**6**	**3**	**45**	**54**
SNS	GAS	7	0	17	24
All Areas		**14**	**4**	**72**	**90**

Notes: 1. Condensate fields have been listed as gas fields although they will also provide light oil.
2. FPSO = Floating Production, Storage and Offloading Facility. FPV = Floating Production Vessel

4.4 Stages of activity

The main stages and activities associated with the licensing process and subsequent exploration, development and production of offshore oil and gas resources are described in Supporting Document *An overview of offshore oil and gas exploration and production activities* (SD_002). This is available as a pdf file on the SEA website, and the key stages in the lifecycle are shown in Figure 4.2.

Figure 4.2 – Oil and Gas Exploration and Production Lifecycle



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5 PHYSICAL AND CHEMICAL ENVIRONMENT

5.1 North Sea overview

The Greater North Sea, as defined by the OSPAR Quality Status Report produced in 2000, is situated on the continental shelf of north-west Europe. It opens into the Atlantic Ocean to the north and, via the Channel to the south-west, and into the Baltic Sea to the east, and is divided into a number of loosely defined areas. The open North Sea is often divided into the relatively shallow southern North Sea (including eg the Southern Bight and the German Bight), the central North Sea, the northern North Sea, the Norwegian Trench and the Skagerrak. The shallow Kattegat is seen as a transition zone between the Baltic and the North Sea. The Greater North Sea (including its estuaries and fjords) has a surface area of about 750,000 km^2 and a volume of about 94,000 km^3. Bathymetry and the names of major features of the North Sea are shown in Figure 5.1.

The overall modern topography of the North Sea has originated from the influences of deep geological structure on the patterns of basin subsidence, uplift and climate on sediment input. The smaller-scale seabed geometry of the continental shelf is a relict of several glacial periods when large volumes of material were eroded from the adjacent mainlands and from the continental shelf itself. This material was then re-deposited on the shelf or in the deeper waters on the adjacent continental slope. The modern sedimentary environment of the North Sea continental shelf is now dominated by very low sediment input and the reworking of the seabed by near-bottom currents.

Brief synopses of physical and chemical characteristics and resources of the North Sea, with specific reference to the SEA 2 areas, are provided below. These refer to previous published reviews where available, in addition to a series of scientific and technical reviews commissioned specifically for SEA 2 which are available from the SEA website.

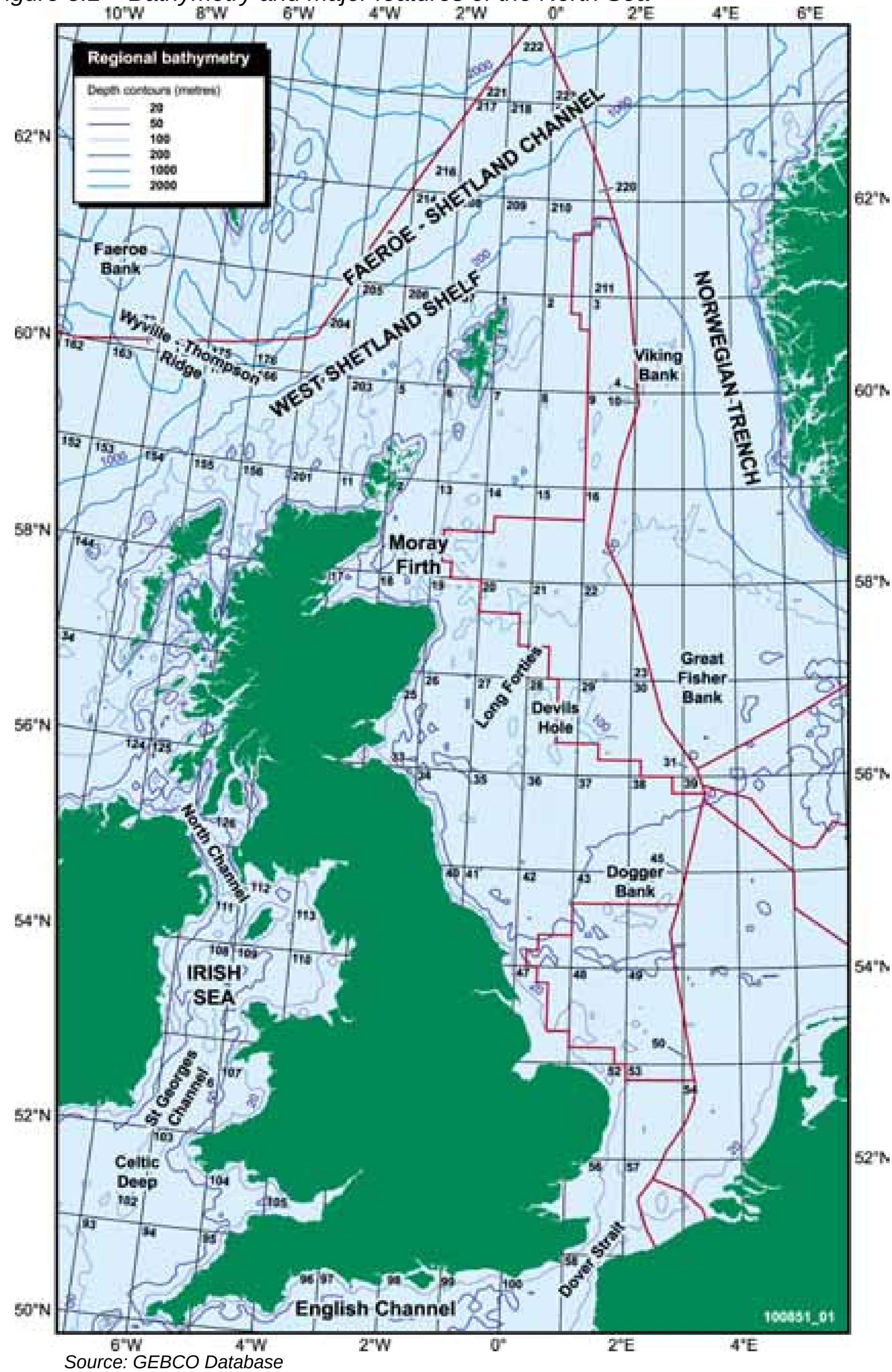
Note, the different sections have differing degrees of reference citation since commissioned reviews contain comprehensive references to published data sources.

5.2 Geology and substrates

5.2.1 Overview and perspective

To support the SEA 2 process, British Geological Survey (BGS) were commissioned to produce a summary of published data and their interpretation from areas in the mature oil and gas areas of the UK North Sea occurring to the east and north of the British Isles. The basis for this review is the premise that the modern environment is a synthesis of past environmental conditions. The purpose is to review (1) the evolution of the deeply-buried sediments with reference to the petroleum geology and production-related seabed subsidence (2) the evolution of the shallow and seabed sediments with reference to present sediment distributions and seabed features (3) the evidence for possible hydrogeological exchange across selected onshore/offshore areas (4) the history of earthquakes and the hazard that they may pose. It is intended that the review will provide a basis for a better understanding of the impacts of possible future changes in the natural environment.

Figure 5.1 – Bathymetry and major features of the North Sea



Source: GEBCO Database

A precursor to the submarine evolution of the North Sea occurred more than 375 million years ago with the deposition of marine limestones. Subsequently, subsidence and burial under thick accumulations of basin sediments has generated gas from coal source rocks, possibly commencing prior to approximately 140 million years ago. Oil and gas has been generated from deeply-buried mudstone source rocks from approximately 65 million years ago to the present day. Commercial petroleum reservoirs occur in almost every sedimentary succession ranging in age from approximately 410-36 million years. Exceptionally, the extraction of oil and gas has lead to production-related seabed subsidence, the effects of which are locally felt. This process appears to be restricted to a few types of reservoir and to date does not appear to have had major environmental impact.

Extreme changes from arctic to temperate climates have been the dominant control on sediment type and the overall very high rate of sediment input into the North Sea from approximately 800,000 years ago to the present day. The overall effect of the repeated glaciations during the cold periods has been to keep the North Sea basin filled with sediments during a time when there was very rapid basin subsidence.

5.2.2 Sediments

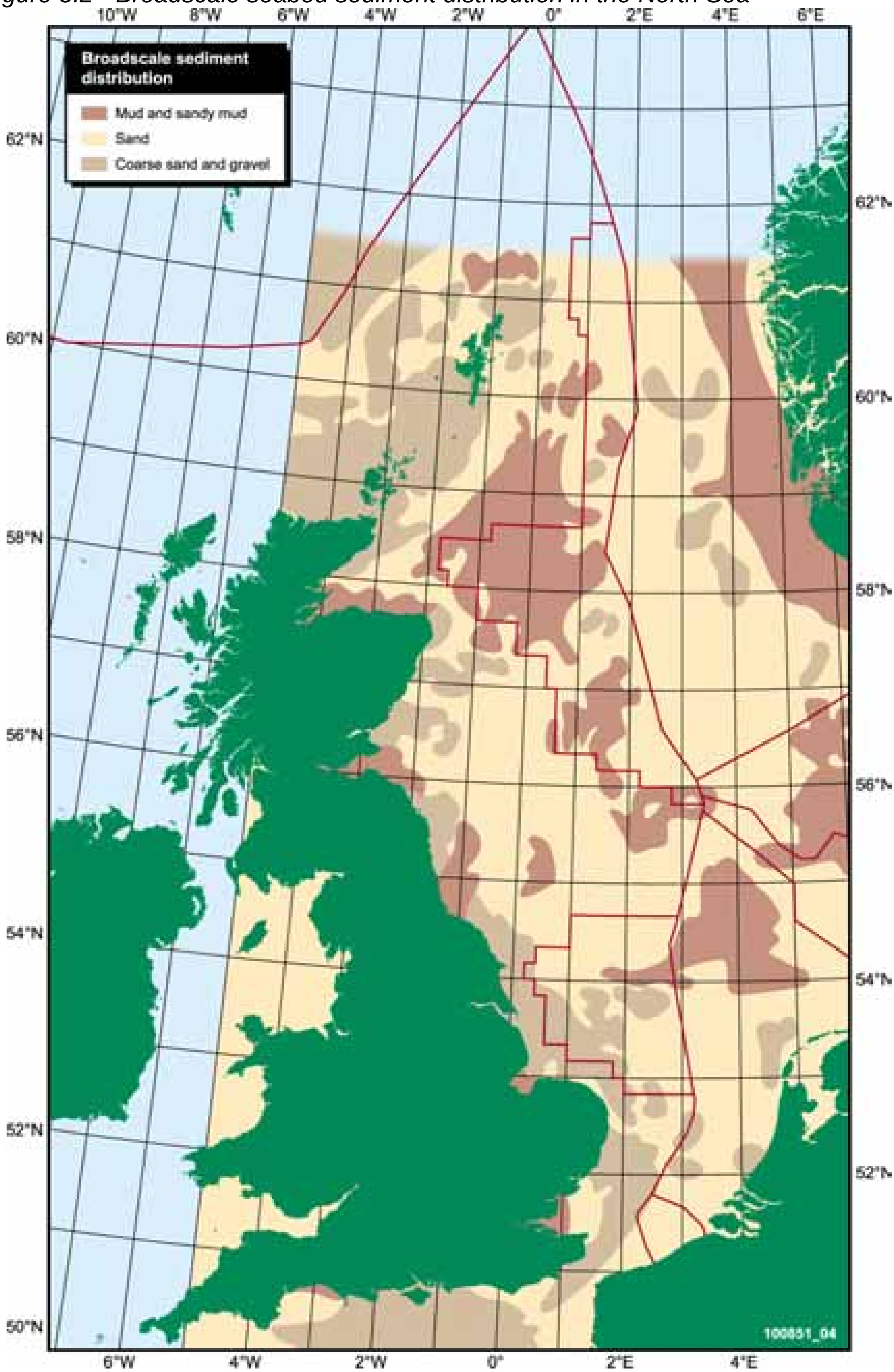
Broadscale seabed sediment distribution is shown in Figure 5.2. The bulk of modern seabed sediments comprises substrates that are more than 10,000 years old and have been reworked from strata by currents that have been generated by tides and sea waves. The reworked sediments typically form large areas of seabed sand and gravel. Such sediments also form large-scale sandbanks and ridges and smaller sand waves.

5.2.2.1 Sandbanks

Both active sandbanks, maintained actively by modern tidal current regime, and moribund sandbanks, formed at periods of lower sea level, are found in the SEA 2 areas (Belderson 1986, Collins *et al.* 1995). Models for sandbank development include spiral water circulation with convergence over the crestline (Houbolt 1968, Caston 1972); lateral migration; and stratigraphic evolution associated with submergence of coastal sand bodies. Detailed hydrography and sediment transport have been studied on Leman and Well Banks (Caston and Stride 1970, Caston 1972) and Broken Bank (Collins *et al.* 1995). From analysis of historic bathymetric charts, Caston (1972) found that some of the more offshore Norfolk Banks had elongated towards the north west, the direction of net regional sand transport. The evidence for bank migration perpendicular to their long axis is, however, more equivocal. These offshore banks are markedly asymmetrical in cross-section with their steeper flanks oriented towards the north east suggestive of migration in that direction. It has been suggested (Caston 1972) that opposing movement of sand streams may magnify localised irregularities into a complex “S” shaped bank surrounding a pair of ebb and flow channels (as in banks of the Haisborough Tail – Winterton Ridge system), with subsequent erosion of the bank apices leaving a line of *en echelon* banks. The internal structure within some of the offshore banks is evidence of north eastward migration although it is uncertain whether migration still occurs at the present time.

The surfaces of many of the Norfolk Banks are covered in active sandwaves which reflect the pattern of modern sand transport around these banks. The sandwaves have their crests aligned more or less at right angles to the bank crest with their steep faces in opposing directions on either side of the sandbank reflecting the dominance of a clockwise circulation of sand around the bank (see multibeam images in Figure 5.3).

Figure 5.2 - Broadscale seabed sediment distribution in the North Sea



Source: OSPAR 2001 (after Eisma 1981)

Linear sandbanks in the southern North Sea have been studied since the early days of hydrographic surveying, with significant early echosounder observations made by Van Veen (1935, 1936). Detailed investigations commenced in connection with offshore oil and gas E&P activities in the late 1960s early 1970s (Caston 1969, 1972). To support the SEA 2 process, sandbanks within the SEA 2 areas were investigated by a survey programme, commissioned by DTI in June-July 2001, which included high-resolution multibeam bathymetry (Figure 5.3), photography of sediment features and epifauna (Figures 5.4 and 5.5 and seabed sampling (Figure 5.6).

5.2.2.2 Hard substrates

Hard substrates which are resistant to reworking are of both conservation and operational interest as they form areas of stable seabed for biota and may present problems for seabed site developments. The three main types of hard substrate occurring at or near seabed comprise the unconsolidated gravel spreads, hard cohesive sediments which were formed during the glaciations and rock outcrops. All three commonly occur together in the nearshore western margins of the North Sea. The distribution patterns of rock, gravel spreads and the hard cohesive gravelly Quaternary sediments are quite well known and have been mapped by regional surveys. Other, usually older, seabed or superficial hard cohesive substrates are patchily developed mid-shelf and are therefore relatively unpredictable.

5.2.2.3 Soft sediments

Soft muds typically cover wide areas in the deeper waters of the continental shelf. In the central and northern North Sea the spreads of soft muds are locally characterised by small depressions or ‘pockmarks’, most of which appear to have been formed at times of fluid/gas escape at seabed. In some cases, where these are associated with modern fluid/gas escape, they contain distinctive biota which are of concern for environmental preservation. The SEA 2 survey programme in June-July 2001 included multibeam bathymetry of pockmarks (Figure 5.7), photography of sediment features and epifauna (Figures 5.8) and seabed sampling (Figure 5.9).

5.2.2.4 Aquifers

Few data are available with which to assess the possible effects of exploration or development operations on onshore and offshore aquifers. What data there are indicate that saline water ingresses inland locally from restricted zones offshore from East Anglia whilst the predominant direction of movement elsewhere is of freshwater offshore. There is a local risk of groundwater contamination if wells are drilled through outcropping aquifers.

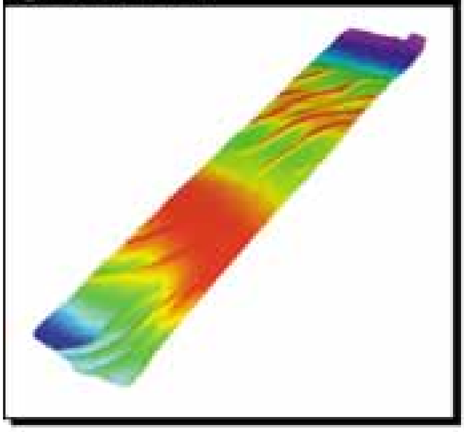
There is a negligible risk of contamination of onshore supplies of freshwater from the mature areas of the oil and gas development provinces in the central and northern North Sea. Overall, the risk of onshore aquifer contamination decreases with increasing distance from offshore developments.

5.2.2.5 Seismic activity

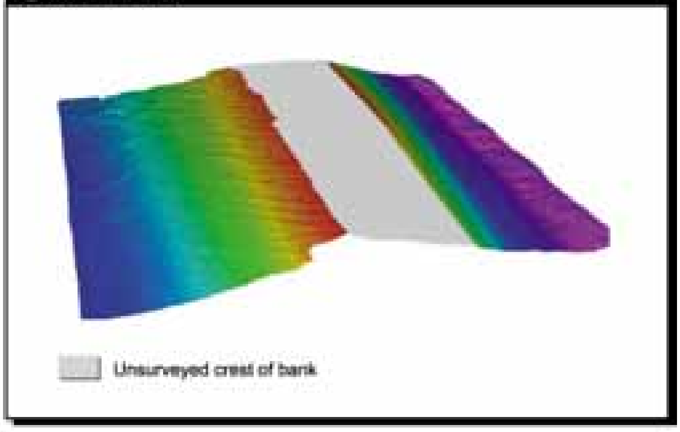
The regional distribution patterns of earthquakes occurring under the North Sea are related to the deep geological structure. Expectations of earthquakes with magnitude of 4 or higher may require special structural design and are therefore also of environmental concern. In the North Sea as a whole, the expectations for a magnitude 4 natural seismic event is approximately every 2 years and a magnitude 5 natural seismic event every 14 years.

Figure 5.3 - Sandbank features of the North Sea.

① Viking bank area



③ Smith's Knoll



Sandbank formation

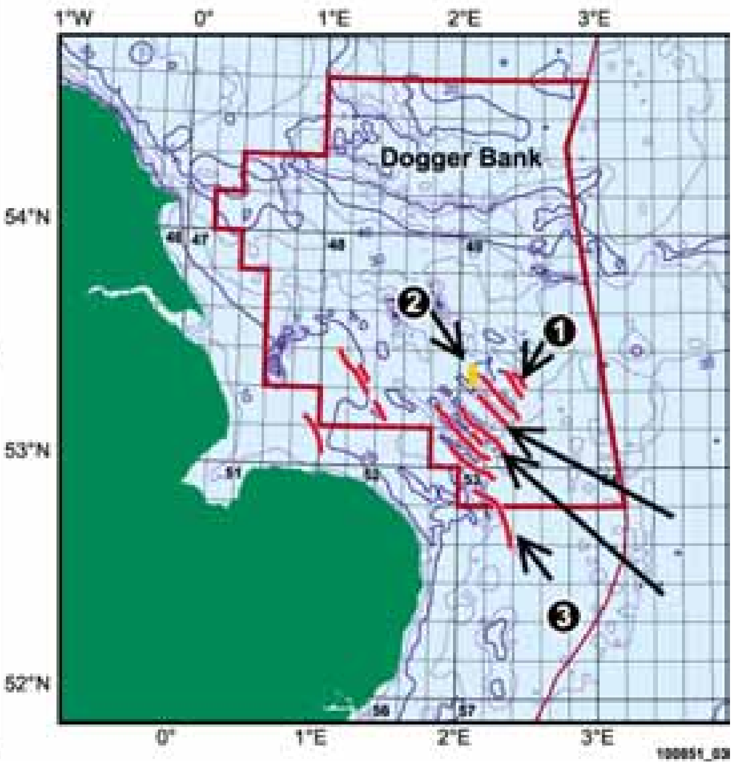
Both active sandbanks, maintained actively by modern tidal current regime, and moribund sandbanks, formed at periods of lower sea level, are found in the SEA2 area (Balderson 1986, Collins *et al.* 1995). Models for sandbank development include spiral water circulation with convergence over the crestline; lateral migration; and stratigraphic evolution associated with submergence of coastal sand bodies. Detailed hydrography and sediment transport have been studied on Well Bank (Caston and Stride 1970, Caston 1972) and Broken Bank (Collins *et al.* 1995).

Sandbank stability

From analysis of historic bathymetric charts, Caston (1972) found that some of the more offshore Norfolk Banks had elongated towards the north west, the direction of net regional sand transport. The evidence for bank migration perpendicular to their long axis is, however, more equivocal. These offshore banks are markedly asymmetrical in cross-section with their steeper flanks oriented towards the north east suggestive of migration in that direction. The internal structure within some of the offshore banks is evidence of north eastward migration although it is uncertain whether migration still occurs at the present time.

The surfaces of many of the Norfolk Banks are covered in active sandwaves which reflect the pattern of modern sand transport around these banks. The sandwaves have their crests aligned more or less at right angles to the bank crest with their steep faces in opposing directions on either side of the sandbank reflecting the dominance of a clockwise circulation of sand around the bank (see multibeam images).

② Galleon sandwave field



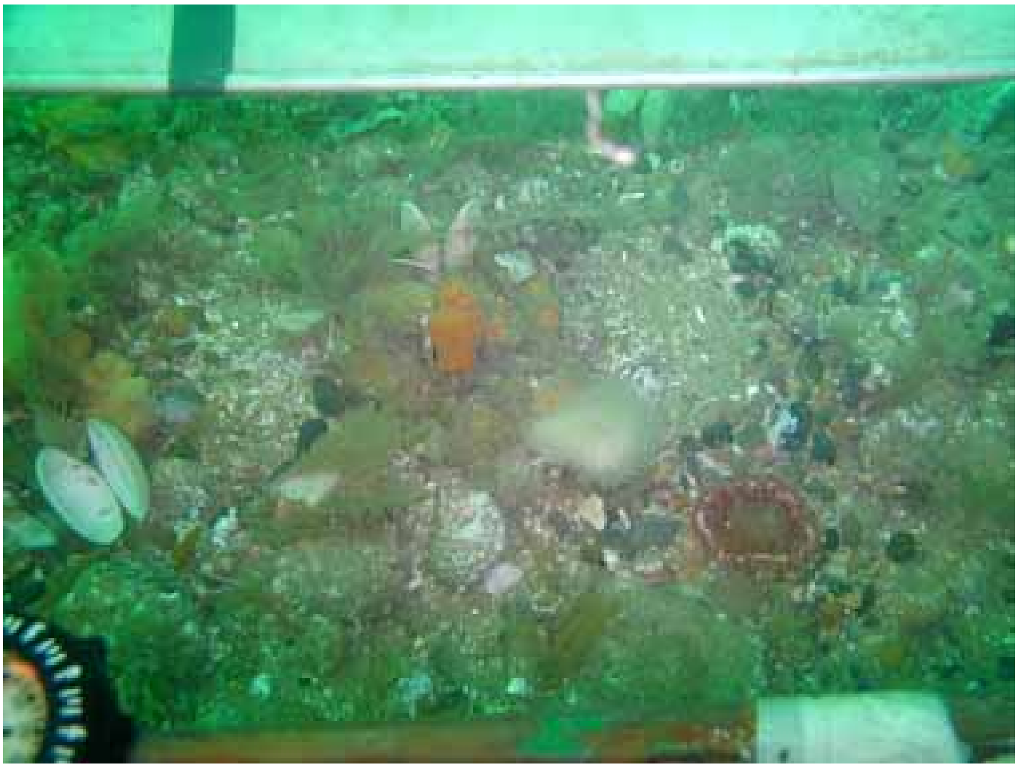
Dogger Bank

The Dogger Bank is a very large shoal area with water depths less than approximately 30 metres, shallowest in the south west where water depths are only 15 metres. The 'bank' is largely composed from a 42 metre thick formation of glacio-lacustrine clays which were deposited during the last glaciation. When the ice retreated 18,000 years ago the deposits were left behind as a upstanding plateau. As sea levels rose Dogger Bank became an island and was probably not completely covered by water until approximately 7500 years ago. The presence of freshwater and saltmarsh peat beds and clays containing intertidal molluscs are evidence of former coastal environments around the margins of the Dogger Bank at this time.

Source: BGS commissioned report, DTI 2001 survey data

Figure 5.4 - Seabed photographs, DTI 2001 Survey, Norfolk Banks. Horizontal field of view ca. 50cm.

Station P2C, Smith's Knoll. Rippled fine-medium sand, typical of the majority of stations on the Norfolk Banks.



Station P5C, Mallory field area. Mixed pebble, sand and shell substrate with diverse sessile epifauna typical of some eastern stations.

Figure 5.5 - Seabed photographs, DTI 2001 Survey, Dogger Bank. Horizontal field of view ca. 50cm.

Station DBEJ-1, Dogger Bank east transect. Mixed sand, pebbles and shell sediment typical of much of the Dogger Bank. Sparse encrusting epifauna present.

Station DBE-1, Dogger Bank east transect. Medium sand substrate. Plaice were commonly observed, particularly at night.

Figure 5.6 - Sampling positions in the southern SEA 2 area (Norfolk Banks)

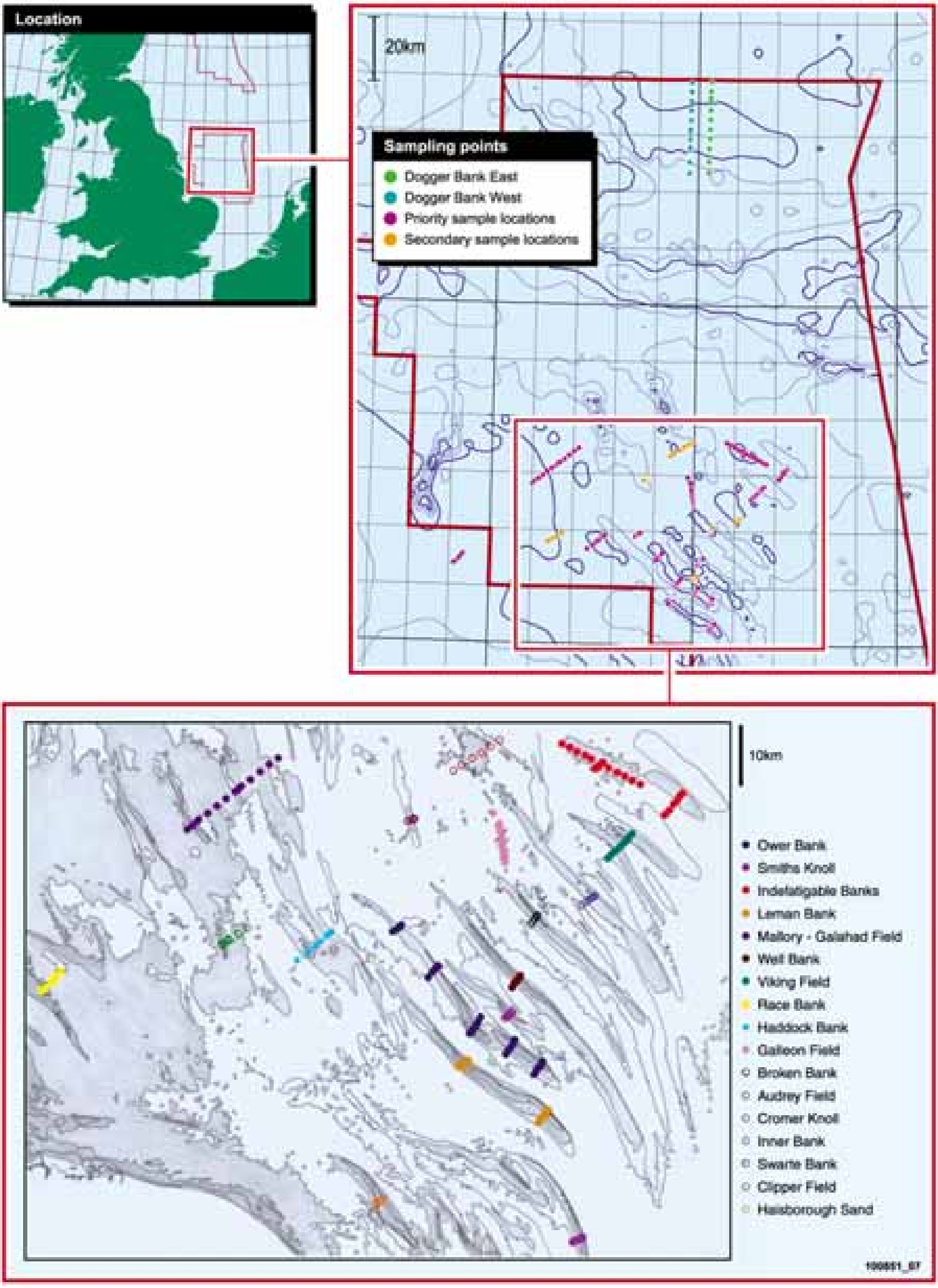


Figure 5.7 - Pockmark features of the North Sea.

Pockmark distribution and formation

Pockmarks are closed seabed depressions that are typically 2-5m deep, 50-200m wide and elongated parallel to the direction of the predominating near-bottom tidal currents. The largest modern pockmarks usually occur in the softer and finer-grained muds and they have formed following seabed excavation by processes involving fluid, gas or liquid, escape at seabed.

There is uncertainty about the precise age and duration of the processes that formed the majority of the presumed inactive (relict) pockmarks found at seabed.

The distribution and likely ages of buried pockmarks indicate that such processes have probably onset with the overall change to a warmer climate following the last glaciation (Long 1992). Giant pockmarks some 50-200m deep and 0.5 to 4km diameter have formed since the start of the early Cenozoic and are now deeply buried under parts of the modern pockmark fields in the central North Sea (Cole *et al.* 2000).

Some seabed pockmarks are sites of modern gas discharge. Fields of moribund pockmarks with densities of up to approximately 20 per km² at the modern seabed provide spectacular examples of historically spasmodic fluid and sediment mobility.

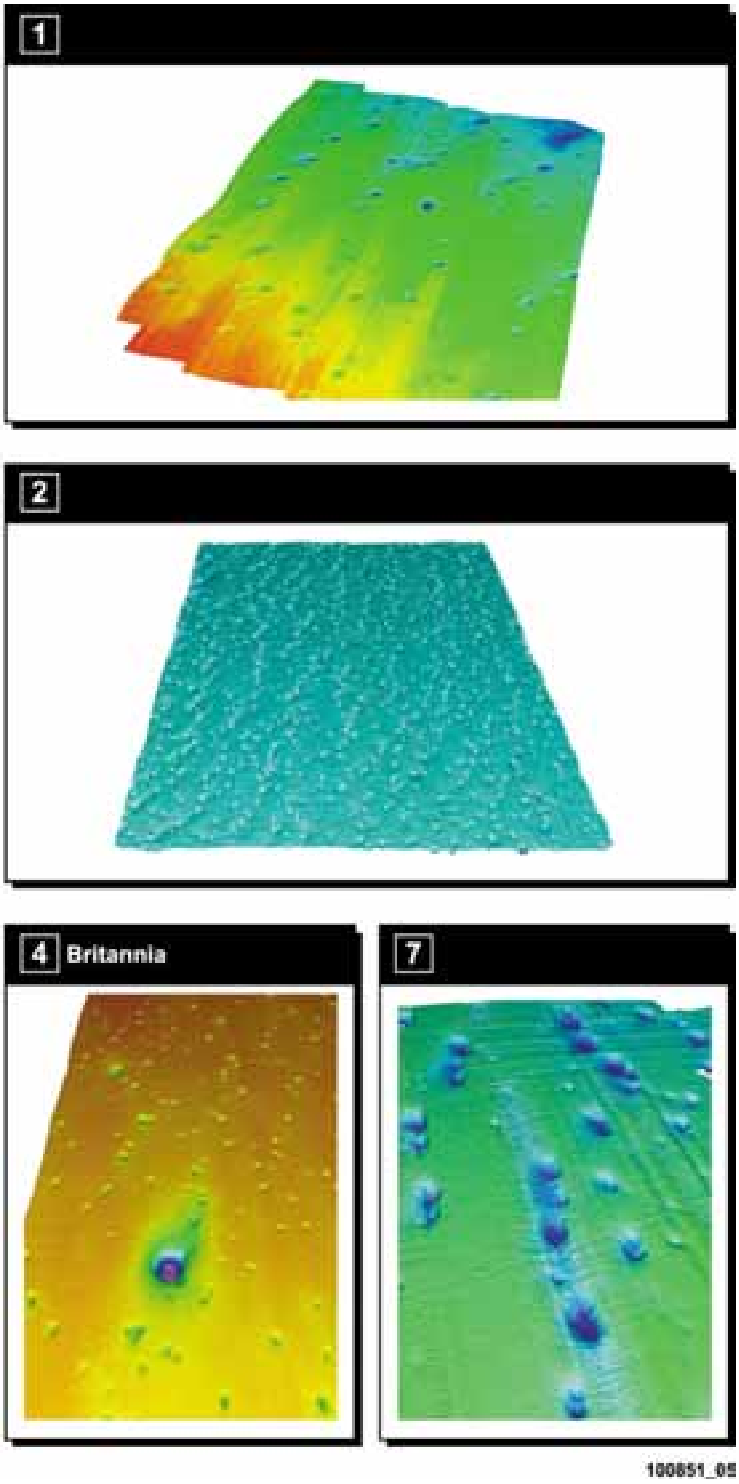
Pockmark significance

Although pockmarks observed with gas discharge at seabed occur with distinctive (local) biological assemblages, until now little research has been done on the impact of the distribution of inactive pockmarks on regional patterns of biodiversity and biological productivity.

Exceptionally, carbonate cements have been reported from pockmarks. In UKCS block 15/25 they occur in a pockmark with methane gas which is actively venting at seabed (Hovland *et al.* 1987, Hovland and Judd 1988). These hardgrounds are formed during the biological oxidation of methane, provide hard substrate for epifaunal colonisation and are possible offshore sites of conservation designation.

Other hardgrounds occurring in soft muds have been reported adjacent to Shetland although there is an insecure connection with gas seepage (Hovland and Judd, 1988)

Pockmarks are regarded by industry as a possible hazard to safe operations during pipeline and other seabed development operations and they are usually avoided whenever possible. The main seabed geohazards posed by the pockmarks are perceived as foundation bridging at the relatively steep flanks of the pockmarks and the potential for loss of formation strength should sediment fluidisation occur.



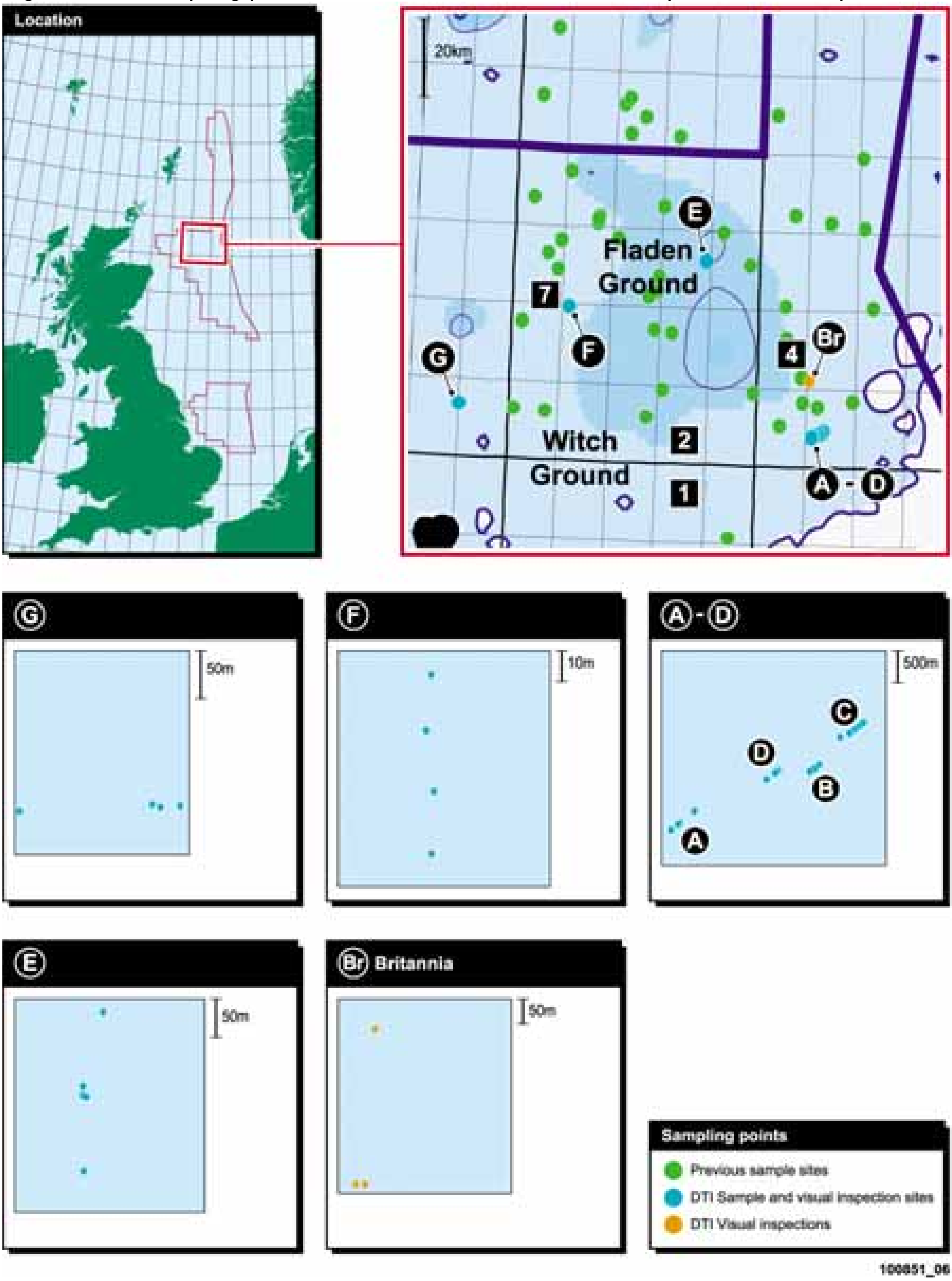
Source: Judd commissioned report, DTI 2001 survey data

Figure 5.8 Seabed photographs, DTI 2001 Survey, Fladen Ground. Horizontal field of view ca. 50cm.

Pockmark 3, south Fladen Ground. Fine mud substrate with surface detrital floc and entrance of Nephrops burrow.

Pockmark 6, south Fladen Ground. Fine mud substrate with both common species of sea-pen, Pennatula phosphorea (below left) and Virgularia mirabilis

Figure 5.9 - Sampling positions in the northern SEA 2 area (Fladen Ground)



5.3 Climate and meteorology

5.3.1 Overview

The central North Sea is situated in temperate latitudes with a climate that is strongly influenced by the inflow of oceanic water from the Atlantic Ocean and by the large scale westerly air circulation which frequently contains low pressure systems (OSPAR 2000). This influence is variable and long-term changes in the strength and persistence of westerly winds are influenced by the winter North Atlantic Oscillation (NAO – a pressure gradient between Iceland and the Azores). Atmospheric circulation has intensified over the last decades (OSPAR 2000), with the most extreme decadal change since the 1860s taking place from about 1960 (very weak westerly winds) to the early 1990s (very strong westerly winds). However, long-term wind data suggests a comparable period in the early 20th Century, and proxy data over several thousand years (from winter tree growth) indicate several occasions when similar increases have occurred.

Metocean (weather and sea) conditions in the North Sea have been intensively monitored, especially since commencement of offshore oil and gas production in the 1970s. Reliable data is therefore available for engineering design and operational planning purposes, and in general the North Sea is no longer considered to be an “extreme” province in terms of metocean conditions.

Meteorological Office wind data for the north, central and southern areas of the North Sea from the period 1854-1994 show the occurrence of winds from all directions, although dominated by winds from south-south-west and south. Predominant wind speeds throughout the year represent moderate to strong breezes (6-13 m/s), with the highest frequency of gales (>17.5m/s) during winter months (November – March).

The major contrast between the northern North Sea and central and southern parts, is the relative frequency of strong winds and gales, particularly from the south. Percentage frequency of winds of Beaufort force 7 and above in January is >30% north of 57ºN, but <20% south of 55ºN (Pilot 1997).

Mean annual rainfall, estimated from Nimbus-7 satellite passive microwave imagery, is relatively low in the western and central North Sea (in comparison to the Atlantic seaboard and to Norwegian coastal waters to the east), in the range 200-400 mm (OSPAR 2000).

Fog in the offshore North Sea is not especially common (Pilot 1997), with maximum frequencies (3 – 4%) in the extreme south during winter. In contrast, coastal fog (“haar”) is common during spring and summer along the east coast of Britain north of the Humber, with up to 14 days per month recorded in exceptional years.

5.3.2 Implications for Strategic Environmental Assessment

In conclusion, meteorological conditions within the SEA 2 areas are well understood and modelled using an extensive historical dataset, and are not considered to be a significant issue in terms of the Strategic Environmental Assessment process. Climate issues, in terms of the potential effects of oil and gas combustion, are outside the scope of this assessment.

5.4 Oceanography and hydrography

5.4.1 Sources and studies

Tidal stream patterns of the North Sea have been studied for navigational purposes over a period of (at least) several thousand years. Scientific investigation of the basic pattern of residual surface and seabed currents commenced in the late nineteenth century, using surface drift bottles and sea-bed drifters to demonstrate the existence of the Fair Isle current (Fulton 1897). Seasonal variability in North Sea circulation was described by Tait (1937) and Steele (1957). The development of recording current meters facilitated the series of JONSDAP '71 pilot exercise, JONSDAP '73 in the southern North Sea, and finally the INOUT experiment of JONSDAP '76, which involved the deployment of more than 200 current meters between Norway and Shetland (eg Riepma 1980, Turrell *et al.* 1992). JONSDAP '76 took place when the northern North Sea was vertically homogenous (see below), and the Autumn Circulation Experiment (ACE – see Figure 5.10) was conducted in 1987-1988 to monitor circulation preceding and during autumnal breakdown of vertical stratification (Turrell *et al.* 1992).

A large number of individual current meter deployments have been conducted in the North Sea, to support scientific naval hydrographic studies and since the 1960s, to support oil and gas exploration and production activities. Data from many of these deployments is held by the British Oceanographic Data Centre (BODC).

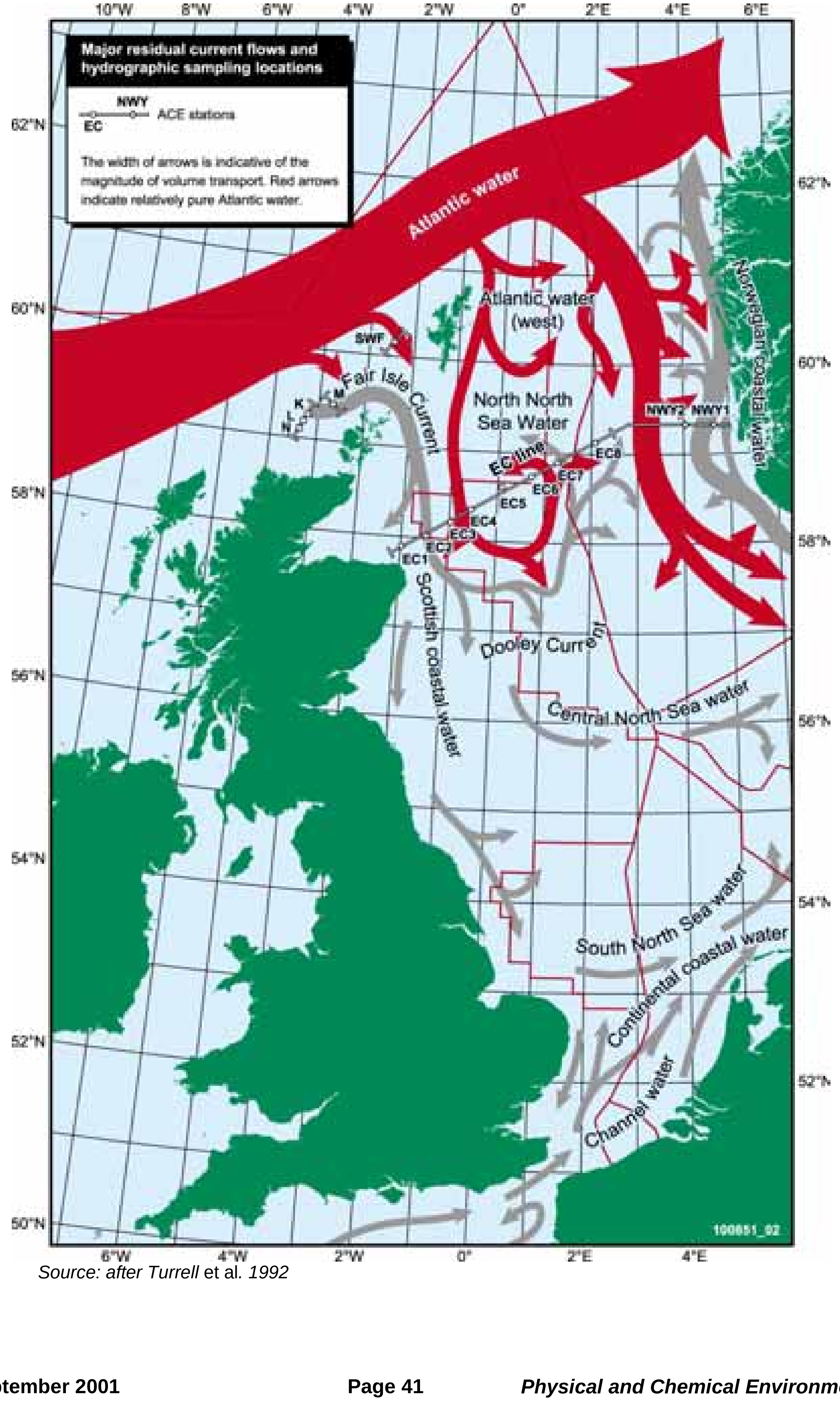
The North Sea Project was a Community Research Project of the Marine and Atmospheric Sciences Directorate of the Natural Environment Research Council (NERC) and was hosted by the Proudman Oceanographic Laboratory from April 1987 to April 1992. The field program was conducted between May 1988 and June 1991, consisting of sixteen cruises along a 1200 nautical mile track (shown in Figure 5.11). The ultimate aim of the NERC North Sea Project was the development of a suite of prognostic water quality models to aid management of the North Sea.

To progress towards water quality models, three intermediate objectives were pursued in parallel:

- production of a 3 dimensional transport model for any conservative passive constituent, incorporating improved representations of the necessary physics–hydrodynamics and dispersion
- identifying and quantifying non-conservative processes - sources and sinks determining the cycling and fate of individual constituents
- defining a complete seasonal cycle as a data base for all the observational studies needed to formulate, drive and test models

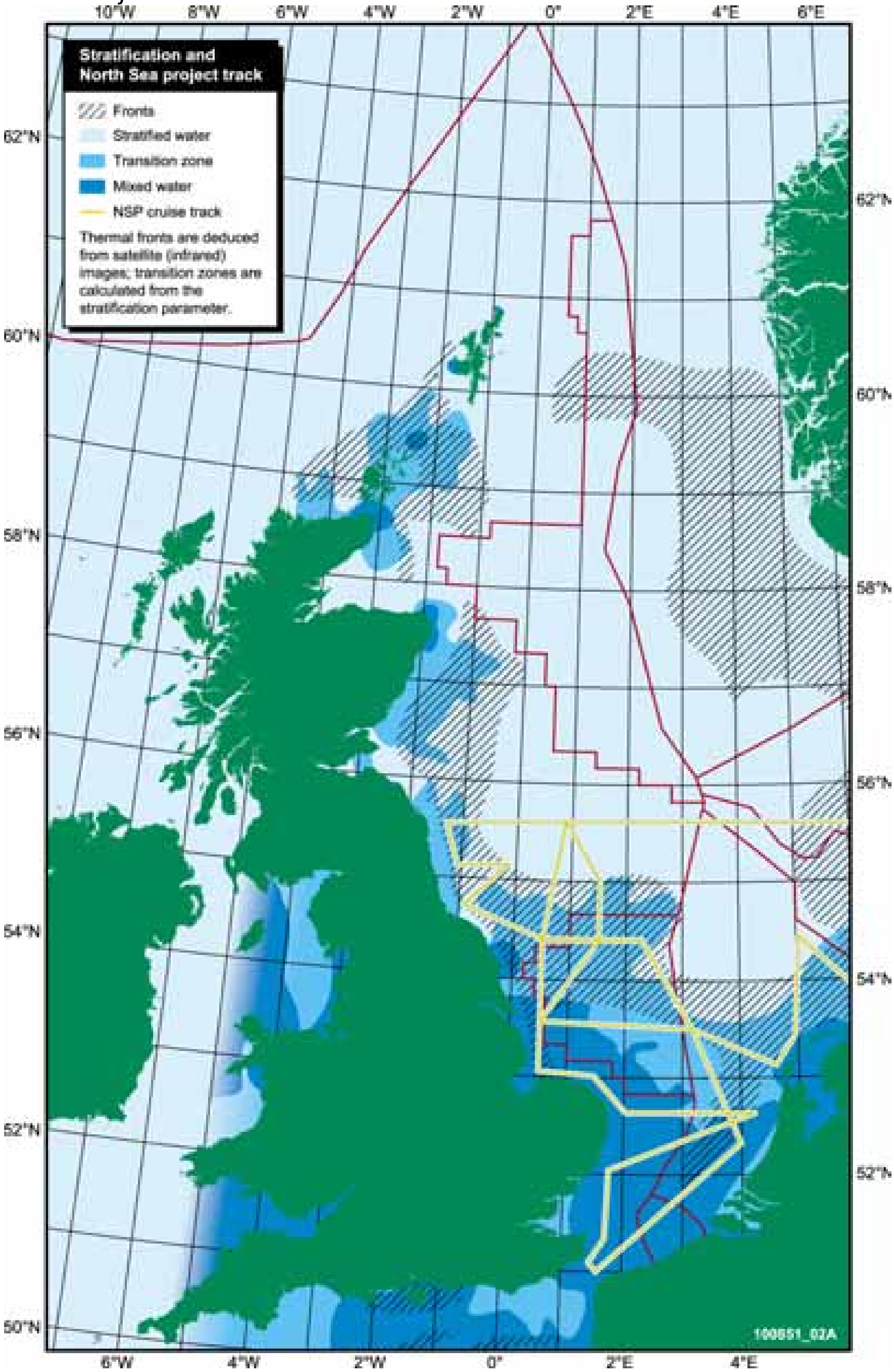
In addition to detailed studies of the Flamborough Head frontal system, Humber and Thames plumes and resuspension processes, a detailed study of the southern North Sea sandwave system was conducted. Drag coefficients based on measured pressure gradients were recorded and sea bed photography used to test bedload prediction formulae. The sand covering much of the southern North Sea is mobile forming banks that are interleaved with mud. Current meter moorings placed either side of a bank were used to estimate its associated circulation and contribution to dispersion. A 3 dimensional model using wave-current interaction enhancing the bed stress is being applied to fine grid (~100m) bathymetry and is being tested using detailed measurements of near-bed currents and turbulence obtained from the STABLE (Sediment Transport And Boundary Layer Equipment) rig.

Figure 5.10 - Residual circulation of the North Sea. JONSDAP and ACE study transect is also shown.



Source: after Turrell et al. *1992*

Figure 5.11 - Frontal zones and stratification of the North Sea. Cruise track for the North Sea Project is also shown.



Sources: OSPAR 2001 (after Becker 1990)

5.4.2 Circulation and structure

Several water masses in the North Sea are derived from mixing of North Atlantic water and freshwater run-off from land, and can be identified on the basis of temperature and salinity distribution, residual current patterns and stratification. The major water masses in the North Sea may be classified (after Turrell 1992, see Figure 5.10) as Atlantic water, Scottish coastal water, north North Sea water, Norwegian coastal water, central North Sea water, south North Sea water, Jutland coastal water and Channel water.

Density stratification is well developed in the summer months of most years in the central and northern North Sea, with the relative strength of the thermocline determined by solar heat input and turbulence generated by wind and tides. Temperature sections across the North Sea at 57º 17'N demonstrate thermocline development at a depth of around 50m, with mean summer surface temperature around 11ºC and nearbed temperature around 6.5ºC.

The shallow parts of the southern North Sea and the Channel remain well mixed throughout the year due to tidal action (OSPAR 2000) although the Kattegat, Skagerrak and Norwegian Trench region of the North Sea have a stable salinity stratification all year. Deep water in these areas is circulated mainly by subduction of high salinity water.

Fronts or frontal zones mark boundaries between water masses, including tidally-mixed and stratified areas, and are numerous in the North Sea. Fronts may restrict horizontal dispersion and may be associated with increased biological productivity. Satellite imagery shows that the central North Sea from Flamborough Head to the Frisian Islands, south-west of Norway and the northern German Bight are frequently characterised by thermal fronts marking transition zones between mixed and stratified water in the North Sea (Becker 1990).

Density stratification in the central and northern North Sea breaks down after September due to increasing frequency and severity of storms and seasonal cooling at the surface.

The main inflow to the North Sea occurs along the western slopes of the Norwegian Trench, with minor inflows from the Channel and Baltic. These inflows are balanced by outflow mainly along the Norwegian coast, with most of the water probably passing through the Skagerrak. Infrequent turnover of water in the deepest part of the Skagerrak occurs through cascades of dense water formed during cold winters over the northern North Sea, west of the Norwegian Trench (Ljøen and Svansson 1972). A schematic diagram of general circulation in the northern North Sea (Figure 5.10, after Turrell 1992) shows cyclonic circulation of mixed water from the Fair Isle inflow via the Dooley Current, and Atlantic water derived from southward flow to the east of Shetland. The resultant coherent gyre (Svendsen *et al.* 1991) is topographically generated, and is characterised by low velocity residual currents; typically 0.2m/s towards the south.

Using JONSDAP and ACE data, Turrell *et al.* (1992) considered circulation patterns in the northern North Sea under stratified and homogenous conditions, concluding that Atlantic inflow from the North was considerably greater under stratified conditions, with the Fair Isle current proportionately less important. The JONSDAP data may also have been influenced by an anomalous period of circulation from 1975 to 1980 (eg Martin and Dooley 1984). The Atlantic inflow from the north has profound implications for circulation of nutrients and contaminants, and for the supply of oceanic planktonic species (eg the dominant copepod *Calanus finmarchicus*) and fish larvae.

The generalised pattern of water movement in the North Sea may be strongly influenced by short-medium term weather conditions, resulting in considerable seasonal and interannual variability. Drastic differences in Atlantic water inflow from year to year, caused by atmospheric forcing, explain some of the observed large scale differences in salinity between years (OSPAR 2000). Storm events may also generate nearbed, wave-induced currents sufficient to cause sediment mobilisation.

The North Sea is considered to be frequently "rough" from October to March (Pilot 1997), with 20-30% exceedance of a significant wave height of 4m north of 57ºN, but <15% south of 55ºN. Extensive measurements have been made to characterise the wave climate of the North Sea, with a range of estimated 50 year maximum wave heights from 32m in the north to 12m in the Channel. Following over thirty years of exploration and production activity, engineering design criteria for installations and infrastructure in the North Sea are well-known and environmental conditions in this mature province are no longer considered a significant source of risk (as they once were).

Semi-diurnal tidal currents are relatively weak in the offshore northern and central North Sea, with maximum velocity approximately 0.4m/s. Tidal streams in coastal waters and throughout the southern North Sea may be stronger, up to 1 m/s off Rattray Head and 1.8m/s off Great Yarmouth (Pilot 1997).

5.4.3 Local hydrography around sandbanks

Significant local variations in patterns of semi-diurnal tidal and residual circulation occur in the vicinity of sandbanks. Bedforms and current meter measurements around the Leman and Well Banks, Smith's Knoll and Hewett Ridges (within or adjacent to the southern SEA 2 area, see Figure 5.6) have demonstrated residual near-bed currents to be strongest towards the bank crestline and in opposing directions on either side of the bank (Caston and Stride 1970, Caston 1972, Huthnance 1973). Current records on each side of Well Bank also demonstrated a clockwise near-bed residual circulation around the bank (Howarth and Huthnance 1984, Collins *et al.* 1995), with maximum semi-diurnal amplitude around 0.75 m/s. This residual circulation pattern is considered to be important in the formation and maintenance of linear sandbanks (see Section 5.2.2) and will also influence the dispersion of soluble and particulate contaminants.

Episodic currents, induced by wave action and storm surges, also influence sandbank development. Numerical model predictions of maximum storm surge currents are described by Flather (1987). The effects of a storm event on the morphology and surficial grain size distribution of the Middelkerke Bank (off the Belgian coast) included lowering of the crest by up to 1.2m, removal of sandwave topography on the bank, and accretion on the lower flank of material removed from the crest (Houthuys *et al.* 1994).

5.4.4 Implications for Strategic Environmental Assessment

The hydrography of the North Sea is relatively well described, although long-term variability in circulation patterns and physical processes remain the subject of long-term investigations. Hydrographic conditions in the North Sea are no longer considered to represent a significant challenge to exploration and production. For the purposes of dispersion and trajectory modelling, large-scale (ie hydrographic) physical forcing processes are well understood, although there remain some difficulties in modelling small-scale dispersion processes (A. Tyler, pers. comm.).

5.5 Contamination of water and sediments

5.5.1 Introduction

CEFAS, in collaboration with FRS, were commissioned to review the extent of existing chemical contamination of the North Sea, in the context of "background" levels and trends. The review was based on a number of previous collations and publications, including CEFAS Aquatic Environmental Monitoring Reports (AEMRs), reports from UKOOA including the recent review of seabed monitoring studies (Harries *et al*. 2001), and OSPAR reports including (OSPAR 2000) which presents an assessment of marine environmental conditions and temporal changes observed in the Greater North Sea since the 1993 Quality Status Report (QSR 1993). The commissioned review also draws on monitoring data acquired through the National Monitoring Programme's first phase (NMP, see MPMMG 1998) and second phase (NMMP).

5.5.2 Sources of contamination from the oil and gas industry

The main contaminants associated with the oil and gas industry in the North Sea come from produced water and drill cuttings. Produced water is now the major ongoing source of hydrocarbons, with hydrocarbon input from drill cuttings essentially eliminated due to replacement of diesel and low-toxicity oil based mud (OBM) discharges with alternative mud systems and disposal methods. There remains, however, a "legacy" of contamination resulting from historic cuttings discharges in the form of piles of cuttings around some installations.

5.5.2.1 Produced water

Produced water is derived from formation water in oil/gas reservoirs and from seawater injected to maintain reservoir pressure and enhance extraction efficiency. Produced water may have a complex composition, including dispersed oil, metals and organic compounds including dissolved hydrocarbons, organic acids and phenols. Produced water composition varies between specific installations, and generally differs considerably between oil and gas reservoirs. Trends in produced water discharges have been assessed by UKOOA and are forecast to decrease despite large increases in water production, due to technical developments including re-injection (considered in more detail in Section 10).

Produced water discharges are also responsible for significant discharges of production chemicals used offshore, where these partition into the aqueous phase. Higher quantities of corrosion inhibitors, gas treatment products and scale inhibitors are discharged into the northern North Sea than production chemicals of any other functional group. Reported discharges of the major process chemical categories are tabulated below see Table 5.1.

Table 5.1 - Peak annual values (in tonnes) of chemicals discharged by functional type between 1992 and 1998 (Value in parenthesis is year observed)

Chemical function	Northern North Sea	Central North Sea	Southern North Sea
Biocides	127 (1994)	98 (1995)	55 (1993)
Corrosion inhibitors	1770 (1996)	215 (1997)	74 (1996)
Gas treatment	1916 (1994)	1810 (1997)	2437 (1994)
Scale inhibitors	2677 (1993)	3030 (1997)	-

Reasons for some aspects of the variability in reported discharges (eg much greater discharge of corrosion inhibitor in the northern North Sea) are unclear. Although the selection of production chemicals for use offshore is regulated under the Harmonised

Mandatory Control System for the Use and Reduction of the Discharge of Offshore Chemicals (see below), which encourages the avoidance of toxic and bio-accumulating chemicals, specific concerns remain associated with the widespread use of synthetic polymers in demulsifiers and stimulation fluids. These materials are generally of low toxicity, but may be persistent in the environment due to their inert nature.

There is an OSPAR presumption against the discharge to sea of persistent synthetic materials, largely on a precautionary basis, since although the materials may not exhibit toxicity, the long term fate and effects cannot be judged (in the past PCBs and halocarbons were viewed as inert and non toxic).

5.5.2.2 Drill Cuttings

Metals in cuttings discharges are derived mainly from rock formation minerals, and from mud additives (principally barite and bentonite). The mud component of current and future discharges of cuttings to the North Sea comprise exclusively water-based mud (WBM), which generally results in wide dispersion of discharged cuttings in comparison to previous discharges of OBM, and little accumulation of contaminants in sediments and biota (Cranmer 1988, Neff *et al.* 1989, Hyland *et al.* 1994, Daan and Mulder 1996).

Cuttings piles resulting from previous OBM discharges are located mainly in the central and northern North Sea, and studies have reported a wide range of metal concentrations. However, in most cases the reported concentrations of the "Red List" metals are low. The average concentration range for a number of metals, at different depths in cuttings piles, was determined following a study of eleven cuttings piles in the North Sea (CORDAH, 1999). The highest average concentration for depths of 1-10 cm for all eleven piles was 8 µg/g Cd, 33 µg/g Hg, 173 µg/g Pb and 40,000 µg/g Fe. For barium, which is a major component of drilling muds, the highest average concentration was 86,000 µg/g – see Table 5.2.

Hydrocarbons are the main contaminants of cuttings drilled with OBM and cuttings piles, with maximum concentrations of total hydrocarbons recorded in excess of 200,000µg/g. A variety of PAHs may also be present (see Table 5.2)

Table 5.2- Concentrations of metals and hydrocarbons in cuttings piles

Metal	Concentration (µg/g)	Hydrocarbon sampled	Concentration (mg/kg)
Cadmium	0.1 – 8 [1]	Naphthalene	75 [1]
Copper	110 [2]	Phenanthrene	3 [3]
Mercury	0.1-33 [1]	Anthracene	12 [2]
Nickel	1-49 [2]	Fluoranthene	0.1 [3]
Lead	16-173 [1]	Pyrene	0.5 [3]
Zinc	2-435 [2]	Chrysene	0.3 [3]
Iron	40,000	Benzo[*a*]anthracene	0.1 [3]
Barium	86,000	Benzo[*a*]pyrene	0.007 [2]

(Sources: [1] Law and Fileman, 1985, [2] Data from Davies et al., 1989, for the Beryl A cuttings pile, [3] Data for the Fulmar cuttings pile.)

5.5.3 Overall consideration

With regard to the wider environment of the North Sea and levels of contaminants in different matrices the following conclusions were made by CEFAS.

5.5.3.1 Water

Water samples with the highest levels of chemical contamination are found at inshore estuary and coastal sites subject to high industrial usage - see Table 5.3. Where, for example, concentrations of total hydrocarbons (THCs) are found to be high offshore, these are in the immediate vicinity of installations with concentrations generally falling to background levels within a very short distance from discharge.

Table 5.3 - Summary of contaminant levels typically found in surface waters of the North Sea

Location	THC (µg/l)	PAH (µg/l)	PCB (ng/l)	Ni (µg/l)	Cu (µg/l)	Zn (µg/l)	Cd (ng/l)	Hg (ng/l)
Oil & Gas Installations	1–30[1]	-	-	-	-	-	-	-
Estuaries	12-15[2,3]	>1	30[2]	-	-	-	-	-
Coast	2	0.02–0.1	1 – 10^4	0.2-0.9[2,3]	0.3-0.7	0.5-2.2	10-32	0.25-41
Offshore	0.5-0.7[2,3]	Below det.	-	0.2-0.6	0.3-0.6	0.5-1.4	10-51	1.6-69

(Sources: [1] Law and Hudson, 1986, [2] OSPAR, 2000, [3] Law et al., 1994, [4] SOAEFD, 1996)

5.5.3.2 Sediments

Trends in the concentration and distribution of contaminants in sediments, particularly hydrocarbons, are similar to those described for surface water contamination – see Table 5.4. There are, however, some notable exceptions. For example, the levels of certain metals appear higher in the southern North Sea compared to the northern North Sea (Pb, V, Cu and Fe). Recent work on seasonal current circulation patterns within the southern North Sea suggests that this may be due to coastal contamination transported offshore without being widely dispersed.

Table 5.4 - Summary of contaminant levels typically found in surface sediments from the North Sea

Location	THC (µg/g)	PAH (µg/g)	PCB (µg/kg)	Ni (µg/g)	Cu (µg/g)	Zn (µg/g)	Cd (µg/g)	Hg (µg/g)
Oil & Gas Installations	10-450[1]	0.02-74.7[2]		17.79[6]	17.45	129.74	0.85	0.36
Estuaries	-	0.2-28[5]	6.8-19.1	-	-	-	-	-
Coast	-	-	2	-	-	-	-	-
Offshore	17-120[2]	0.2-2.7[3,4]	<1[4]	9.5	3.96	20.87	0.43	0.16

(Sources : [1] Daan et al. 1992, [2] Law and Fileman 1985, [3] Klamer and Fomsgaard 1993, [4] OSPAR 2000, [5] CEFAS 1998, [6] Harries et al. 2001)

5.5.3.3 Evidence Of Biological Effects

There are two main sources of potential biological effect upon marine organisms that are associated with oil and gas production activities: those caused by production discharges, ie produced water, and those associated with drilling activities. Operational aerial emissions may also give rise to deposition of contaminants (in particular the lower molecular weight compounds such as naphthalene and pyrene) on the sea surface.

Exposure of marine organisms to contaminants occurs by two routes, either through passive diffusion or active uptake processes via surface membranes, or through absorption from the gut in association with fatty materials. Organisms spending the majority of their life-cycle in the water column are therefore likely to receive the highest exposure to contaminants that remain in solution. Contaminants that are/or become readily associated with suspended particles are likely to become associated with the sediments. The main exposure route for particle bound contaminants will be through direct ingestion by various benthic species or indirectly when these same species are consumed by other organisms. In addition, those organisms living in close association with the sediments may also absorb contaminants from interstitial water.

The effects of contaminants upon biological systems can be manifested at a number of different levels of organisation ranging from the cellular and organ level through to changes in the sizes of populations and ultimately to altered diversity and functioning within the community of interacting populations. Changes that occur at the cellular and organ level may provide an 'early warning system' of more dramatic and possibly irreversible effects upon populations or communities. CEFAS have reviewed a range of biomarkers of contaminant exposure, including induction of 7-ethoxyresorufin-O-deethylase (EROD) activity, bile metabolite concentrations, DNA adducts, lysosomal membrane damage, immune response impairment and disease induction. All the reviewed biomarkers are indicators of PAH exposure, and studies of EROD induction in fish (principally dab, sandeel and adult and larval gadoids) from various locations in the North Sea have been interpreted in terms of PAH concentrations in sediments and the water column (e.g. Davies *et al.* 1984, Stagg and McIntosh 1996, Aas and Klungsøyr 1998). Laboratory exposure studies have confirmed the sensitivity of EROD and immune response impairment to OBM cuttings (Stagg 1994, Tahir *et al.* 1993); and EROD, bile metabolites and DNA adducts to crude oil (Aas *et al.* 2000).

Much of the work carried out on contaminant effects (including acute toxicity) relates to PAH associated with OBM drill cuttings. Although this work is of great relevance to the management of "legacy" contaminants in cuttings piles, current and future drilling activities will not result in discharges of OBM to the marine environment. Activities considered within the scope of SEA 2, therefore, will not result in environmental effects from this source. Metals and organic compounds (including low concentrations of aliphatic oils and monoaromatics) discharged in WBM do not appear to result in significant toxicity (eg Daan *et al.* 1994), and drilling activities primarily have direct physical disturbance effects on the benthic fauna directly underneath and some distance from the well surface location. Ecological effects of drilling and drill cuttings are considered in more detail in Section 10.

Contaminants in produced water plumes could potentially have direct effects on populations of both pelagic invertebrate and vertebrate species in the vicinity of the discharge and also indirect effects via bioaccumulation and bioconcentration of contaminants through the food chain. However, composition and toxicity of produced water varies greatly (reviewed by CEFAS, see above) and although laboratory and enclosure studies have frequently demonstrated the toxicity of produced water from various sources (eg Gamble *et al.* 1987, Davies and Kingston 1992, Stromgren *et al.* 1995), high dispersion means that significant toxicity in actual receiving waters has rarely been demonstrated (Stagg *et al.* 1996). Ecological effects of produced water are considered in more detail in Section 10.

Another issue of concern is the potential for cumulative impacts in areas where a number of platform 'footprints' overlap, and further fingerprinting of hydrocarbons and other contaminants, together with suitable numerical modelling is recommended by CEFAS. It is also suggested that future research should assess the significance of offshore discharges relative to larger discharges from coasts (including atmospheric deposition) and their relative impacts in intermediate and offshore waters.

5.5.4 Implications for Strategic Environmental Assessment

In conclusion, understanding of contamination of water and sediments in the SEA 2 areas of the North Sea, in terms of present status and trends, is considered adequate for assessment of the potential effects of licensing. Specific issues associated with emissions and discharges from predicted activities are addressed in Section 10.5.4.

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6 ECOLOGY

6.1 North Sea overview

Typically for a shallow coastal region in a temperate climatic zone, the North Sea is a complex and productive ecosystem which supports important populations of fish, seabirds and marine mammals. Pelagic and benthic communities are interlinked in more or less tightly coupled food webs which together with the abiotic environment, make up marine ecosystems.

In a holistic and integrated summary of the status of the entire OSPAR maritime area (OSPAR 2000), marine ecological processes were summarised as follows:

Microscopic phytoplankton constitute the 'grass' of the sea and the basis for production at higher tropic levels. Phytoplankton is grazed by zooplankton, which again forms the food for plankton-feeding fish (e.g. anchovies, herring, mackerel) and whales. Benthic animals living in or on the seabed feed on plankton and dead organic material sinking out from the upper layer. Fish, squid, sea mammals and seabirds feed on smaller fish or benthic animals. Kelp and other macroalgae grow as plants in the lighted zone in shallow waters. Microorganisms contribute to decomposition of organic material and recycling of nutrients.

Productivity and biogeographic importance of the North Sea is probably most evident in terms of seabird populations (Section 6.7). Although there are no endemic seabird populations, the North Sea supports substantial proportions of the global population of some species (eg great skua). Conversely, the North Sea is of less overall importance to cetaceans, although some areas are important for minke whales, harbour porpoise, white-beaked dolphin. The North Sea supports about half the North-East Atlantic population of grey seals and a similar proportion of the eastern Atlantic harbour seal subspecies (Section 6.8).

The planktonic, benthic and fish populations which support these top predators are reviewed in the following sections. While discernible patterns are present in pelagic community distributions, considerable variations occur throughout the North Sea, and regional and local heterogeneity is most obvious in benthic community structure, where characteristic species assemblages are associated with particular seabed habitats – these range from shallow sands in the south to deep, pockmarked muds in the north. Benthic habitats and communities also reflect the recent geological history of the North Sea, and can be considered to be in a process of continuous change in response to climatic and other factors (Section 6.3).

Planktonic communities in the northern and central North Sea show the strong influence of North Atlantic inflow. Planktonic communities also reflect climatic and hydrographic variability, with significant changes observed over decadal or shorter timescales (Section 6.2).

Brief synopses of the ecological characteristics and resources of the North Sea, with specific reference to the SEA 2 areas, are provided below. These refer to previous published reviews where available, in addition to a series of scientific and technical reviews commissioned specifically for SEA 2 which are available from the SEA website.

Note, the different sections have differing degrees of reference citation since commissioned reviews contain comprehensive references to published data sources.

6.2 Plankton

6.2.1 Introduction

SAHFOS was commissioned to review plankton ecology in the North Sea. The report describes the plankton community structure and how this has changed over the past few decades.

Plankton in the North Atlantic and North Sea has been monitored for almost 70 years using the Continuous Plankton Recorder (CPR), a well conceived project which continues to provide extremely valuable information. From this data, changes in abundance and long term trends can be distinguished. Planktonic organisms constitute a major food resource for many commercial fish species and changes in their populations are therefore important.

6.2.2 Planktonic communities in the North Sea

Plankton can be divided into phytoplankton (plants) and zooplankton (animals).

The most common phytoplankton groups are the diatoms, dinoflagellates and the smaller flagellates. The latter are often referred to as pico or nano plankton but, because of their small size, they are difficult to study and are under researched. Much of this group consists of bacteria, in addition to blue-green algae, and at times may make up 15 to 33% of the total plankton biomass.

The phytoplankton community in the northern North Sea is dominated by the dinoflagellate genera *Ceratia*. CPR results have shown an increase in the dinoflagellates with a gradual decrease in the diatom species. In the southern North Sea *Ceratia* again dominate, but there are higher numbers of the diatoms *Chaetocera*, *Hyalochaete* and *Phaeoceros.* Phytoplankton biomass has increased over the last four decades over the majority of the North Sea.

The zooplankton communities of the northern and southern North Sea regions are broadly similar. Copepods have the highest abundance, with *Calanus* dominating. In the southern North Sea meroplanktonic echinoderm larvae are the second most abundant group recorded.

The larger zooplankton, known as megaplankton, includes euphausiids (krill), thaliacea (salps and doliolids), siphonophores and medusae (jellyfish). The gelatinous taxa are poorly sampled as their bodies disintegrate on contact with the CPR although they are known to be more abundant in late summer and autumn.

Salps and doliolids are known to produce huge swarms, peaking in late summer to October. This can lead to depleted food sources for other herbivorous plankton with subsequent effects to the higher trophic levels. Siphonophores (colonial hydrozoa) can also reach large densities in the North Sea.

Krill is very abundant throughout the North Sea and is a primary food source for fish and whales. During times of increased flow of colder water from the Norwegian Sea, euphausiid numbers increase.

Meroplankton are the larval stages of benthic organisms that spend a short period of their lifecycle in the pelagic stage before settling on the benthos. Important groups within this category include the larvae of starfish and sea urchins (echinoderms), crabs and lobsters (decapods), and some fish.

The northern North Sea has seen an increase in decapod larvae since the late 1980s, with a dramatic rise in 1998, tied in with a large Atlantic inflow. The southern North Sea has also shown a general increase in abundance, though no pronounced increase in 1998. Echinoderm larvae also increased in the northern North Sea in the late 1990s. The southern North Sea population shows no change.

6.2.3 Plankton blooms in the North Sea

In the North Sea a natural phytoplankton bloom occurs every spring, often followed by a smaller peak in the autumn. In spring, as the day length increases and the water column becomes stratified, there is a bloom of diatoms. As little mixing of the water occurs, nutrients essential for the diatoms become depleted and other groups bloom, such as flagellates, followed later by dinoflagellates. As nutrients become further depleted, primary production slows down. Autumn introduces stronger winds which mix the water, introducing nutrients back to the photic zone, initiating a secondary bloom of dinoflagellates. As light levels reduce through the latter part of the year, primary production is again limited. With little primary production during the winter months, nutrients rise to levels to support the spring bloom.

The winter distribution of phytoplankton and zooplankton around three sandbanks off the Belgian coast was investigated by M'harzi *et al.* (1998), who found significant differences in phytoplankton taxa between the banks. This was attributed to salinity, temperature and turbidity differences and suggests that spatial heterogeneity in plankton communities during late winter may influence "starting positions" (in terms of community composition) for the spring bloom.

CPR results show exceptional phytoplankton blooms in the late 1980s. This was connected with very mild atmospheric conditions together with a large oceanic inflow into the North Sea.

Under certain conditions (eg rapid reproduction, reduced grazing pressures, favourable environmental factors) blooms can occur at other times of the year. Many of these blooms involve nuisance or noxious species and are described as Harmful Algal Blooms (HABs). Examples include those connected with paralytic shellfish poisoning.

6.2.4 The influence of hydro-climatic changes in the North Sea

A key influence of the North Atlantic weather patterns is the North Atlantic Oscillation (NAO; see also Section 5.4). During certain conditions, westerly winds increase over the North Sea which introduce warmer air and increase the North Sea surface temperatures. In addition, the increase in wind reduces stratification of the surface waters, delaying the onset, or altering the community structure of the spring bloom. These conditions have been more predominant in the last few decades and there is a suggestion that this may be an effect of global warming.

The plankton community in the North Sea has changed over the last few decades with the population composition of *Calanus* changing markedly over the last 10 years. There has also been a considerable increase in phytoplankton density over the last decade in most areas of the North Sea. These changes have coincided with an increase in sea surface temperature, linked to the state of the NAO.

In addition to the general trend in increasing sea surface temperature, there have been times when water of differing salinity and/or temperature has entered the North Sea and changed the local ecosystem. In the late 1970s a pulse of cold, low salinity water entered the North Sea which delayed and lowered the primary production of the spring bloom. Conversely, in the late 1980s and again in the late 1990s warm, more saline oceanic water entered the North Sea.

Recent research has suggested that inflow into the North Sea is becoming more persistent, rather than episodic. This is notable in the phytoplankton community, with diatoms decreasing and dinoflagellates increasing over the last decade. This could have important ramifications, as many dinoflagellate (and flagellate) species are noxious to other organisms.

It is therefore apparent that hydro-climatic events are important in altering the ecosystem of the North Sea. Current research suggests that these events have a greater impact on the biota of the North Sea than the anthropogenic factors.

6.2.5 Sensitivity to disturbance/contamination

Ship traffic is high in the North Sea, resulting in a high risk of oil spills. Effects on plankton have not been studied extensively although the effects from relatively recent oil spills from tankers eg *Torrey Canyon*, *Braer* and *Sea Empress* have been assessed.

Work after the *Sea Empress* spill failed to find any significant effects on the plankton although other studies have shown lowered fecundity and offspring mortality. There is a strong suggestion that dispersant treated oil has a more pronounced effect. Any long-term genetic changes are difficult to assess.

Oil pollution from exploration/production only forms a small percentage of entry of oil to the marine environment. In less major spills, bacteria can play an important role in removing the oil.

6.2.6 Ballast water and invasive species

Ballast water in ships has been recognised as a source for the introduction of non-indigenous and potentially harmful organisms. A number of exotic planktonic organisms have been identified in the North Sea and there is a growing concern considering the risk of alien species and the importance of protecting native biodiversity. Legislation is currently under development to protect coastal waters.

6.3 Benthos

6.3.1 Recent history of North Sea

While the North Sea has a long geological history dating back to the Permian (about 275 million years ago), events over the last 11,000 years are the prime influences on modern day seabed fauna distributions. During the last glacial period which ended about 11,000 years ago, sea levels were around 100m below present and much of the North Sea was dry land or covered by ice. The present status in the North Sea was achieved about 6,000 years ago when the Flandrian transgression occurred, flooding the shallow land south of the Dogger Bank. Thus the seabed fauna of the North Sea has colonised and developed over the last 6,000 to 11,000 years, in the process being subject to a change from Arctic to more temperate Boreal conditions. While conditions are comparatively stable, they are not static, with long term climatic/hydrographic cycles (OSPAR 2000) and short term extreme events occurring (eg the harsh winter of 1962/3, Crisp *et al*. 1964) which result in progressive or sharp ecological changes. Overlain on natural changes are the effects of man's activities which occur at a local and ecosystem level (see Section 6.3.8).

6.3.2 History of benthic studies in the North Sea

After the adoption of the binomial system of biological nomenclature introduced by Linnaeus in the eighteenth century, studies of the seabed on the North Sea (and elsewhere) consisted chiefly of the collection of specimens in the search for new species to be described and named. Such specimens were usually collected qualitatively, often without much ancillary ecological information.

This phase was superseded in the early twentieth century by quantitative sampling of the seabed when the main impetus for research was commercial fisheries. This is exemplified by the title of one of the classic studies of the time by CGJ Petersen (1918) "*The sea bottom and its production of fish food. A survey done in connection with valuation of the Denmark waters from 1883-1917".* The other main objectives of seabed sampling at that time were to elucidate zoogeographic patterns and the distribution of regularly occurring groups of animals (communities found in equivalent habitats).

In the latter part of the twentieth century, in addition to fisheries and ecological studies, seabed surveys in the North Sea began to be conducted to identify the sites of potential conservation importance and of assess the effects of man's activities, in particular pollution. The majority of conservation studies were restricted to coastal waters (see Hiscock 1998), although in the last few years consideration has started to be given to offshore habitats and species. In many areas, environmental studies form the bulk of the surveying effort and although not confidential, much of the information remains unpublished and difficult to obtain readily. In recognition of this, UKOOA commissioned the compilation of an inventory of all oil and gas related seabed surveys carried out on the UKCS, the establishment of a repository for the reports and publication of the database on CD together with a report (Harries *et al*. 2001). A similar exercise has also been undertaken in Norway (Carroll *et al*. 2000).

6.3.3 Biogeographic zones

Biogeographic zones are distinguished by patterns of overlapping occurrence of species, which in turn reflect major ecological influences such as water temperature. Generally, there are not sharp boundaries between biogeographic zones since individual species tolerances to ecological factors are different. The dividing lines can be further blurred where long term changes in conditions occur. Given this blurred picture, it is unsurprising that there should have been various interpretations of the patterns shown by seabed animals and plants, and that alternative (but similar) groupings are identified for other components of the marine system such as the plankton.

Different authors have given different interpretations of biogeographic zones, in part on whether they were “lumpers” or “splitters”. Ekman (1953) and Briggs (1974) regarded the North Sea as lying at the centre of the Eastern Atlantic Boreal Region extending from Brittany to northern Norway. This pattern accords with the work of Longhurst (1998) for the pelagic system, where the UKCS is part of the Northeast Atlantic Shelves Province which extends from Brittany to mid Norway.

According to recent work carried out on behalf of OSPAR (Dinter 1999), the UK lies at the junction of five biogeographical zones (Provinces):

- Boreal Province including the North and Irish Seas
- Lusitanian-Boreal Province comprising the Celtic Sea and west coasts of Ireland and Scotland
- Norwegian Coast Province, extending from the Skagerrak to beyond Lofoten
- Arctic Deep-Sea Province, a deep water zone centred on the Norwegian Sea but extending into the Faroe Shetland and Faroe Bank Channels
- Atlantic Deep-Sea Province, a deep water zone to the west of northeast Europe

There is general agreement that the part of the North Sea comprising the UKCS is typical of the Boreal Province, although in the extreme northern North Sea a number of species occur which point to the influence of Arctic waters.

6.3.4 Broad patterns of community distribution and types

Each biogeographical province can be further subdivided according to physical and biological features. Various authors have noted that the faunal distributions at the seabed in the North Sea appear to reflect hydrographic patterns and Glémarec (1973) developed this and proposed three subdivisions of the area on the basis of thermal stability over time:

- The northern North Sea where the water mass stratifies strongly in summer, effectively insulating the bottom water and seabed fauna from the large scale temperature changes that occur in the upper water column. The annual temperature range at the seabed is only 1-2°C. This area is to the north of 58°N and approximately bounded by the 100m depth contour
- The central North Sea (between the 100m depth contour and the Dogger Bank) where the annual temperature variation is 7 or 8°C
- The southern North Sea (south of the Dogger Bank) where the water column remains mixed year round and tidal, daily and seasonal variations in temperature occur and the variation over the year is in excess of 10°C

Within each subdivision of the North Sea, Glémarec was able to distinguish a series of faunal communities inhabiting specific sediment types, which accorded well with previous community descriptions. Subsequent studies, including a series of surveys combined to give North Sea wide coverage coordinated by ICES (Künitzer *et al.* 1992), have supported the broad divisions identified by Glémarec. In many cases however, the community groupings distinguished are dependant on the scale of the survey, with smaller scale surveys revealing more localised community types usually reflecting local sediment distribution patterns. It should be noted that such small scale features (eg pockmarks) and localised communities may be of conservation interest on account of their local or wider rarity. The broad scale patterns of seabed faunal community distribution are illustrated in Figure 6.1, developed from Glémarec (1973), Basford *et al.* (1990), Duineveld *et al.* (1990), Künitzer *et al.* (1992) and Jennings *et al.* (1999).

These broad patterns of North Sea seabed faunal distribution parallel those identified in the pelagic system. Within the North Sea, Adams (1987) recognised 7 ecological subdivisions on the basis of hydrography and plankton composition:

- Offshore Northern (north of 58°N, bounded by the 100m depth contour to the south and west, and by the 200m contour to the east)
- Norwegian Deeps (covering the deep Norwegian Channel)
- Offshore Central (in the central North Sea bounded by the 100m depth contour to the north and the 50m contour to the south)
- Offshore Southern (in the southern central North Sea between the 50m depth contour to the north and the 40m contour in the south)
- Continental Coastal (east of the midline between British and French, Belgian and Dutch waters, bounded in the north by the 40m depth contour)
- Southern British Coastal (west of Continental Coastal and extending to Flamborough Head ca. 54°N)
- Northern British Coastal (extending north from Flamborough Head initially as a narrow strip then broadening north of St Abbs Head ca. 56°N extending eastwards to the 100m depth contour)

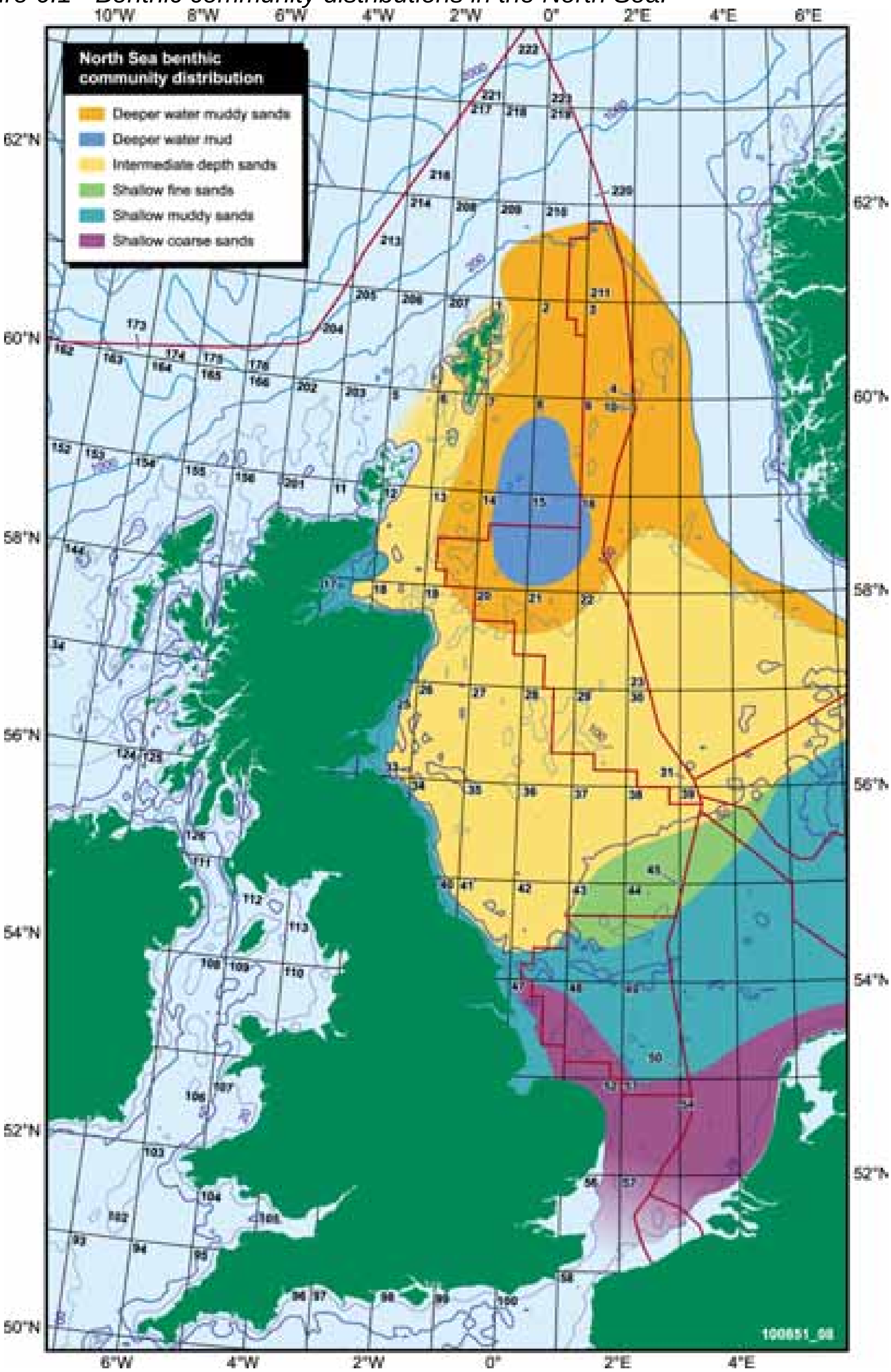
The ecological divisions identified by Adams (1987) are similar to those proposed earlier but with the division of British Coastal waters into a northern and southern components.

In contrast to the macrofauna, the smaller seabed fauna (meiofauna) of the North Sea has been poorly studied with large numbers of species yet to be named in the scientific literature (Heip and Craeymeersch 1995). This basic information is required before different community types can be distinguished and mapped and the full biodiversity of the seabed can be assessed.

6.3.5 Southern North Sea regional context

The seabed of the southern North Sea was the subject of early studies by Petersen (1914 and 1915) and Davis of the Dogger Bank (1923) and southern North Sea (1925). The Danish surveys continued between 1932 and 1955 culminating in a series of papers describing the species composition and distribution of various groups of seabed animals (Ursin 1960, Kirkegaard 1969, and Petersen 1977). The Danish sampling was centred on the Dogger Bank and adjacent areas, reflecting the importance of the area for fisheries. Results of sampling on the central and western Dogger Bank between 1952 and 1954 by Birkett remained largely unpublished until included in a paper by Kröncke (1991), although an important finding regarding the persistence of dense populations of the bivalve *Spisula* was published by Birkett (1953).

Figure 6.1 - Benthic community distributions in the North Sea.



Sources: after Glémarec 1973, Basford et al. 1990, Duineveld et al. 1990, Künitzer et al. 1992, Jennings et al. 1999

More recently, numerous investigations of the seabed have been carried out in the southern North Sea. These have primarily been small spatial scale environmental monitoring of various industrial activities, but also include a number of wide area surveys which provide a regional setting in which information from local surveys may be placed. Regional surveys are summarised below:

Table 6.1 – Regional surveys

Reference	North Sea area covered	Notes
Govaere *et al.* 1980	Belgian and southern Dutch offshore waters	Sampled infauna. Coverage stopped just south of the SEA 2 area
Dyer *et al*. 1982, 1983	The North Sea between 52° 45' and 61° 39'N	Epifauna sampled by otter trawl since 1978
Creutzberg *et al.* 1984	Majority of Dutch waters	Sampled infauna.
Frauenheim *et al*. 1989	The North Sea between 51° 45' and 60°N	Epifauna sampled by beam trawl
Duineveld *et al.* 1990	The Dutch exclusive economic zone	Sampled infauna. Data also incorporated into the ICES survey of the North Sea (Künitzer *et al*. 1992)
Künitzer *et al*. 1992	The North Sea between 51° and 61°N	Addressed infauna. Several of the contributory studies are also published separately
Kröncke 1992	The Dogger Bank and some immediately adjacent areas	Infaunal surveys carried out in 1985-1987 which revisited many of Ursin's 1950 stations
Duineveld 1992, Holtmann *et al.* 1998	The Dutch exclusive economic zone	A series of infaunal surveys from 1992 to 1997 with results published and compared annually
Jennings *et al*. 1999	The North Sea between 51° 40'and 61° 11'N	Epifauna sampled by beam trawl in 1996
Rees *et al*. 1999	The North Sea between 51° 30'and 58° N (for epifauna) and 51° 30'and 55°N	Infauna sampled by Day grab 1993-1994, epifauna sampled by beam trawl between 1992 and 1996

The infaunal communities identified by various authors show consistency at a high level. However, depending on the intensity and spatial extent of sampling, localised community types or more subtle variations are distinguished. In terms of broad community distribution, the ICES survey reported by Künitzer *et al*. (1992) provides a good picture. In the southern North Sea four main communities were found in:

- fine sands in 50-70m with a fauna typified by the polychaetes *Ophelia borealis* and *Nephtys longosetosa*
- muddy fine sands in 30-50m with the bivalve *Nucula nitidosa*, the shrimp *Callianassa subterranea* and the cumacean crustacean *Eudorella truncatula*
- coarse sediments mainly in less than 30m (1) with the polychaete *Nephtys cirrosa*, the sea urchin *Echinocardium cordatum* and the amphipod crustacean *Urothoe poseidonis*
- coarse sediments mainly in less than 30m (2) with the polychaetes *Aonides paucibranchiata* and *Pisione remota* and the amphipod crustacean *Phoxocephalus holbolli*

All these major community types are represented within the SEA 2 area.

From the work of Vanosmael *et al.* (1982) on the Kwinte Bank of Belgium, the fauna of linear sandbanks appears distinctive in a number of features, in particular the very high densities of interstitial (that is living in the interstices between sediment grains) polychaetes present. These species show very high variability between sampling stations which either reflects patchiness of distribution or very tightly defined habitat requirements, so that a small alteration in location of samples results in a large difference in the fauna recorded.

Similar sandbanks occur on the southern part of the SEA 2 area although there appears to be no published quantitative information on the fauna present. Since some sandbanks in waters of 20m or less may be considered for inclusion in UK Natura 2000 sites (potential SACs), the DTI commissioned detailed surveys of these habitats within the SEA 2 and adjacent areas. Preliminary results of the survey are available from samples screened on a 5mm mesh and summarised below.

It is clear that there are major sediment and faunal differences between the offshore linear sandbanks (the Norfolk Banks) and the banks in the approaches to the Wash. The Wash approach banks (Galahad field, Dudgeon Shoal, Cromer Knoll and the western end of the Haddock Bank) have a stony and coarse shell sediment with extensive epifauna and infauna. In contrast, the offshore linear banks were sandier with a fauna typified by the sea urchin *Echinocardium cordatum* and the bivalve *Fabulina fabula* with sandeels (two species) common. An initial conclusion from the 5mm sieved samples is that the fauna of the bank flanks and crests is little different. This should be reviewed once the results of the 1.0 and 0.5mm sieved samples are available.

The DTI samples of the Dogger Bank indicate a richer (more and larger animals of a range of species) fauna than that found on the sandbanks to the south. At the 5mm material level, no major differences can be discerned between the various stations sampled across the Dogger Bank. Predominant species were *Echinocardium cordatum*, *Fabulina fabula* and a range of worms including the sand mason *Lanice conchilega* and *Owenia fusiformis*.

The fauna recorded during the DTI survey of the southern SEA 2 sandbanks accords closely in terms of species distribution with previous surveys of the area.

Dyer *et al*. (1983) conducted cluster analyses of trawled (primarily epi-) fauna from MAFF groundfish surveys over the whole North Sea, showing the area could be divided into 4 northern and 3 southern groups. The southern groups corresponded to the northern slopes of the Dogger Bank (S3), the shallowest part of the Dogger Bank and other shallow stations on the western side of the North Sea (S2), and the broad area of muddy fine sands off the Dutch coast forming group S1.

The cluster analysis performed by Jennings *et al*. (1999) indicated that the epifauna of the whole North Sea south of the Dogger Bank was similar and formed a single cluster. In contrast, Rees *et al*. (1999) concluded that the area could be divided into 6 groupings based on sediment type and epifauna. Those included within the SEA 2 area were northwestern North Sea gravel, Stony, east Channel and east coast of England gravel, nearshore muddy sand/Dogger Bank, and southern North Sea sand, with the latter two being most extensive.

6.3.6 Central and Northern North Sea regional context

The first quantitative investigation of seabed fauna of the area was carried out by Stephen (1923) as part of wide scale sampling to define seabed communities. In addition to a large number of sampling stations in Scottish coastal waters, he sampled three offshore transects in the North Sea, from Hull to the Skagerrak, from the Moray Firth to Stavanger, and down the east side of Shetland. For the stations in the deeper North Sea he concluded that, "The results obtained show, firstly, that the same type of fauna occurs over wide areas." The fauna of the area of intermediate depths of the central North Sea was characterised by the brittle starfish *Ophiura affinis* and *Amphiura filiformis* and the sea urchin *Echinocyamus pusillus.* The fauna of the Fladen Ground area was described as a Foraminifera community typified by abundance of the foraminiferans *Saccammina sphaerica*, *Psammosphaera fusca* and *Astrorhiza arenaria* together with the bivalve *Thyasira flexuosa* and the brittle starfish *Amphiura filiformis* and *A. chiajei*. Figure 5.9 provides an indication of the locations of previous sampling in the Fladen Ground from both published studies and unpublished oil industry surveys.

McIntyre (1961) collected 20 grab samples from a station near the centre of the Fladen Ground and also found the fauna dominated by dense populations of foraminiferans, together with the polychaete worms *Levinsenia gracilis*, *Lumbrineris* spp. and *Myriochele heeri* and the bivalve *Thyasira equalis.*

In terms of spatial coverage, the most comprehensive survey of the central North Sea was that of Eleftheriou and Basford (1989) who sampled 97 stations for infauna (animals living within the sediments). Multivariate analyses of the full infaunal dataset showed 4 major groupings of stations with cluster IV, comprising stations within the Fladen Ground, with muddy sediments and fauna typified by *Levinsenia gracilis* and *Lumbrineris gracilis* (polychaetes) and *Eriopisa elongata* (amphipod crustacean). A description of the other offshore station groupings is given below.

Eleftheriou and Basford's results were further analysed by Basford *et al*. (1990). A different cluster analysis method was used and again showed 4 major groupings split between offshore and coastal groups. The "offshore sub-group 4" was extensive and centred on the muddier Fladen Ground stations in the central North Sea. The Fladen Ground fauna was typified by *Thyasira* spp. (bivalve mollusc), *Prionospio multibranchiata*, *Lumbrineris gracilis*, *Ceratocephale loveni* (polychaetes) and *Eriopisa elongata* (amphipod crustacean). Offshore sub-group 3 (surrounding the Fladen Ground) was also characterised by *Thyasira* spp. and *Prionospio multibranchiata*, but distinguished from sub-group 4 by presence of the polychaete *Spiophanes bombyx* and absence of *Lumbrineris gracilis*, *Ceratocephale loveni* and *Eriopisa elongata*.

Eleftheriou and Basford's results were included in a synoptic survey of the North Sea conducted under the auspices of ICES. The infaunal results were published by Künitzer *et al*. (1992) including a classification analysis of all North Sea stations. This indicated that a major faunal division occurred around the 70m depth contour. Essentially all stations north of the 100m depth contour formed a single cluster typified by finer sediments and indicator species *Minuspio cirrifera*, *Aricidea catherinae*, *Exogone verugera* (polychaetes) and *Thyasira* spp. (bivalve mollusc). In view of the wide range in sediment type and associated fauna found in the deeper parts of the North Sea, the conclusion that all the stations north of the 100m depth contour represented a single faunal assemblage should be treated with caution. Eleftheriou and Basford's samples were screened on a 0.5mm sieve while those of the rest of the ICES survey were sieved at 1.0mm. This will have introduced a distortion into the dataset, with many smaller species being retained on the 0.5mm mesh. Clearly, the groupings of stations and indicator species identified by multivariate analyses depend on the scale of ecological variability within the area surveyed and the level of faunal identification.

The seabed fauna of the muddy sediments of the Fladen Ground is generally regarded as uniform with moderate species richness and faunal densities, and with moderately high productivity but low biomass. The low biomass may be in part an artefact of inadequate sampling of deep burrowing species such as the crustaceans *Nephrops* and *Calocaris*, and the hagfish *Myxine* which, although contributing substantial biomass, are generally poorly sampled by grab and core samplers.

With the exception of the large bivalve mollusc *Arctica islandica* and the cold water coral *Lophelia pertusa,* the fauna of the SEA 2 areas does not contain any very long lived species. *Arctica islandica* is widely distributed in the North Sea (Seaward 1982, Witbaard 1997) but reaches a southern limit between 53 and 54°N (Witbaard 1997, Holtmann *et al.* 1998) and can grow to over 12cm, at which size they may be over 200 years old (Ropes 1985). The vast majority of *Arctica* found in the North Sea are small, young specimens but populations with individuals in excess of 100 years old have been reported from the southern North Sea (Witbaard *et al*. 1994) and in particular the Fladen Ground (Witbaard *et al*. 1997). Although *Arctica* is long lived, lays down a record of environmental conditions in the shell and appears to suffer mortality when young and damage when adult from demersal trawling (Witbaard 1997), it is not the subject of any conservation measures or legal protection.

The coral *Lophelia* is a potentially long lived species, which in some areas forms massive reefs. *Lophelia* is a deeper water Atlantic species, but has been recorded as a dead fragment from the southeastern Moray Firth (Wilson 1979), possibly as a fishing discard. However the species has recently been recorded alive from fixed installations in the North Sea eg in the Beryl and Brent fields (Bell and Smith 1999), and may occur alive on suitable hard substrates in the outer Moray Firth and northern North Sea. However, there is no historical or recent evidence that the species has established large colonies of potential conservation interest in the North Sea, including the SEA 2 area.

The horse mussel *Modiolus modiolus* is a widely distributed species which in suitable conditions can establish dense and persistent beds. These beds influence the seabed topography, sediment type and fauna present and can be considered as biogenic reefs. In the North Sea such beds are typically found in fully marine coastal areas down to about 70m, although they have not been recorded south of the Humber estuary (UKBG 1999) or alive in the central and northern North Sea (Seaward 1982). While it is unlikely that *Modiolus* beds occur in the SEA 2 areas the possibility cannot be ruled out. Individual *Modiolus* can live for about 50 years (Anwar *et al.* 1990) and the species has a Biodiversity Action Plan for it in the UK. Although the species is not listed in the Annexes to the EU Habitats and Species Directive it may be afforded protection under the Directive by virtue of forming biogenic reefs.

Another large and relatively long lived bivalve mollusc *Pinna (Atrina) fragilis* occurs in the North Sea but probably not within the SEA 2 areas. McKay and Smith (1979) record the presence of the species off Wick and Kinnaird Head, Seaward (1982) indicates the species is of south and western distribution not extending further into the North Sea than Orkney and the Moray Firth and the UK Biodiversity Group notes six specimens being recovered on fishing lines off Aberdeen in 1841/2 (UKBG 1999). Earll (1983) notes the trawling up of half a ton of *Pinna* to the east of Duncansby-Wick. *Pinna* is a large and long lived species which is susceptible to physical damage and a Biodiversity Action Plan has been developed for it in the UK although the species is not listed in the Annexes to the EU Habitats and Species Directive.

Glacial moraines can be interpreted as reefs under the EU Habitats and Species Directive and moraines are abundant in the area of continental shelf to the northeast and northwest of Shetland. Such moraines consist of mixed boulders, cobbles and finer material and can develop rich and spectacular epifaunal communities. Information provided by Johnson *et al.* (1993) and in the British Geological Survey report commissioned in support of the SEA process indicates that moraines do not extend into the SEA 2 area and are thus not considered further.

Pockmarks are a widespread feature in muddy sediments in the central and northern North Sea but because of their small size until the advent of ROVs and highly accurate position fixing systems have only recently begun to be explored in detail. The macrofaunal ecology of an active Fladen Ground pockmark (in block 15/25, within the northern SEA 2 area) was described by Dando *et al.* (1991), who found that the fauna of sediments within the pockmark was characterised by the bivalve *Thyasira sarsi* (which is known to contain symbiotic sulphur-oxidising bacteria) and a mouthless and gutless nematode, *Astomonema southwardorum*, which also contains symbiotic bacteria. The carbon isotope compositions ($\delta^{13}C$) of the tissues of benthic animals from in and around the pockmark indicated that little methane-derived carbon was contributing to their nutrition. Preliminary findings of the DTI commissioned survey of pockmarks in the Fladen and Witch Grounds indicate that potentially characteristic species (eg *Thyasira sarsi*) were not present at any of the pockmarks sampled (Graham Oliver, pers. comm.). To date, only the samples screened on a 5mm sieve have been analysed and firm conclusions must await results from the 1.0 and 0.5mm samples. The 5mm samples are remarkably uniform, with the sea urchin *Brissopsis lyrifera* present at most sites where larger fauna was found. There are no consistent differences evident between stations inside and outside pockmark features.

Another manifestation of gas seepage, the formation of carbonate cemented columns have been found in the Kattegat (eastern North Sea) by Jensen *et al*. (1992). Such features have been included within the Annexes to the EU Habitats and Species Directive, but are not known to occur in the SEA 2 area.

Foraminiferans are an important part (numerically and probably ecologically) in the seabed fauna of the deeper muddier parts of the northern North Sea. The group has typically not been identified or counted in the majority of recent seabed surveys although their likely composition and abundance can be extrapolated from Stephen (1923), McIntyre (1961), Murray (1985) and Kristensen & Sejrup (1996).

Seabed observations (photographs and video) made in 2001 during the DTI commissioned survey of shallow sandbanks and selected pockmarks showed the presence of abundant burrow structures believed to be of *Nephrops* and *Calocaris* together with numerous hagfish *Myxine* at the sediment surface in and around Fladen Ground pockmarks (Stuart Anderson, pers. comm.).

6.3.7 Epifauna

Dyer *et al*. (1983) conducted cluster analyses of trawled (primarily epi-) fauna from MAFF groundfish surveys over the whole North Sea, showing the area could be divided into 4 northern and 3 southern groups. Their N1 group covers the Fladen Ground and adjacent area of muddy sand, and is distinguished from the remaining northern North Sea (group N2). In addition to their analysis of North Sea benthic regions, Dyer *et al*. (1982) and Cranmer *et al*. (1984) published information on the distribution of individual species, which indicated the widespread occurrence of many epifaunal species.

The infaunal work of Eleftheriou and Basford was complemented by epifaunal studies in the same areas (Basford *et al*. 1989 and 1990) in which 152 stations were sampled for epifauna (animals living on the sediments). Classification analyses of this dataset also indicated groupings of stations covering wide areas - the northern North Sea typified by *Asterias rubens*, *Astropecten irregularis* (starfish), *Brissopsis lyrifera* (sea urchin), with the Fladen Ground further distinguished by the presence of the seapen *Pennatula phosphorea.* Basford *et al*. (1989) also included species distribution maps which also emphasise the widespread occurrence of most species.

The most recent study of epifaunal distribution across the North Sea is that of Jennings *et al*. (1999). On the basis of free living epifauna, they divided the North Sea into three groups which accord well with the zone (étages) distinguished by Glémarec (1973). The Fladen Ground and other northern muddy sediment stations grouped together with typical species being the prawn *Pandalus borealis* and the sea-urchin *Echinus acutus*.

Seabed observations made during the 2001 DTI commissioned survey of shallow sandbanks and selected pockmarks showed numerous seapens (both *Pennatula phosphorea* and *Virgularia mirabilis*) in the muddy sediments of the Fladen Ground (Stuart Anderson, pers. comm.).

Within each province subdivision it is possible to distinguish a series of faunal communities inhabiting specific sediment types. Often these communities extend over wide areas (eg the fine sands of the central North Sea and the sandy muds of the Fladen Ground. In addition, there are a number of highly localised habitats and communities, some of which are the subject of biodiversity action either at an OSPAR, EU or UK level.

6.3.8 Anthropogenic effects on the North Sea benthos

6.3.8.1 Fishing

The North Sea has been fished for millennia but it is only since the introduction of the combustion engine that offshore areas have been subjected to intensive demersal fishing. In recent years, the extent and nature of changes at the seabed resulting from fishing activity have become apparent and is the subject of reviews including Lindeboom and de Groot (1998) and Jennings and Kaiser (1998). Effects at the species level may be positive or negative for example, physical damage of large, long lived and fragile species can lead to mortality and potentially local extinction, while other species such as hermit crabs which survive trawling may increase in number, finding a rich supply of food in the discards of fish and killed or damaged benthic organisms. At the ecosystem level, a shift towards a seabed community where shorter generation, more opportunistic species predominate has been proposed and for which evidence is beginning to accumulate eg Frid and Hall (1999).

All parts of the SEA 2 areas are or have been fished intensively (see Sections 8.3) and the types of seabed effects noted above are to be expected in the area.

6.3.8.2 Aggregate extraction

In a number of discrete, licensed areas in the southern North Sea (including a number in the southern SEA 2 area) sand and gravel is removed by dredger for use on land or at the coastal. Such extraction removes the habitat and kills or disperses the seabed fauna. The effects of this localised activity have been reviewed by Newell *et al*. (1998) and appear similar to the effects of major storms where extensive sediment redistribution occurs followed by recolonisation and an ecological succession. The resulting benthic community may be different from that which existed previously as the sediment type may be different (eg muddy sand as opposed to clean sand as a result of the changed seabed topography).

6.3.8.3 Dumping

With the exception of capital and maintenance dredging from harbours and shipping channels and occasionally fish processing and natural inert materials, no wastes are now dumped in the North Sea. Previously, dredged material, industrial wastes and sewage sludge were dumped at defined licensed sites resulting in a range of effects at the seabed related to the nature of the site and the type and volume of wastes. These effects included physical smothering, alteration of sediment type, chemical contamination and organic enrichment with ecological effects ranging from none detectable to substantial alteration of community type (QSR 1993 and OSPAR 2000).

There are no dumping grounds within SEA 2 areas but in the southern North Sea there are a number just to the west of the boundary, although all are now disused.

6.3.8.4 General contamination of the North Sea

The North Sea, and especially the southern part, is surrounded by large centres of population, agriculture and industry and serviced by some of the busiest shipping lanes in the world. These have resulted in substantial diffuse inputs of nutrients, contaminants and sediments either directly or from atmospheric fallout, which have resulted in a wide range of ecological effects. These effects range from sublethal changes to individuals eg the endocrine disruption caused by tributyltin antifouling paints (Ten Hallers-Tjabbes *et al.* 1994) and bioenergetic changes (McDowell *et al.* 1999), through enrichment of the seabed by enhanced phytoplankton productivity (Pearson *et al*. 1985) to the annihilation of benthic animals by low concentrations of oxygen in following intense phytoplankton blooms (Rachor 1990).

These effects are well summarised in QSR (1993) and OSPAR (2000) (and their component reports) and in general are viewed as declining in intensity as control measure take effect. Such effects are also not regarded as significantly affecting the seabed fauna of offshore waters although Kröncke (1992) suggests that the faunal changes noted on the Dogger Bank might be due to eutrophication (although system changes resulting from fisheries interaction is an alternative explanation).

6.3.8.5 Wrecks and artificial substrates

The deliberate and accidental placement of hard substrates in the North Sea where the seabed is predominantly sand and mud will allow the development of “island” hard substrate communities. Such “islands” occur naturally, for example on glacial dropstones and moraines but the substantial expansion of the number of hard surfaces has a number of potential implications for seabed fauna. Firstly, the additional surfaces can provide “stepping stones” allowing species with short lived larvae to spread to areas where previously they were effectively excluded. The rapid colonisation of new oil and gas platforms has been documented a number of times (eg Forteath *et al.* 1982) and such colonising species can have very rapid growth rates compared to other locations (eg the horse mussel *Modiolus modiolus*, Anwar *et al*. 1990), and cause slight enrichment at the seabed through dislodged animals and settlement of the wastes produced (Myers and Southgate 1979). In the context of the projected scale of installations in the SEA 2 areas, such effects are concluded to be only minor.

6.3.8.6 Exotic species introductions

The deliberate or accidental introduction of animal, plant and microbial species to the North Sea (and adjacent areas) can have major effects at the seabed through disease, direct competition or indirect exclusion. The majority of the seabed species introductions have occurred through transport as fouling growth on ship's bottoms, with ship's ballast or ballast water or associated with commercial shellfish imported for aquaculture (Reise *et al.* 1999). Most species originate from and colonise estuarine or nearshore areas (eg the slipper limpet *Crepidula fornicata* which was recorded at four of the sandbanks sampled during the 2001 DTI survey). Recently a number of offshore species (eg the razor shell *Ensis directus/americanus*) appear to have colonised the southern North Sea.

6.3.8.7 Effects of oil and gas

Environmental monitoring of the seabed around North Sea installations began on 1973 and continues. An extensive published and unpublished body of literature exists, the majority focussed on the effects of drilling discharges, and in particular oil based muds.

In those parts of the southern North Sea where water currents are strong and sediments coarse (the majority of the southern SEA 2 area), biological effects from drilling discharges tend to be subtle and short lived. In the central and northern North Sea, where oily cuttings tend to accumulate as a discrete piles, surveys show a typical pattern of physical, chemical and biological gradients. Following initial smothering of the existing seabed fauna, the most contaminated sediments are colonised by a range of characteristic species, typically including the worm *Capitella,* an opportunistic worm able to rapidly colonise sediments disturbed by natural events and human activities, including pollution.

In addition to larger animals, the cuttings material is colonised by a range of bacteria and fungi which metabolise the organic matter (oil) aerobically or anaerobically. This reduces the contaminant load over time and allows colonisation by animals containing chemosynthetic bacteria such as the bivalve *Thyasira sarsi* which actively seek the hydrogen sulphide on which the bacteria feed (Dando and Southward 1986).

The range of species and their succession over time follows the general patterns of faunal response to organic enrichment summarised by Pearson and Rosenberg (1978). See for example, the recent compilation of all oil and gas related seabed surveys carried out on the UKCS (Harries *et al*. 2001) and a synthesis of recent Norwegian monitoring results (Carroll *et al*. 2000).

Large oil spills can result in oil reaching the seabed offshore. Effects reported from such accidents range from none detected (eg after the Ekofisk blowout in 1977) to chemical contamination but no acute biological effects detectable (eg after the wreck of the *Braer*, Kingston *et al*. (1995)).

6.4 Cephalopods

6.4.1 Data source

The University of Aberdeen was commissioned to provide a review of cephalopods in the North Sea. The report discusses their biology, fisheries, sensitivity to metal contamination and other conservation considerations.

6.4.2 Cephalopods in the North Sea

Knowledge of squid distribution in North Sea waters is mainly based on information from commercial whitefish vessels that take squid as a by-catch.

The main cephalopod species recorded from commercial fisheries in the northeast Atlantic are the lolinigid squids *Loligo forbesi* and *Loligo vulgaris*, the ommastrephid squids *Todarodes sagittatus, Todaropsis eblanae* and *Illex coindetii*, the cuttlefish *Sepia officinalis* and the octopuses *Octopus vulgaris* and *Eledone cirrhosa* (Pierce and Guerra 1994).

A total of 24 cephalopod species have been recorded from the North Sea (Seaward 1982). In addition to species listed above, frequently recorded species are *Alloteuthis subulata*, *Sepiola atlantica* and *Rossia macrosoma*. A number of oceanic species may occasionally occur in the North Sea (e.g. *Mastigoteuthis*, *Octopoteuthis*, *Heliocranchia*).

The two common lolinigid squids are pelagic species with ranges which overlap extensively. Analysis of fishery data collected between 1980 and 1990 indicated that *L. forbesi* was widely distributed on the continental shelf (Pierce *et al*. 1994c). This is supported by data from trawling surveys by *R/V Scotia* (Pierce *et al*. 1998). *L. vulgaris* is less abundant than *L. forbesi* in the northern part of its range but increasingly replaces *L. forbesi* with decreasing latitude and, in the southern part of the range, *L. vulgaris* dominates (Pierce *et al*. 1994b; Pierce *et al*. 1994c). In Scottish waters, only *L. forbesi* is common (Pierce *et al*. 1994c).

An influx of the squid *Todarodes sagittatus* to the North Sea during 1937 was accompanied by an influx of common dolphins that same year, and it was assumed that the common dolphins were feeding on these squid (Fraser 1946).

Eledone cirrhosa is a benthic octopus with a life-span thought to be between 18 and 24 months (Boyle 1983). *E. cirrhosa* has a wide distribution over shelf regions from the Mediterranean in the south to the Norwegian Lofoten Islands in the north. The animal generally occurs in depths between 50 and 300 metres and can be found on a wide variety of sea-bed types from soft mud to rocky bottom (Boyle 1983). Cuttlefish of the genera *Sepia*, *Sepiola* and *Rossia* are generally inshore species associated with sandy substrates (often among eel-grass beds).

Cephalopods are short-lived, carnivorous animals that have rapid growth rates. Cephalopods play an important part in marine food webs, feeding on fish, crustaceans and other cephalopods. In turn, cephalopods are prey themselves to whales, dolphins, seals, birds, some large fish species and other cephalopods. *Loligo forbesi* and *L. vulgaris* breed between December to May peaking around February to March in Scottish waters.

6.4.3 Cephalopods and metals

Cephalopods naturally accumulate high levels of some trace metals. Copper content in some cephalopod species' livers has been found to be 100 times higher than the mean vertebrate level and 100,000 times higher than seawater (Rocca 1969). Studies in California have revealed cephalopod levels to be three orders of magnitude higher than concentrations found in scallops, oysters and mussels (Martin and Flegal 1975). Studies of pilot whales off the Faroe Islands (where there is little or no anthropogenic pollution) have revealed high levels of cadmium (Caurant *et al.* 1994, Amiard-Triguet and Caurant 1997). This is thought to be accumulated through their primary diet of squid suggesting the potential for bioaccumulation up the food web.

6.5 Fish

6.5.1 Data sources

CEFAS, working in collaboration with FRS, was commissioned to review fish and fisheries information of relevance to the SEA 2 process. The report describes the fish resources of the region (ie spawning grounds, nursery areas), and also the intensity and distribution of commercial fishing activity. It describes those fisheries management measures which recommend seasonal closures of parts of the North Sea to protect spawning or juvenile fish, and regions where these may have consequences for oil and gas exploration and production. The report also summarises the most important consequences of oil and gas exploration for fish populations and commercial fisheries, such as the use of seismic surveys and the placement of structures on the sea bed.

6.5.2 Fish ecology

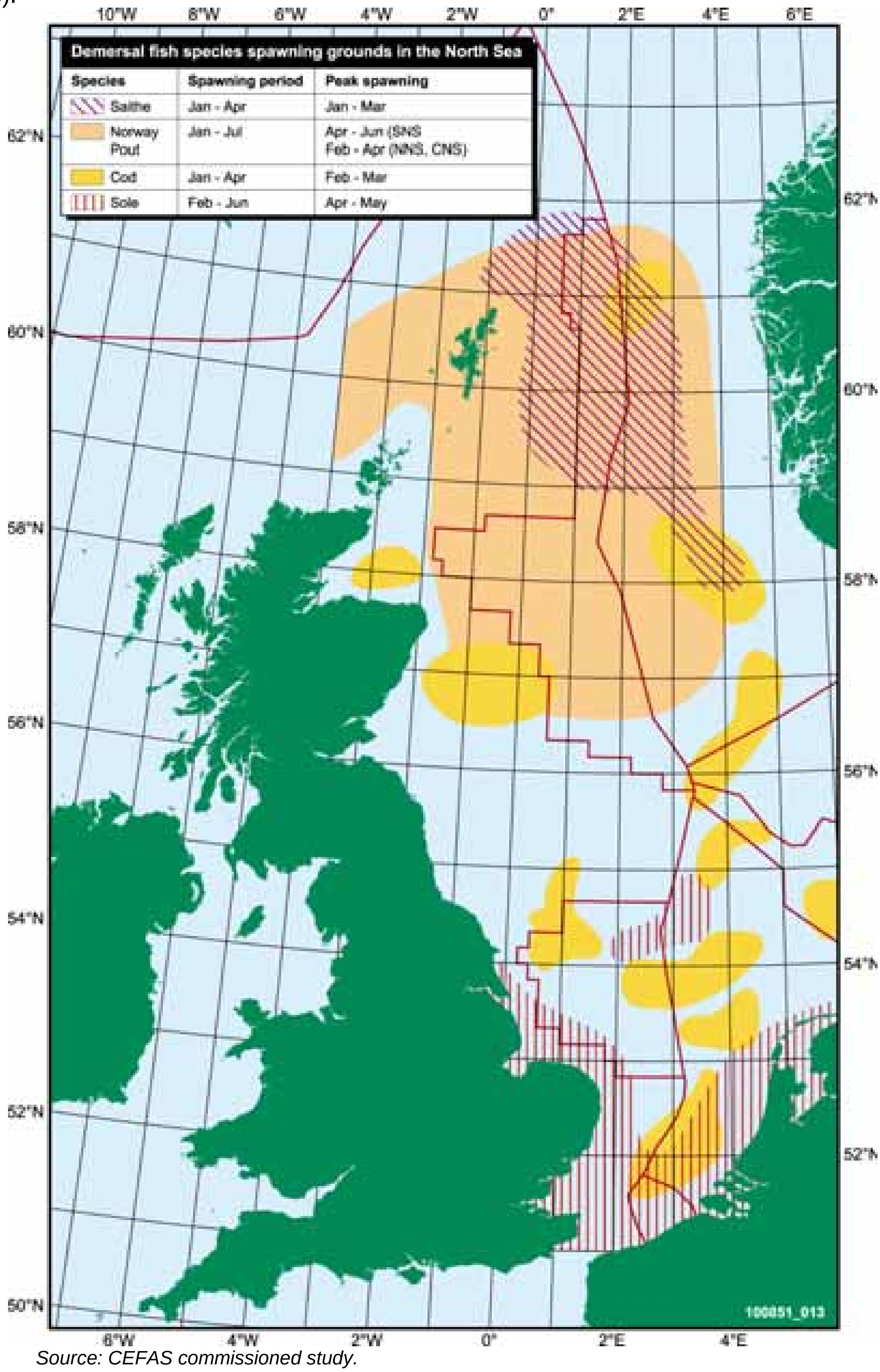
Most of the commercially important fish species spawn between January and June (Figures 6.2 to 6.5), although sandeel and herring are exceptions which spawn outside this period. Shrimp, edible crab and lobster tend to be winter spawners, but the period of egg brooding is protracted. Spawning areas and nursery grounds for most fish species are dynamic features of life history and are rarely fixed in one location from year to year. Thus, while some species have similar patterns of distribution from one season to the next, others show greater variability. The combined distribution of spring-spawning fish species showed that much of the northern SEA2 region supports spawning activity of three or more of these species, while in the central region spawning activity is more sporadic, and some areas have low sensitivity (Fig. 3.3.3). In the southern SEA2 region the greatest spawning activity occurs in coastal waters and in the most easterly part.

Information on the seasonal distribution of commercially important fish and shellfish is available from several sources. The most reliable of these are the routine research vessel surveys undertaken by European Research Laboratories. These annual surveys, often co-ordinated by the International Council for the Exploration of the Sea (ICES), target major commercial species but also record information on the distribution and abundance of the non-target components of the fish and shellfish catch. In addition, information on distribution of commercial species can be obtained from landings data obtained from local and regional fish markets by DEFRA (formerly MAFF) and SEERAD. Only for cod and sandeel fisheries were the total international landings by ICES rectangle available; for other species the UK landings have been used.

It is important to realise that fisheries-independent survey data describe a snapshot of the distribution of a species in a region at a particular time. Spawning areas and nursery grounds are dynamic features of fish life history and are rarely fixed in one location from year to year. While some fish species exhibit the same broad patterns of distribution from one year or season to the next, others show a large degree of variability.

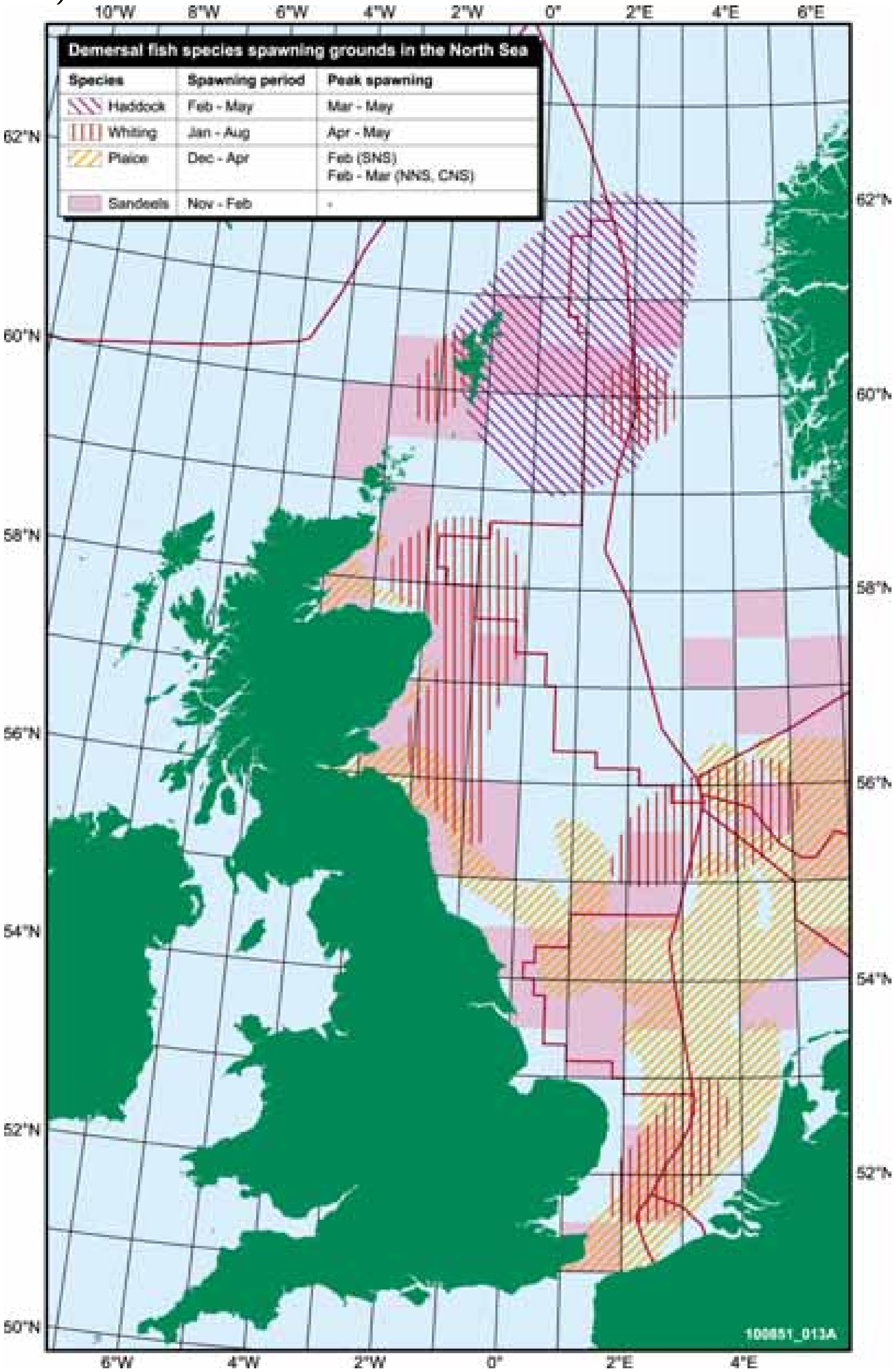
Recent research has suggested that there have been substantial changes in the fish communities of the North Sea during the 20th Century. These communities consist of species that have complex interactions with one another and the natural environment, either acting as predators at higher trophic levels, providing prey items for larger predators, or consuming a wide range of benthic invertebrates. Fish species in these communities will undergo natural variation in population size, largely as a result of variation in year to year success in recruitment. Broad scale patterns of climate change, and the impact of human exploitation, will also contribute to these population trends.

Figure 6.2 Demersal fish spawning areas in the North Sea (saithe, Norway pout, cod and sole).



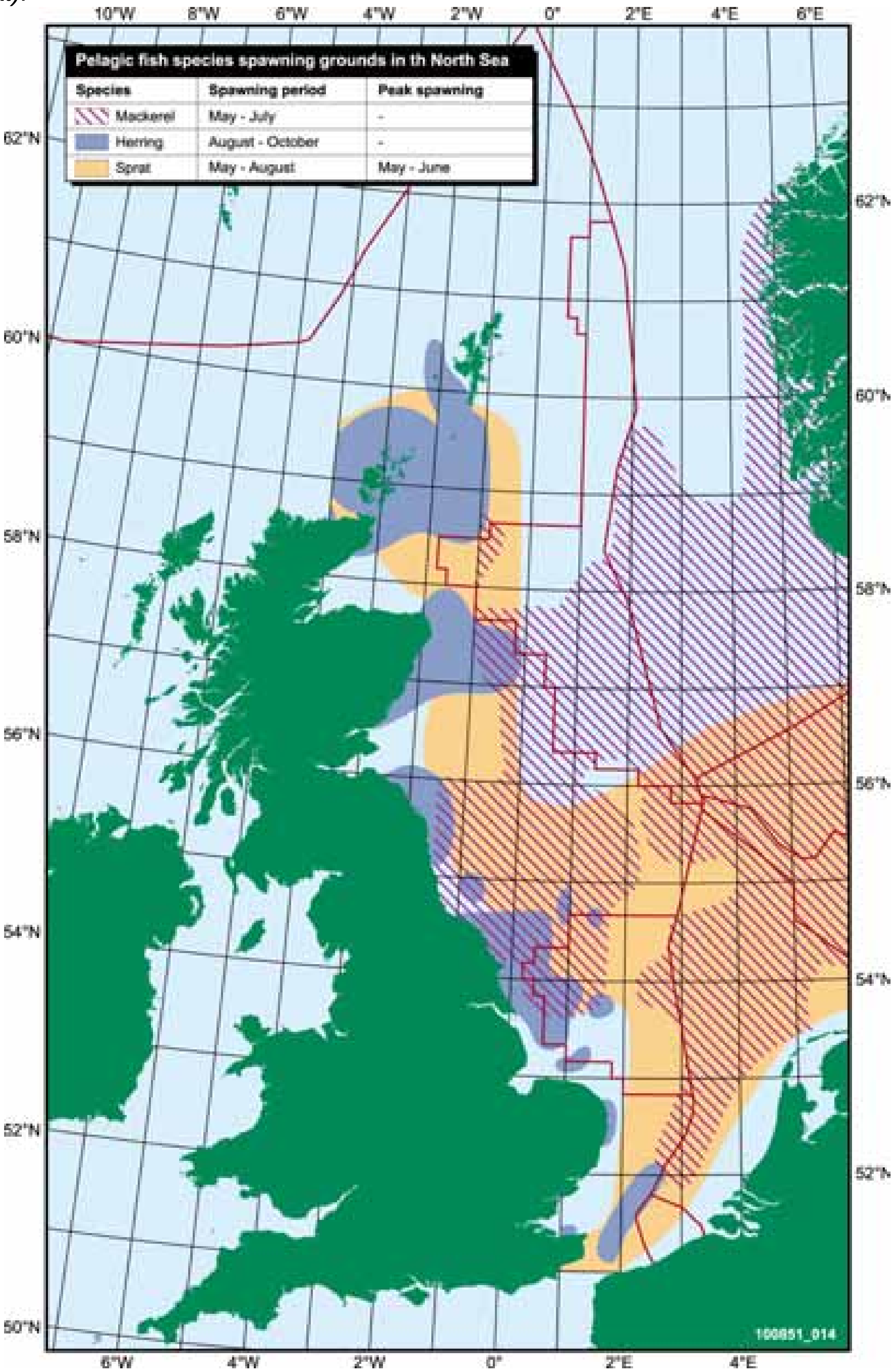
Source: CEFAS commissioned study.

Figure 6.3 Demersal fish spawning areas in the North Sea (haddock, whiting, plaice, sandeels).



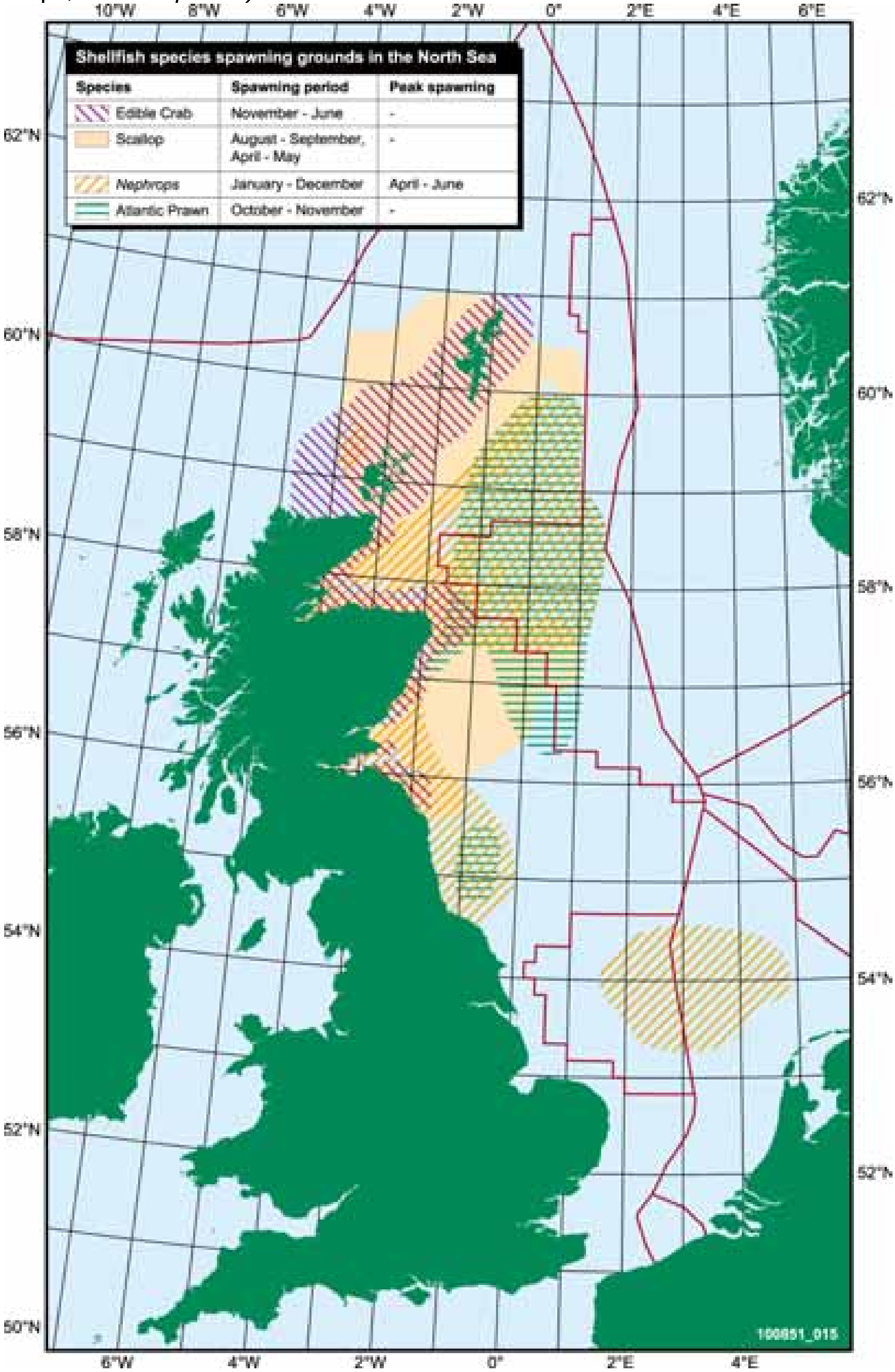
Source: CEFAS commissioned study

Figure 6.4 - Pelagic fish spawning areas in the North Sea (mackerel, herring and sprat).



Source: CEFAS commissioned study

Figure 6.5 Shellfish spawning areas in the North Sea (edible crab, scallop, Nephrops*, Atlantic prawn).*



Source: CEFAS commissioned study

6.5.3 Commercial Species

Whiting is one of the most numerous and widespread species found in the North Sea. The recaptures of tagged whiting, and the use of a number of fish parasites as markers, show that the populations to the north and south of the Dogger Bank form almost separate populations. It is also possible that the whiting in the northern North Sea may contain both inshore and offshore populations (Hislop and MacKenzie 1976).

The main spawning areas for whiting are in the Southern Bight, in the central North Sea north of the Dogger Bank, and off the east coast of Scotland (Figure 6.3). The spawning season is long, and extends from January in the Southern Bight through to late August or early September in the North, but the majority of spawning takes place in April-May. The spatial distribution of 0-group whiting in the pelagic phase (3-5cm in length) is extensive, and during summer juveniles can be found throughout much of the North Sea, but particularly to the north-east and east of Scotland, off north-eastern England and in the German Bight (Gordon 1977).

Cod occur throughout the northern and central areas of the North Sea. The recaptures of cod tagged in the North Sea show that there is limited exchange of individuals between the North Sea and waters to the West of Scotland, but that there is much more exchange between the North Sea and the Eastern Channel and the North Sea and the Skagerrak. These tagging studies also showed that the distance travelled from the release point was generally limited to about 200 miles, but that more extensive migrations were possible.

Cod spawn all over the North Sea, although there are several areas where spawning is concentrated, particularly in the northern North Sea, the central North Sea around the Dogger Bank and in the southern North Sea and the German Bight (Figure 6.2). There is also spawning activity in coastal waters of the east coast of Scotland and the northeast coast of England. Spawning mainly takes place between January and April, peaking in February and March in the central North Sea. The horizontal distribution of the larvae is determined by circulation and bottom topography (Brander 1994). Cod aged 1 and 2 years old can be found all over the North Sea but are concentrated in the shallow coastal waters of the eastern North Sea, and the rocky coastal waters of the UK and Norwegian coast.

Haddock occur throughout the northern North Sea, although in the Norwegian Deep adult haddock are not regularly encountered below 250 m and the highest catch rates occur between 80 m and 200 m (Albert 1994). Although the haddock has a northerly distribution, they can occasionally be caught south of the Dogger Bank during the summer. Haddock are generally regarded as benthic fish but they can also be found in midwater, and this is confirmed by their adult diet, which includes sandeel, Norway pout, long rough dab, gobies, sprat and herring (Cranmer 1986).

In the North Sea haddock spawn between February and May, with peak spawning activity between mid-March and early April. The main spawning area is in the central northern North Sea between the Shetland Islands and the Norwegian Deep, and southwards towards the Fladen Ground (Figure 6.3). After spawning, adult haddock disperse and migrate westward toward the Orkney and Shetland Islands and into the central part of the North Sea to feed.

Saithe is a northern species, and is widely dispersed in northern European waters from the Celtic Sea to Greenland, Iceland and Spitzbergen. Adults are generally found in continental shelf and slope waters at depths of 80-450m. Adult saithe feed on a range of demersal prey, including crustaceans and fish species such as sandeel, Norway pout, and haddock.

The main spawning areas for saithe are in the northern North Sea east of the Shetland Islands and along the edge of the Norwegian Deep (Figure 6.2). There is a regular pattern of spawning migration from the Norwegian coast to spawning grounds in the northern North Sea and elsewhere in the Norwegian Sea. Spawning takes place mainly over the period January to March. After a short pelagic phase, the young fish migrate into inshore and coastal waters. By winter most of the juvenile stages are concentrated in the coastal waters of Norway, Scotland, Iceland and the Faeroe Islands. Young saithe remain in these nursery areas up to the age of 3 or 4 before slowly migrating into deeper water. Tagging experiments have shown that young saithe leave their Scottish and Norwegian coastal nurseries during the spring (Nedreaas 1987) and recruit to the stocks in the northern North Sea (Newton 1984).

Norway pout are generally found in waters of 80-200 m over sandy and muddy substrates, but also occur in waters of up to 450 m depth in the Norwegian Deep. They are typically found in the northern and central areas of the North Sea and in the Skagerrak and Kattegat, with the centre of distribution lying midway between the Shetland Islands and the Norwegian coast (Knijn *et al*. 1993). They are a gregarious species, often found in large schools. Norway pout is a benthic predator, usually found within a few metres of the seabed where it preys upon small crustaceans, amphipods, shrimps and small fish (Mattson 1981).

Spawning usually takes place between January and April on the continental shelf, with the period of most intense activity during February and March. In deeper parts of the northern North Sea spawning occurs slightly later, between March and May, and may extend into early summer. The precise location of spawning areas is not well understood, but most spawning activity appears to be restricted to waters within the depth range of 50 - 200m (Figure 6.2). Norway pout are not generally considered to have specific nursery grounds, but pelagic 0-group fish remain widely dispersed in the northern North Sea close to spawning grounds.

Plaice are typically a coastal species, and can be found at highest abundance in the Southern part of the North Sea, along the east coast of the UK, and in the eastern Channel, Skagerrak and Kattegat. Plaice are flatfish which live on mixed substrates at depths of between a few metres to around 200 m, with older individuals generally occurring in deeper water.

Plaice spawn throughout the shallower parts of the southern North Sea and off the eastern coast of Britain, from Flamborough Head to the Moray Firth. Centres of high egg production occur in the Southern Bight, whilst egg production around the Dogger Bank and in the German Bight is more diffuse (Figure 6.3). Peak spawning occurs in early January in the eastern part of the English Channel, and during February in the Southern Bight, German Bight and off Flamborough Head. The duration of the planktonic developmental stages, two to three months, is long compared with that of many fish species. This prolonged period results in long exposure to residual currents, leading to the young plaice settling in nursery areas some distance from where they were spawned. Part of the North Sea plaice population spawns in the English Channel and returns to its feeding grounds in the North Sea after spawning. The offspring of this spawning population are thought to enter the North Sea by passive drift on the prevailing currents. Many shallow, sandy bays and estuaries on the North Sea coasts of England and continental Europe act as important nursery areas for plaice, especially the Dutch Wadden Sea (Kuipers 1977). Such shallow coastal waters support the majority of 1 year old plaice, and juveniles gradually disperse further offshore away from these nursery areas as they mature.

The sole is a southern species that is close to the northern limits of its distribution in the North Sea. It is confined to those parts of the southern North Sea where winter temperatures do not fall below 5^{0}C for prolonged periods, and seasonal movements are generally governed by the local temperature regime. During extremely cold winters, dense aggregations of sole occur in deeper and warmer waters of the North Sea such as the Silver Pit.

Sole spawn in shallow inshore areas and close to sandbanks less than 30m deep during April and May. Spawning occurs earlier in the southern part of the North Sea and later in populations off the northeast coast of England and in the German Bight. Major southern North Sea spawning grounds include the Belgian coast, the Thames Estuary, the Norfolk Banks, the Wadden Sea, and the German Bight (Figure 6.2). Whilst sole larvae are pelagic at first, during a period of approximately one month they metamorphose into the demersal phase. This relatively brief period in the water column prevents the offspring from moving large distances away from spawning grounds. It is therefore likely that local abundances of 0-group sole reflects the spawning success of local spawning aggregations. Nursery grounds are situated in shallow waters along the English and continental European coasts at depths between 5 and 10 m.

Despite its name, the lemon sole does not belong to the sole family. The centre of distribution of mature lemon sole is in the coastal waters of northern Scotland and the Orkney and Shetland Islands, but they are also found off the north-eastern coast of England and throughout the central and northern North Sea. There do not appear to be seasonal differences in distribution, and the species as a whole probably does not undertake extensive migrations. Little is known about the spawning habits of lemon sole, and it is thought to spawn everywhere it is found. The spawning season is long, and off the Scottish East coast extends from April to September.

In UK waters there are two species of monkfish, also called anglerfish, the black bellied monkfish *Lophius budegassa*, and the white monkfish, *Lophius piscatorius* The latter predominates north of latitude 55^{o}N in the North Sea and West of Scotland. The basic biology of the two species is very similar, although in the waters surrounding the UK and Ireland, black bellied monkfish are found predominantly in the deeper waters of the continental shelf and slope. Monkfish are found in an unusually wide range of depths, extending from the very shallow inshore waters down to around 1,100m. Juvenile monkfish (mainly white monkfish) can be found over most of the northern North Sea to depths of about 150m, while spawning adults are found at all depths but are generally scarce in coastal waters.

Spawning takes place during January to June in relatively deep water, and although monkfish have a long spawning season, each female probably produces only one batch of eggs. After hatching, young fish spend three or four months in mid-water before they settle on the seabed (Hislop *et al*. 2001).

Atlantic herring are found throughout the shelf waters of north-western Europe from the northern Bay of Biscay to Greenland, and east into the Barents Sea. During daytime, herring shoals remain close to the sea bottom or in deep water to a depth of 200m. At dusk they move towards the surface and disperse over a wide area. These diurnal vertical movements may be related to the availability of prey items, or to the stage in their maturation cycle.

Although most fish species have a single spawning season in the North Sea, herring is an exception. Sub-populations of North Sea herring spawn at different times and localised groups of herring can be found spawning in almost any month. At present there are three major populations of herring in the North Sea, which can be identified by differences in their spawning time and area. These 'races' are mixed for the majority of the year, but separate during the breeding season when each race migrates to its own spawning grounds (Daan *et al*. 1990). The races are:

- Buchan / Shetland herring, which spawns off the northeast Scottish coast and Shetland coasts during August to September.

- Banks or Dogger herring, which spawns in the central North Sea off the northeast English coast during August to October.

- Southern Bight / Downs herring, which spawns in the English Channel and Southern Bight of the North Sea during November to January.

Spawning normally takes place in relatively shallow water, at depths of approximately 15-40m (Figure 6.4). Herring deposit their sticky eggs on coarse sand, gravel, shells and small stones, and shoals congregate on traditional spawning grounds where all members of the shoal spawn more or less simultaneously. The result of such spawning activity is an 'egg carpet', which may be 4 to 9 layers thick and cover an area of one hectare (Blaxter and Hunter 1982). Each female will produce a single batch of eggs every year, but there are pronounced differences the number, sizes and weights of the eggs produced by each of the different spawning 'races' in the North Sea. Incubation of herring eggs takes one to three weeks depending on water temperature, and when the eggs hatch the larvae become pelagic and are transported by the prevailing water currents. Most autumn spawned herring larvae drift in an easterly direction from the western North Sea towards important nursery grounds in the eastern North Sea and to the Skagerrak and the Kattegat. Larvae from the west of Scotland are thought to drift into the Moray Firth, and the Firth of Forth also provides a nursery area for herring of more uncertain origin.

The dependency of herring on specific substrates makes the species particularly susceptible to impacts resulting from oil and gas exploration and production.

There are five species of sandeel in the North Sea, though the majority of commercial landings are of *Ammodytes marinus*. Sandeels are a shoaling species which lie buried in the sand during the night, and hunt for prey in mid-water during daylight hours (Winslade 1974).

Spawning of *A. marinus* usually takes place between November and February. Spawning activity occurs throughout much of the southern and central North Sea, but especially near sandy sediments off the coasts of Denmark, northeastern England, eastern Scotland, and the Orkney Islands (Figure 6.3). Sandeel eggs are demersal, and are laid in sticky clumps on sandy substrates. On hatching, the larvae become planktonic, resulting in a potentially wide distribution, and the larvae of *A. marinus* are the most abundant of the sandeel larvae in the North Sea. Sandeels adopt a demersal habit by around 2-5 months after hatching (Wright and Bailey 1996) and are believed to over-winter buried in the sand. Tagging experiments have shown that there is little movement between spawning and feeding grounds, indicating that fishing and spawning grounds may coincide (Kunzlik *et al,* 1986). Sandeels are an important food item for mackerel, whiting, cod, salmon, other economically important fish species, and sea birds.

Mackerel are fast swimming pelagic fish that are widespread in North Atlantic shelf waters. Two main stocks occur in the northeast Atlantic, the western stock and the North Sea stock, and this separation is based on differences in the timing and the areas used for spawning.

The North Sea stock has been at a very low level for many years due to high fishing pressure and poor recruitment.

North Sea mackerel overwinter in the deep water to the east and north of the Shetland Islands, and on the edge of the Norwegian Deeps. In spring, they migrate south to spawn in the North Sea between May and July, but they may also spawn along the southern coast of Norway and in the Skagerrak (Lockwood 1978; Dawson 1991) (Figure 6.4). The pelagic eggs can be found in the central North Sea at depths to 60m below the surface, but the majority are found in the upper mixed layer above 26m (Coombs *et al.* 1981).

The Western mackerel stock is found on the shelf and near to the continental slope to the west of British Isles, and occupies a very large area. These fish spawn between March and July, mainly to the southwest of the UK and Ireland. After spawning, the western stock migrates northwards to the feeding grounds north of Scotland and in the North Sea and Norwegian Sea. The western stock currently over-winters in the northern North Sea, off northern Scotland and around the Shetland Isles, where they mix with the North Sea stock. During the late 1960s and throughout the 1970s, most of the western stock over-wintered in the western English Channel. It is not understood why these changes took place, but it may have been a response to changes in the environment, possibly water temperature. In late winter and early spring, adult western mackerel move from the wintering grounds back towards their spawning areas (Lockwood 1988).

Sprat are most abundant in the relatively shallow waters of the southern North Sea and Skagerrak, and are found in the UK coastal waters as far north as the east coast of Scotland and the Orkney Islands. Most sprat spawn for the first time at an age of about two years, and important spawning areas in the North Sea are centred on the inner German Bight, the area off the north-western coast of Jutland, and the English East coast (Figure 6.4). Spawning in the vicinity of the southern SEA 2 region is from May to August and peaks during May and June.

6.5.4 Species of conservation significance

There are six fish species that require the designation of SAC in UK waters under Annex II and IV of the Directive (Potts and Swaby 1993). Only the European sturgeon *Acipenser sturio* and the whitefish *Coregonus lavaretus* require strict protection within SAC under Annex IV.

Of these, the European sturgeon is relatively rare and there are only sporadic catches of adults around the North Sea coasts. The species is at its northerly limit here, as it occurs in greater abundance on the French west coast in rivers such as the Gironde. The basking shark, tope and porbeagle are likely to occur in small numbers throughout the North Sea at times of peak zooplankton distribution and abundance. The common skate can be found at low density throughout the northern part of the North Sea, but is rare in, or absent from, the southern North Sea. The angel shark is rarely seen in the North Sea.

The majority of the remaining fish species of conservation importance are coastal and occur in greatest abundance in relatively shallow coastal water. The shad species, allis shad and twaite shad, and the lampreys (*Lampetra fluviatilis and Petromyzon marinus*) are migratory, making spawning migrations into the tidal and freshwater reaches of rivers and occupying estuarine and inshore waters to feed. These species are rarely encountered in large numbers.

Two species of goby, the giant goby and Couch's goby, are extremely rare in the coastal waters of the British Isles, and have not been recorded from the offshore waters of the North Sea. The whitefish (Coregonids) are related to the salmon family and are distributed almost exclusively in lakes and rivers of northwest Europe, but may enter brackish waters in the northern part of the North Sea.

6.6 Marine reptiles

6.6.1 Occurence

Leatherback turtles *Dermochelys coriacea* are occasionally recorded off eastern coasts of the UK from Shetland coast to Norfolk, mostly in summer and most commonly in northern areas. The leatherback turtle is now thought to be a regular visitor in Scottish waters at certain times of the year (Brongersma 1972; Langton *et al.* 1996); previously, they were considered to be vagrants. Threats to turtles from oil and gas activities in the North Sea are believed to be very limited, with the probability of interaction further reduced by the low numbers present as the North Sea is on the fringe of their normal range.

6.6.2 Records

Records of turtles since 1970 have been collated by MJS Swan in the JNCC Coastal Directory series, as follows:

Shetland – occasional records

Orkney - thirteen leatherback turtles - seven alive and six dead - recorded either swimming at sea or stranded

Cape Wrath to St. Cyrus - eleven leatherback turtles; eight seen swimming freely, and three that had been netted accidentally in fishing gear and released unharmed

Montrose to Eyemouth - four leatherback turtles have been recorded in the region, three alive but entangled in fishing nets and one dead, stranded on the shore. One other unidentified marine turtle has been recorded swimming at sea.

Berwick-upon-Tweed to Filey Bay - since 1990, two leatherback turtles, both dead, have been found stranded on the North Yorkshire coast

Flamborough Head to Great Yarmouth - since 1980 the corpse of one leatherback turtle *Dermochelys coriacea* has been recovered from the Norfolk coast

Lowestoft to Dungeness - there are no recent JNCC records of marine turtle sightings or strandings in the region, although a single leatherback was stranded at Sizewell in January 1998 (Robin Law pers comm.).

6.7 Seabirds

6.7.1 Data sources

In 1979 the Nature Conservancy Council (NCC) Seabirds at Sea Team (SAST) began systematic survey work in the North Sea (SAST 1), with further work in a second phase (SAST 2) between 1983 and 1986 (Tasker *et al.* 1987). Subsequent SAST projects have concentrated effort to the north and west of Britain, although ongoing effort in the North Sea has filled several data gaps for specific areas and months of the year.

Comparable programmes around the Netherlands, Belgium, Germany, Denmark, Sweden and Norway are described by Stone *et al.* (1995), and international collaboration between organisations throughout north-west Europe has resulted in one common database for the waters of this area, the European Seabirds at Sea (ESAS) database. ESAS contains over one million records of birds sightings, consisting of processed data from strip transect observations from two types of observation platform: ships and aircraft. Resulting publications include an atlas of bird concentrations vulnerable to oil and other surface pollutants in the North Sea (Carter *et al.* 1993), a distribution atlas of seabirds in north-west Europe (Stone *et al.* 1995), and an electronic atlas of seabird distribution and vulnerability (BODC 1998).

Count data for seabird breeding colonies is collated by the Seabird Colony Register, including the “Operation Seafarer” survey in 1969-70 and a repeat survey of the whole coast of Britain and Ireland in 1985-87 (Lloyd *et al.* 1991). Seabird colony counts are currently underway as part of the “Seabird 2000” programme, although counts in some areas have been disrupted by foot-and-mouth access restrictions.

Observations are also recorded from North Sea installations through the North Sea Bird Club.

6.7.2 North Sea overview

Internationally important numbers of several species of seabird breed on the North Sea coastal margin, and depend on the offshore North Sea for their food supply and, for much of the year, their habitat. Of the seabird species which breed regularly in Britain and Ireland, fulmar, cormorant, shag, gannet, six species of gull and five species of tern breed around mainland North Sea coasts; with Manx shearwater, Leach’s petrel, storm petrel, great and arctic skua also breeding in Shetland and Orkney. Black guillemot breed in the northern isles and south to the Moray Firth.

Evans (1973) estimated the North Sea population of breeding seabirds to be around 1,300,000 pairs, while Tasker *et al.* (1987) estimated total breeding populations as 4.25 million seabirds. Although many of these birds range into Atlantic waters outside the breeding season, and further afield, a substantial proportion are reliant on the North Sea at all seasons of the year. Skov *et al.* (1995) estimated the total number of birds (including seabirds, divers, grebes and ducks) occurring in internationally important numbers within six most important areas of the North Sea, Channel and Kattegat as 3.94 million (and noted that this was a substantial under-estimate of total numbers of birds within the area).

In general, offshore areas of the North Sea including the areas included in SEA 2 contain peak numbers of seabirds following the breeding season and through winter, with birds tending to forage closer to coastal breeding colonies in spring and early summer. Large numbers of shorebirds and waterfowl also use North Sea coastal waters and shores, particularly in winter. These species, which include divers, grebes, swans, geese, ducks and waders may be highly vulnerable to surface pollution in coastal waters, on account of their amount of time spent on the water, proportion of total biogeographical population, reliance on the marine environment, and potential rate of population recovery (Williams *et al.* 1994). Several of the most important areas for seabirds and waterfowl in the North Sea, including the Skagerrak, southwest Norwegian Trench, eastern German Bight and Cap Gris Nez – Schiermonnikoog areas, are within potential trajectories of major oil spills from the SEA 2 areas.

Comprehensive reviews of seabird status, distribution and vulnerability in the North Sea have been published (Lloyd *et al.* 1991, Carter *et al.* 1993, Stone *et al.* 1995, Skov *et al.* 1995). The following synopsis therefore summarises available information.

6.7.3 Species accounts

Generalised distribution patterns and movements of seabirds in the North Sea are summarised in Figure 6.6 North Sea breeding populations, including the proportion of the relevant biogeographical population for each species are shown in Table 6.2.

Table 6.2 Numbers of seabirds breeding around North Sea coasts (not Baltic)

Red-throated diver	800**	**Herring gull**	237,100**
Fulmar	308,000	**Great black-backed gull**	24,400**
Manx shearwater	250	**Kittiwake**	415,400**
Storm petrel	>1000	**Sandwich tern**	30,500**
Leach's petrel	1-500	**Roseate tern**	38
Gannet	43,800**	**Common tern**	61,500**
Cormorant	2,200	**Arctic tern**	74,700*
Shag	19,800**	**Little tern**	2,300
Arctic skua	3,200**	**Guillemot (individuals)**	680,400**
Great skua	7,300**	**Razorbill (individuals)**	73,100**
Black-headed gull	129,300*	**Black guillemot(individuals)**	23,700**
Common gull	73,300**	**Puffin (individuals)**	226,000**
Lesser black-backed gull	49,300**		

Source: BODC (1998) (data from Tasker et al. (1987), Dunnet et al. (1990) and Seabird Colony Register (unpublished).

*Figures are pairs or apparently occupied sites unless otherwise stated. * = more than 5%, ** = more than 10% of biogeographical population. Petrel and shearwater numbers are very approximate*

Fulmar *Fulmarus glacialis*

Fulmars are the most numerous seabird breeding in Britain and Ireland (571,000 pairs, Lloyd *et al.* 1991) although the total North Sea population is equivalent in size to single breeding colonies in the Bering Sea (Sowls *et al.* 1978). Fulmars are generally the species recorded in highest numbers offshore throughout the UKCS. This species has undergone a remarkable population and range expansion in western Europe, for reasons that are still unclear but may include a combination of food availability from whaling offal and fishing discards; genetic factors, and climate change (reviewed by Lloyd *et al.* 1991).

Fulmar colonies around the North Sea are located principally in Orkney and Shetland (containing 88% of the breeding population, Tasker *et al.* 1987) but also throughout mainland Britain, in the Helgoland Bight and in western Norway.

Wintering densities are relatively low throughout the North Sea (except for the most northern areas), probably due to widespread dispersion of young birds in the north Atlantic and Arctic, and periodic colony attendance by breeding adults. During March and April, breeding birds undergo an exodus from the colonies, while at the same time fourth year and older pre-breeding birds return to the vicinity of their natal colonies. Overall fulmar densities are therefore high around Orkney and Shetland, in the northern North Sea and inshore off eastern Britain. Distribution during early and late breeding season is more widespread, with increasing numbers in the southern and central North Sea leading to a peak density in September. It is probable that moulting fulmars, particularly immature and non-breeding birds, move southwards and eastwards in the North Sea with peak numbers of moulting birds from May to September. Strong correlation has been observed between the presence of trawlers and high densities of fulmars, although this influence is variable and other factors obviously affect distribution (Tasker *et al.* 1987).

Other petrels

Sooty shearwaters *Puffinus griseus*, Manx shearwaters *Puffinus puffinus*, storm petrel *Hydrobates pelagicus* and Leach's petrel *Oceanodroma leucorhoa* are less frequently recorded from the North Sea. Sooty shearwaters undertake a circular migration in the Atlantic Ocean, from their closest breeding colonies on the Falkland Islands, and relatively small numbers penetrate the North Sea between June and November. Manx shearwaters breed in small numbers (a few hundred pairs) in Orkney and Shetland, and are present in low numbers in the northern North Sea between May and October. Several thousand pairs of storm petrels nest in Orkney and Shetland, and are recorded in the North Sea from May to November with the vast majority of records from north of 59ºN. There are two known breeding colonies of Leach's petrel in the Shetland Islands with very few sightings recorded from the North Sea.

Gannet *Sula bassana*

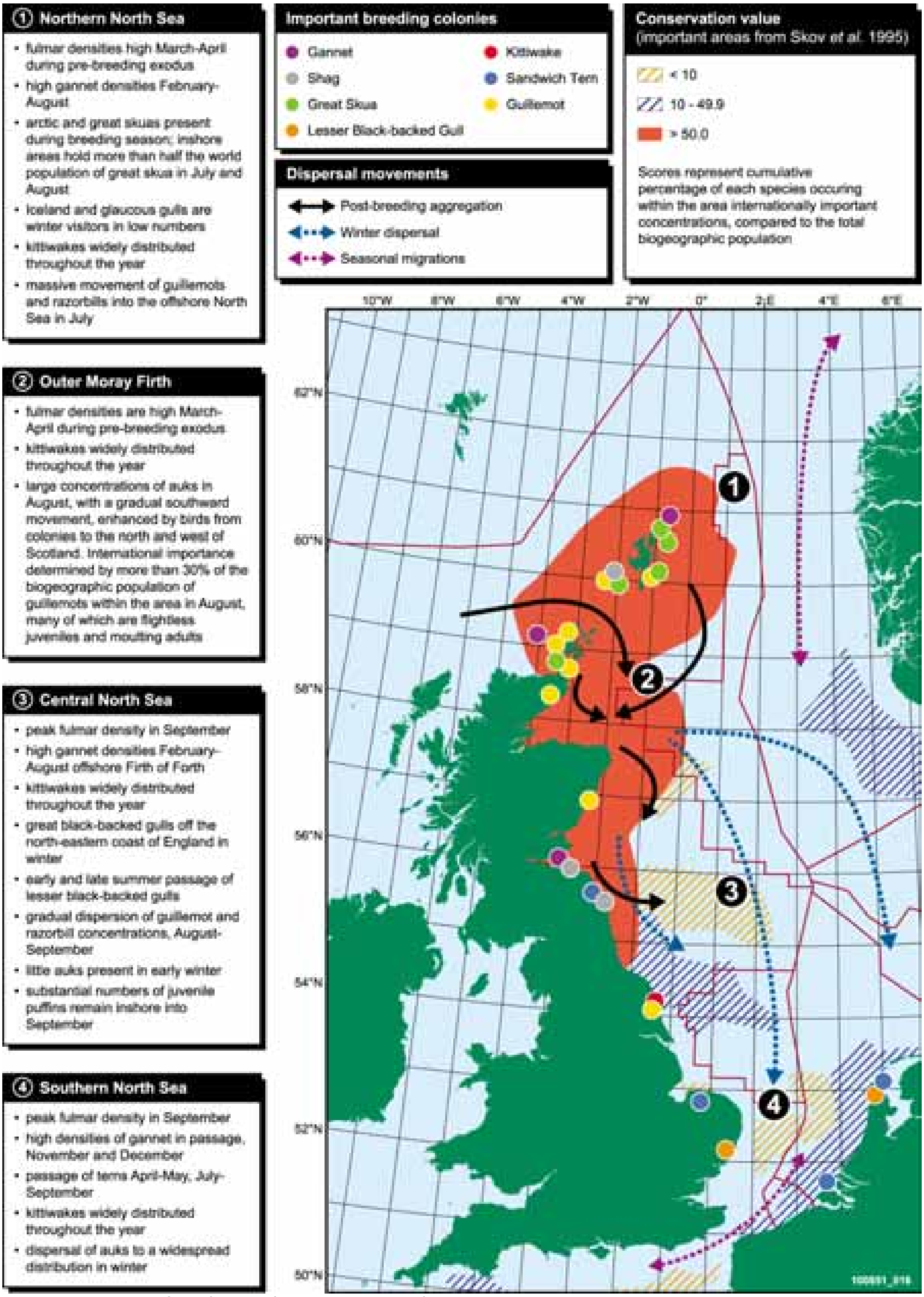
Six colonies on the North Sea coast hold approximately 17% of the total population (Wanless *et al.* 1986) in addition to 59,000 occupied sites on Sule Stack and 4,300 breeding pairs in Norway and the Faroes. A long term increase in the gannet population in Britain and Ireland is believed to have resulted from the introduction of bird protection laws about 100 years ago (Lloyd *et al.* 1991), in contrast to colonies in the Gulf of St Lawrence which have catastrophically declined over the same period.

The southern North Sea holds relatively high gannet densities in November and December, when dispersion from breeding sites is at a maximum. High densities in the southern North Sea probably represent passage of breeding adults. During the pre-breeding and breeding seasons (February – August), gannets are concentrated inshore and offshore around the major breeding colonies in Shetland and the Firth of Forth. During chick rearing, the majority of gannets from Noss, Shetland were found to forage within a radius of 37km (Tasker *et al.* 1985). Gannets frequently accompany fishing vessels and discarded fish form part of their diet.

Cormorants

Cormorants *Phalacrocorax carbo* and shags *Phalacrocorax aristotelis* are essentially coastal species which are rarely recorded offshore.

Figure 6.6 - Seabird distributions and movements in the North Sea. Important areas for seabird conservation are also shown.



Sources: after Skov et al. 1990, Stone et al. 1995

Seaduck
Eider *Somateria molissima*, long-tailed duck *Clangula hyemalis*, common and velvet scoter *Melanitta nigra* and *M. fusca*, goldeneye *Bucephala clangula* and red-breasted merganser *Mergus serrator* are coastal species, occasionally recorded offshore in the southern North Sea. Scoters are more common offshore than other species, and have been recorded in all parts of the central and southern North Sea throughout the year.

Skuas
Pomarine skua *Stercorarius pomarinus*, arctic skua *Stercorarius parasiticus*, long-tailed skua *Stercorarius longicaudus* and great skua *Stercorarius skua* are recorded offshore throughout the North Sea. Pomarine and long-tailed skuas are occasional passage migrants, breeding in the high arctic. Approximately 3,200 pairs of arctic skuas and 7,300 pairs of great skuas breed around the North Sea, mainly in Orkney and Shetland where distribution is centred during the breeding season. These numbers represent important biogeographic populations. Arctic skuas are present in the North Sea from April to December, while great skua show similar seasonality although a few birds are recorded in winter. Both species disperse widely in the Atlantic following breeding (predominantly to the Patagonian shelf in the case of arctic skua).

Gulls
Little gull *Larus minutus*, black-headed gull *Larus ridibundus*, common gull *Larus canus*, lesser black-backed gull *Larus fuscus,* herring gull *Larus argentatus*, Iceland gull *Larus glaucoides*, glaucous gull *Larus hyperboreus*, great black-backed gull *Larus marinus* and kittiwake *Rissa tridactyla* are distributed throughout the North Sea at all times of year. All gulls may significantly associate with fishing vessels.

Little gulls are concentrated mainly in inshore and southern areas during spring and autumn. Very few black-headed gulls are recorded offshore, despite large coastal breeding populations (in excess of 129,000 pairs around the North Sea). Peak abundance of common gulls in the North Sea is in winter, and distribution is predominantly southern and inshore although a summer concentration occurs around the Dogger Bank. Iceland and glaucous gulls are winter visitors in low numbers to the northern North Sea. Lesser black-backed gulls are principally summer visitors to the North Sea, with numbers offshore evidencing passage of birds to breeding colonies around the North Sea (49,300 pairs), mainly in the Skagerrak, south-west Norway and the Helgoland Bight. Great black-backed gulls breed around the northern coasts of the North Sea, and highest densities are recorded at sea between September and April. At all times of the year, numbers of great black-backed gulls are highest in the western North Sea, and the area off the north-eastern coast of England is most important during the winter period.

Herring gulls breed on virtually all natural habitats of all North Sea coastal areas with the exception of the Wash. In relation to other seabirds, herring gulls from North Sea breeding populations are relatively sedentary, generally remaining throughout the year within 100km of their natal colony. Wintering populations are supplemented by migratory birds from northern Scandinavia and arctic Russia. Herring gull densities in offshore southern areas of the North Sea are highest from November to March, and very low from April to October. Densities in the offshore north-west North Sea are higher throughout the year, although densities are again highest in winter.

Kittiwakes have a circumpolar distribution, with over 400,000 breeding pairs around the North Sea coast of Britain and lower numbers in the low countries and Scandinavia. Kittiwakes from colonies in eastern Britain disperse throughout the North Sea and Bay of Biscay in winter, in contrast to birds from north and west British colonies which disperse widely in the Atlantic with many ringing recoveries from west Greenland. Kittiwakes are dispersed widely in the North Sea during winter, with increasing densities inshore around breeding colonies during spring and summer. However, substantial numbers of kittiwakes are present offshore during the breeding season, possibly due to movement of non-breeding birds into the North Sea from the Atlantic.

Terns

All terns are summer visitors to the North Sea, normally recorded between April and October. Three species are commonly recorded offshore: Sandwich tern *Sterna sandvicensis* breed around the southern and eastern North Sea with largest numbers in the Waddensee, common tern *Sterna hirundo* nest on all coasts of the North Sea and arctic tern *Sterna paradisea* have colonies mainly in northern areas although small numbers breed on all coasts of the North Sea. Substantial numbers of terns migrate northwards though the offshore North Sea in April and May, with return passage from July to September.

Auks

A total of about 680,000 guillemots *Uria aalge*, 73,000 razorbills *Alca torda*, 21,000 black guillemot *Cepphus grylle* and 226,000 puffins *Fratercula arctica* have been counted in the breeding season at colonies around the North Sea, of which the vast majority are in Britain, particularly in Orkney and Shetland. Substantially higher numbers of birds are associated with the colonies, around 2,073,000 guillemots and an estimated 183,000 razorbills (Tasker *et al.* 1987). All four species breed in colonies on cliffs or offshore islands free from mammalian predators, although the breeding distribution of black guillemots is more dispersed than those of other auk species.

Between March and June, most guillemots are found within 30km of their colonies, with a massive movement of birds into the offshore North Sea in July. Large concentrations of guillemots occur in the central northern North Sea at this time, with a gradual southward movement in concentration to off eastern Scotland and north-east England through August and September, and dispersal to a more widespread distribution in the southern North Sea in winter. North Sea guillemot populations are enhanced in late summer and autumn by birds from colonies to the north and west of Scotland. During the post-breeding movement of birds away from colonies, guillemots moult and are flightless, and therefore are highly vulnerable to surface pollution.

Razorbills follow a broadly similar seasonal distribution pattern to guillemots, although with a more northerly concentration in the east Shetland basin in July and off the outer Moray Firth and east of Orkney in August. Razorbills from more southerly colonies are relatively sedentary.

Black guillemots are relatively sedentary, coastal birds and are very rarely encountered offshore. This species is concentrated in Orkney and Shetland, with lower numbers in Caithness and south to the Moray Firth. Low numbers breed in western Norway, and the Kattegat.

Little auks *Alle alle* are arctic breeders and regular winter visitors to the Norwegian coast and North Sea. Distribution records suggest a net movement from the western North Sea in November and December towards southern Norway during late winter, with migration northwards between February and May. Total numbers present in the North Sea are relatively insignificant in terms of overall little auk breeding population (Tasker *et al.* 1987).

Outwith the breeding season, the life history of puffins is much less understood than those of other auk species. Ring recoveries are rare and no clear description of puffin winter distribution is available from ringing recovery information. Sightings data indicate that departure from breeding colonies commences in July with movement south and east from the northerly colonies. Adults from colonies in eastern England move north to the Firth of Forth and central North Sea, with rapid offshore dispersal of juveniles, except for the most southerly breeding areas (Flamborough Head), where substantial numbers of juvenile puffins remain inshore into September. Winter puffin distribution in the North Sea is widespread with low densities.

6.7.4 Importance of individual areas of the North Sea

Based on seabird surveys carried out from 1979-1994 (incorporated in the ESAS database, see above), Skov *et al.* (1995) concluded that 20 areas of the North Sea, the Channel and the Kattegat contained concentrations of birds which were regarded as internationally important (Figure 6.6). Of these, six important areas accounted for more than 80% of the conservation value for birds. These areas are predominantly coastal, inshore of the SEA 2 areas although there are limited areas of overlap with the eastern extremity of the Orkney-Shetland area, and offshore parts of Moray Firth-Aberdeen Bank, Long Forties, Flamborough Head and Brown Ridge-Broad Fourteens areas. In addition, as noted above, coastal areas of the south and east North Sea lie within potential trajectories of major oil spills from the SEA2 areas (this issue is discussed further in Section 10).

In contrast, the central North Sea, the deepest parts of the North Sea north of Shetland, the Fladen Ground, deeper parts of the German Bight and the Danish west cost were the poorest zones in terms of their conservation value for birds.

Relative importance of the identified important areas may be summarised as follows:

Orkney-Shetland – extent of the area is mainly determined by the distribution of more than half the world population of great skua in July and August. Overall, contains 20.5% of internationally important concentrations of all species in the North Sea (second in importance only to the northern Kattegat), see Skov *et al.* (1995) for details.

Moray Firth-Aberdeen Bank – mainly determined by more than 30% of the biogeographic population of guillemots within the area in August, many of which are flightless adults due to moult of flight feathers. Overall proportion of importance 15.2%

Flamborough Head and the Hills – overall proportion of importance 5.9%

Brown Ridge-Broad Fourteens – overall proportion of importance 1.7%

Long Forties – overall proportion of importance 0.4%

In relation to the SEA 2 areas, therefore, the major seabird conservation concerns in the context of international and biogeographic seabird populations relate to guillemot concentrations in limited areas of the outer Moray Firth in August; and (with a slightly lower conservation importance) the Flamborough front to Dogger Bank area. In this context, the majority of the SEA 2 area is of relatively low conservation importance for seabirds.

6.7.5 Sensitivities and vulnerability

Overall status of seabirds in Britain and Ireland is reviewed by Lloyd *et al.* (1991), who conclude that probably the most important factor currently affecting seabird numbers is the quality and abundance of their food. In terms of individual species, total population estimated have increased over recent decades for fulmar, gannet, great skua, black-headed gull, lesser black-backed gull, great black-backed gull, kittiwake, Sandwich tern, little tern, guillemot, black guillemot and possibly arctic skua. Storm petrel and common tern numbers appear little changed; while Manx shearwater, cormorant, shag, common gull, razorbill population changes are unknown either because of secretive nesting habits (Manx shearwater and puffin), lack of reliable or comparable data or because short term fluctuations mask longer-term change (eg shag).

Herring gull numbers have decreased, probably due to a reduction in availability of fishing discards. Roseate tern colonies have decreased in recent years, mainly due to predation and disturbance, and breeding populations of arctic terns in Orkney and Shetland have reduced to a lack of sandeels, for unknown reasons.

Commercial fishing has resulted in major, but complex changes in seabird food stocks (Furness 1987) including removal of food source (especially herring), reduction in competition (by removal of predatory fish), and availability of fishing discards. In addition, entanglement in nets may be a major cause of seabird mortality, for example in coastal waters of north-west Ireland where salmon drift-netting has resulted in heavy mortality of puffins and other seabirds. Using evidence from ringing recoveries, Mead (1989) considered that modern fishing techniques, particularly the use of monofilament nets, are now the main cause of unnatural death among auks, especially in the seas around Britain and off Iberia.

Pollution of the sea by oil, predominantly from merchant shipping, can also be a major cause of seabird mortality. Although locally important numbers of birds have been killed directly by oil spills (resulting from transportation, rather than exploration and production of oil), for example black guillemots in Yell Sound following the *Esso Bernicia* spill in December 1978, and common scoter off Milford Haven following the *Sea Empress* spill in 1996, little or no direct mortality of seabirds has been attributed to exploration and production activities.

Chronic pollution resulting from illegal dumping or tank washing probably has a greater impact on seabirds than accidental spills from shipping casualties (eg Andrews and Standring 1979). Beached bird surveys around the UK (Stowe and Underwood 1983), and elsewhere in Europe (eg Vauk 1984), provide useful data on the risks to seabirds of oil pollution in the North Sea. Although a high proportion of seabirds and coastal birds recovered dead from beaches show signs of oiling (eg up to 64% of divers, Stowe 1982 cited in Pollock *et al.* 2000), most of the oil samples taken from bird plumage suggest that bunker oils from shipping discharges were predominantly involved (Cormack 1984). It is also likely that a proportion of oiled bird carcasses were dead prior to coming in contact with oil.

The vulnerability of bird species to oil pollution is dependant on a number of factors and varies considerably throughout the year. The Offshore Vulnerability Index (OVI) developed by JNCC and used to assess the vulnerability of bird species to surface pollution considers four factors:

- the amount of time spent on the water,
- total biogeographical population,
- reliance on the marine environment,
- potential rate of population recovery (Williams *et al.* 1994).

Vulnerability scores for offshore areas are determined by combining the density of each species of bird present with its vulnerability index score (see Table 6.3). Of the species commonly present offshore in the North Sea (see above), gannet, skuas and auk species may be considered to be most vulnerable to oil pollution due a combination of heavy reliance on the marine environment, low breeding output with a long period of immaturity before breeding, and the regional presence of a large percentage of the biogeographic population. In contrast, the aerial habits of the fulmar and gulls, together with large populations and widespread distribution, reduce vulnerability of these species.

Vulnerability scores for individual UKCS licence blocks have been calculated by JNCC, and smoothed seabird vulnerability maps are published by BODC (1998). Overall vulnerability to surface pollutants (taking seasonal variability into account); seasonality (expressed as number of months in which very high vulnerability occurs) and data gaps (defined as blocks for which two or more consecutive months are unsurveyed) are shown in Figures 6.7 and 6.8.

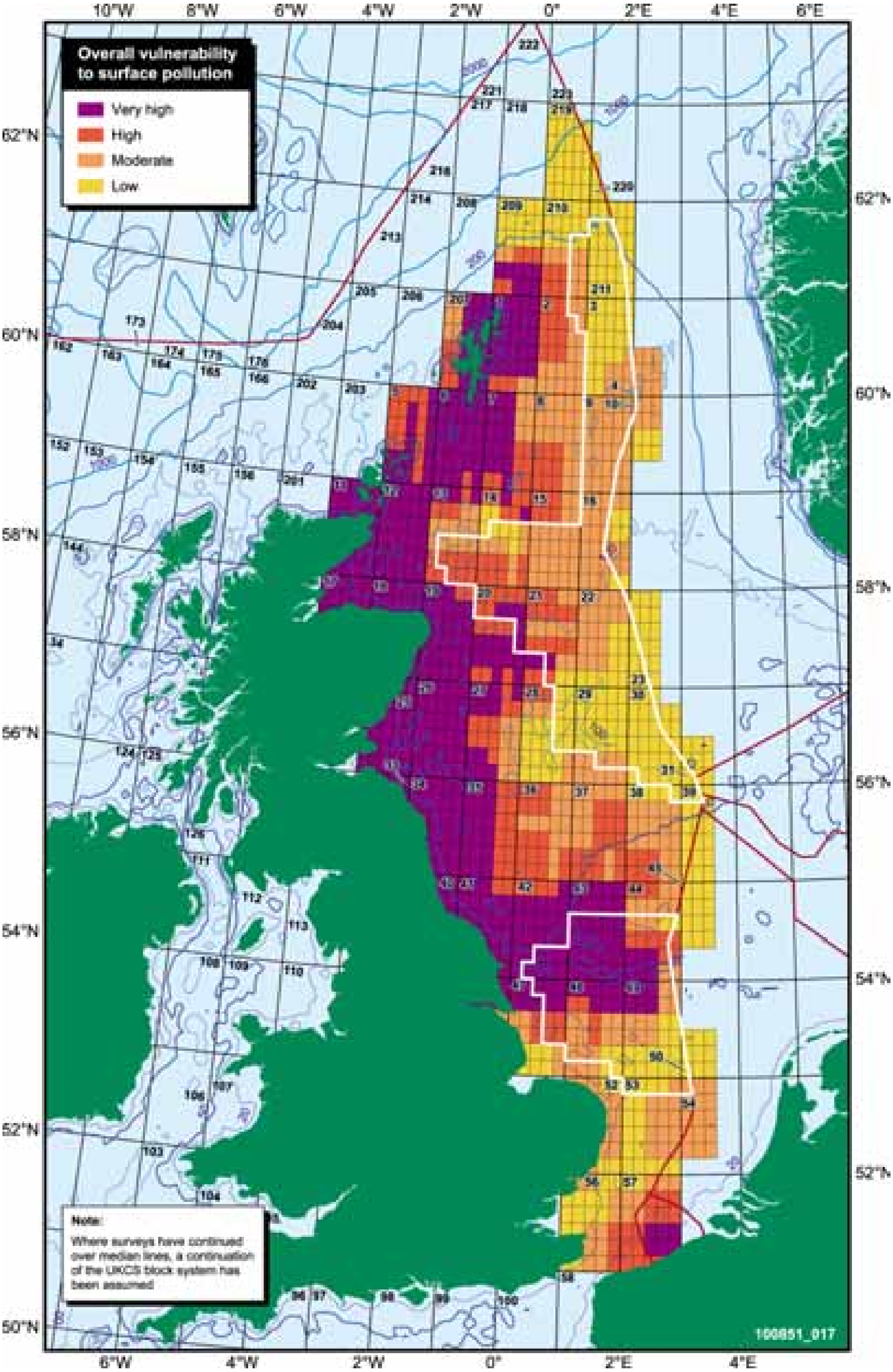
Overall seabird vulnerability to surface pollution is very high in parts of Quadrants 42, 43, 47, 48 and 49 (southern North Sea) and in coastal areas to the east of SEA2 areas from Shetland to the Humber (Figure 6.7). Six blocks in Quadrants 20 and 21 (central North Sea) also had very high overall vulnerability. Much of the seabird vulnerability is associated with proximity of breeding colonies and post-breeding dispersal of auks and is therefore seasonal. However, vulnerability within the SEA 2 areas is very high for at least nine months of the year in the same parts of Quadrants 42, 43, 47, 48 and 49 (southern North Sea), and in all months in parts of Quadrants 42 and 47 off Flamborough Head. Block 19/03, immediately adjacent to the SEA 2 areas in the outer Moray Firth, is also very highly vulnerable throughout the year. A proportion of blocks within the central North Sea and southern North Sea are highly vulnerable for 6-8 months; while remaining blocks within the SEA 2 areas are highly vulnerable for less than six months; ie had operational windows within which vulnerability is lower.

Table 6.3 - Individual species vulnerability index scores

Red-throated diver	29*	**Arctic skua**	24
Black-throated diver	29*	**Great skua**	25
Great northern diver	29*	**Little gull**	24
Great crested grebe	23*	**Black-headed gull**	11
Red-necked grebe	26*	**Common gull**	13
Fulmar	18	**Lesser black-backed gull**	19
Sooty shearwater	19*	**Herring gull**	15
Manx shearwater	23*	**Great black-backed gull**	21
Storm petrel	18	**Kittiwake**	17
Gannet	22	**Sandwich tern**	20
Cormorant	20	**Common tern**	20
Shag	24*	**Arctic tern**	-6
Scaup	20*	**Little tern**	19
Eider	16*	**Guillemot**	22*
Long-tailed duck	17*	**Razorbill**	24*
Common scoter	19*	**Black guillemot**	29*
Velvet scoter	21*	**Little auk**	22*
Goldeneye	16*	**Puffin**	21*
Red-breasted merganser	21*		

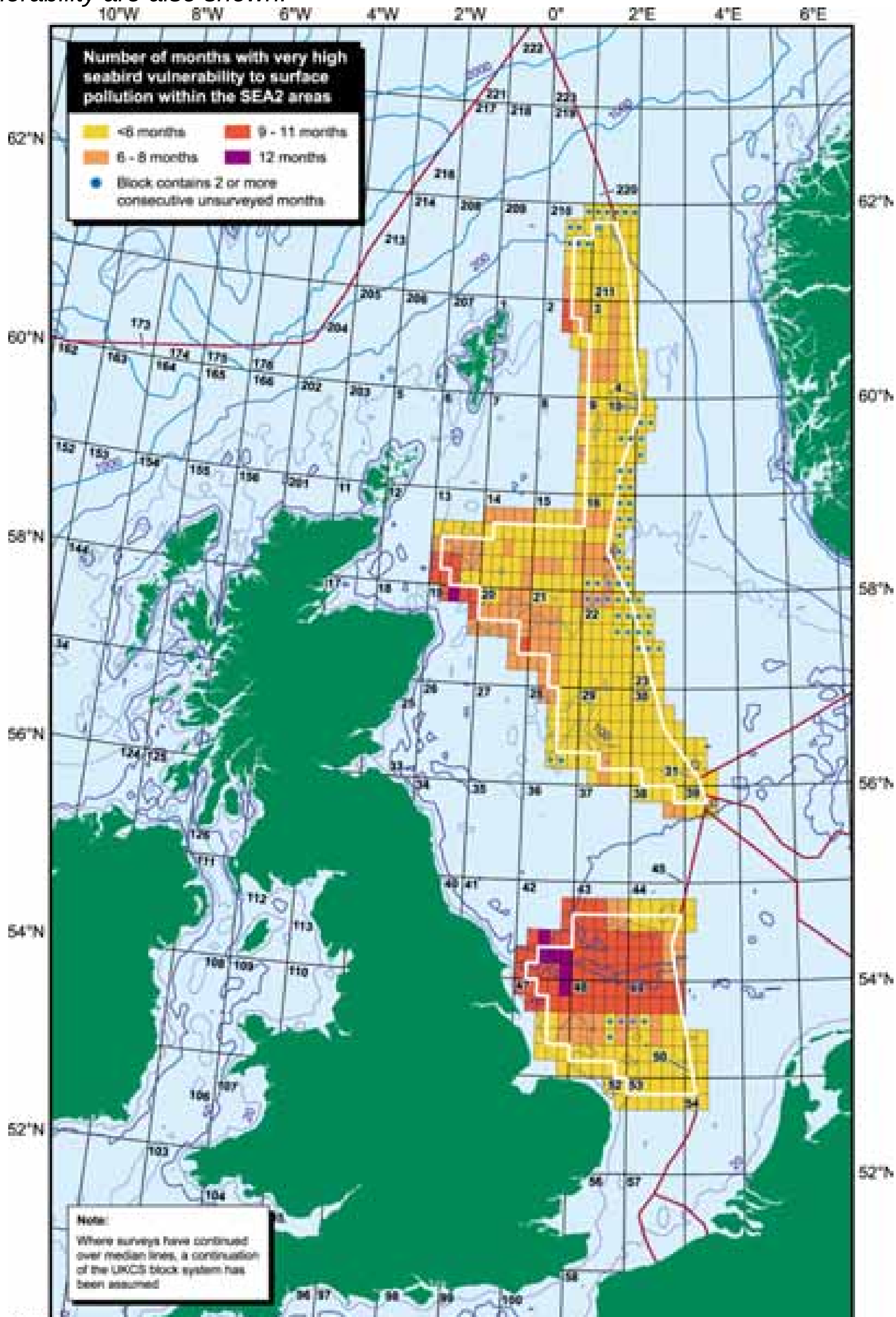
* large proportion of time spent on the surface of the sea and therefore individuals of this species are at high risk from surface pollutants.
(source: BODC 1998)

Figure 6.7 - Overall vulnerability of seabirds to surface pollution.



Source: JNCC block vulnerability data

Figure 6.8 - Seasonal vulnerability of seabirds to surface pollution (expressed as number of months in which very high vulnerability is present. Data gaps for seabird vulnerability are also shown.



Source: JNCC block vulnerability data

Data gaps are present for relatively few of the SEA 2 area blocks, although there are significant areas at the northern extremity of the northern North Sea area, along the Norwegian median line, and offshore from the Wash, for which vulnerability data are not available.

In addition, much of the available information dates from SAST work in the early 1980s (principally SAST 2 between 1983 and 1986) and significant ecological change may have occurred since then. (It is known, for example, from continuous plankton recorder (CPR) data in the North Sea that many species of phytoplankton and zooplankton showed marked changes in abundance after 1987, coinciding with a large increase in catches of the western stock of the horse mackerel (*Trachurus trachurus*) in the northern North Sea. This "regime shift" is thought to be linked to NAO anomalies associated with stronger and more southerly tracks of westerly winds and higher temperatures in western Europe (Reid *et al.* 2001; see also Section 5.4). Such changes in multiple trophic levels of a marine ecosystem, resulting from hydrographic and atmospheric events at decadal and regional scales would also be expected to influence seabird distributions.)

6.8 Marine mammals

6.8.1 Data sources

A review of marine mammal distribution, ecological importance and sensitivity to disturbance and contamination was carried out by the Sea Mammal Research Unit (SMRU).

6.8.2 Distribution and abundance

Eight marine mammal species occur regularly over large parts of the North Sea: grey seal, harbour seal, harbour porpoise, bottlenose dolphin, white-beaked dolphin, Atlantic white-sided dolphin, killer whale and minke whale. There is extensive information on the distribution and abundance of grey seals around Britain from annual aerial surveys of breeding colonies and from over 100 animals fitted with satellite-relayed data loggers. Information on harbour seals is available from aerial surveys and VHF telemetry. There is also extensive information on distribution in the North Sea from a number of summer sightings surveys (SCANS-94, NASS-89 and NILS-95). Estimates of abundance are available from these surveys for some species. There are also many records from year-round surveys by the European Seabirds at Sea Consortium (ESAS) since 1979, from cetacean observations made during seismic surveys in 1996-98, and sightings by voluntary observers compiled by the Sea Watch Foundation.

Minke whales occur throughout the central and northern North Sea in summer particularly in the west. Highest densities appear to be in the northwest North Sea, particularly off the mainland coast of Scotland and into the western part of the central SEA 2 area. Estimates of summer abundance in the area range from 5,000 to 20,000 whales. It is clear that the central SEA 2 area in particular, and to a lesser extent the northern SEA 2 area, are important areas for minke whales in summer - see Figure 6.9.

The harbour porpoise is the commonest cetacean in the North Sea. Highest densities in summer are north of 56ºN, mostly in a north-south band between 1ºE and 3°E. In summer 1994, there were an estimated 268,000 porpoises in the North Sea. It is clear that the northern and central SEA 2 areas are very important areas for harbour porpoises in summer, and that the southern SEA 2 area is also important, despite the predicted low densities – see Figure 6.10.

The small, geographically isolated, resident population of bottlenose dolphins in the North Sea appears to be distributed coastally in summer but numbers decrease in winter. Animals from this population may move offshore at this time of year; possibly into the central SEA 2 area.

White-beaked dolphins are restricted to the North Atlantic. In the North Sea, they occur year-round where they are most commonly distributed between 54˚N and 59˚N, across the central SEA-2 block and northern half of the southern SEA 2 area. Summer abundance of white-beaked dolphins in the North Sea is estimated at 7,900 animals. The Atlantic white-sided dolphin is primarily an offshore species but does occur in the North Sea, especially in summer. Estimated summer abundance of white-beaked and Atlantic white-sided dolphins combined is 11,800 animals.

Killer whales have been observed throughout the north-western North Sea in all months except October. Most records are from the northern part of the northern SEA 2 area and in the north-eastern part of the central SEA 2 area. Other cetacean species are not common in the North Sea.

Harbour seals are one of the most widespread pinniped species and have a practically circumpolar distribution in the Northern Hemisphere. Harbour seals are found in all coastal waters around the North Sea, including Orkney and Shetland. A minimum population estimate in the North Sea is 38,000; just over half of the Northeast Atlantic subspecies. During the pupping and moulting seasons in June to August they spend more time ashore than at other times of the year. In the SEA 2 areas, they are likely to occur in significant numbers only in the south-western part of the southern SEA 2 area – see Figure 6.11.

Grey seals are restricted to the North Atlantic; total abundance is approximately 300,000 animals. The population in the northeast Atlantic has been increasing at around 6% annually since the 1960's; its current size is estimated at around 130,000-140,000 individuals, of which approximately 70,000 are associated with breeding colonies in the North Sea. In the North Sea, pupping occurs from October (in the north) to January (in the south) and moulting occurs in February-March. Most of the population will be on land most of the time for several weeks during these periods and densities at sea will be lower. Extensive information on the distribution of British grey seals at sea shows that although they do occur in the SEA 2 areas, the grey seal population as a whole does not spend significant time in these areas – see Figure 6.12.

6.8.3 Ecological importance

Grey seals are important marine predators in the North Sea. Their diet comprises primarily sandeels, whitefish and flatfish, in that order of importance, but varies seasonally and from region to region. A current estimate of annual prey consumption in the North Sea is approximately 130,000 tonnes, of which almost 50% is sandeels. Grey seal foraging movements are on two geographical scales: long and distant trips from one haul-out site to another; and local repeated trips to discrete offshore areas. The large distances travelled indicate that grey seals in the North Sea are not ecologically isolated and can thus be considered as coming from a single ecological population. Foraging destinations at sea are typically localized areas characterized by a gravel/sand seabed sediment; the preferred burrowing habitat of sandeels, an important component of grey seal diet – see Figure 6.13. The limited distance from a haul-out site of a typical foraging trips indicates that the ecological impact of seal predation may be greater coastally, rather than further offshore. Recent and ongoing mathematical modelling has generated predicted distributions of where grey seals spend their time foraging around the British Isles. Although the model predicts that grey seals do spend some time foraging in the SEA 2 areas, it is a small percentage of total time at sea. Additional information indicates that the southern SEA 2 area may be more important for grey seals that the modelling currently predicts.

The harbour seal is the smaller of the two species of pinniped that breed in Britain but is also an important predator in the North Sea. The diet is composed of a wide variety of prey including sandeels, whitefish, herring and sprat, flatfish, octopus and squid. Diet varies seasonally and from region to region. A very approximate estimate of annual consumption of prey by harbour seals in the North Sea is 65,000 - 90,000 tonnes. Direct information on foraging movements and the distribution at sea of harbour seals in the North Sea is limited to studies in the Moray Firth, where harbour seals forage within 60km of their haul-out sites. It is highly unlikely, therefore, that harbour seals forage in the central and northern SEA 2 areas. However, if foraging ranges in the south-western North Sea are similar, harbour seals are likely to forage in the south-western part of the southern SEA 2 area.

There is relatively little information on the ecology of cetaceans in the North Sea. Harbour porpoises feed mainly on fish found on or near to the seabed. The main species consumed are herring, sprats, sandeels, whiting, cod and other cod-like fish and this diet does not appear to have changed during the past 40 years. The harbour porpoise is the most numerous marine mammal in the North Sea and total annual fish consumption is likely to run into hundreds of thousands of tonnes for the North Sea as a whole. The significance of this species' predation from an ecological perspective has not been assessed, nor has the importance of the areas under consideration with respect to the entire North Sea.

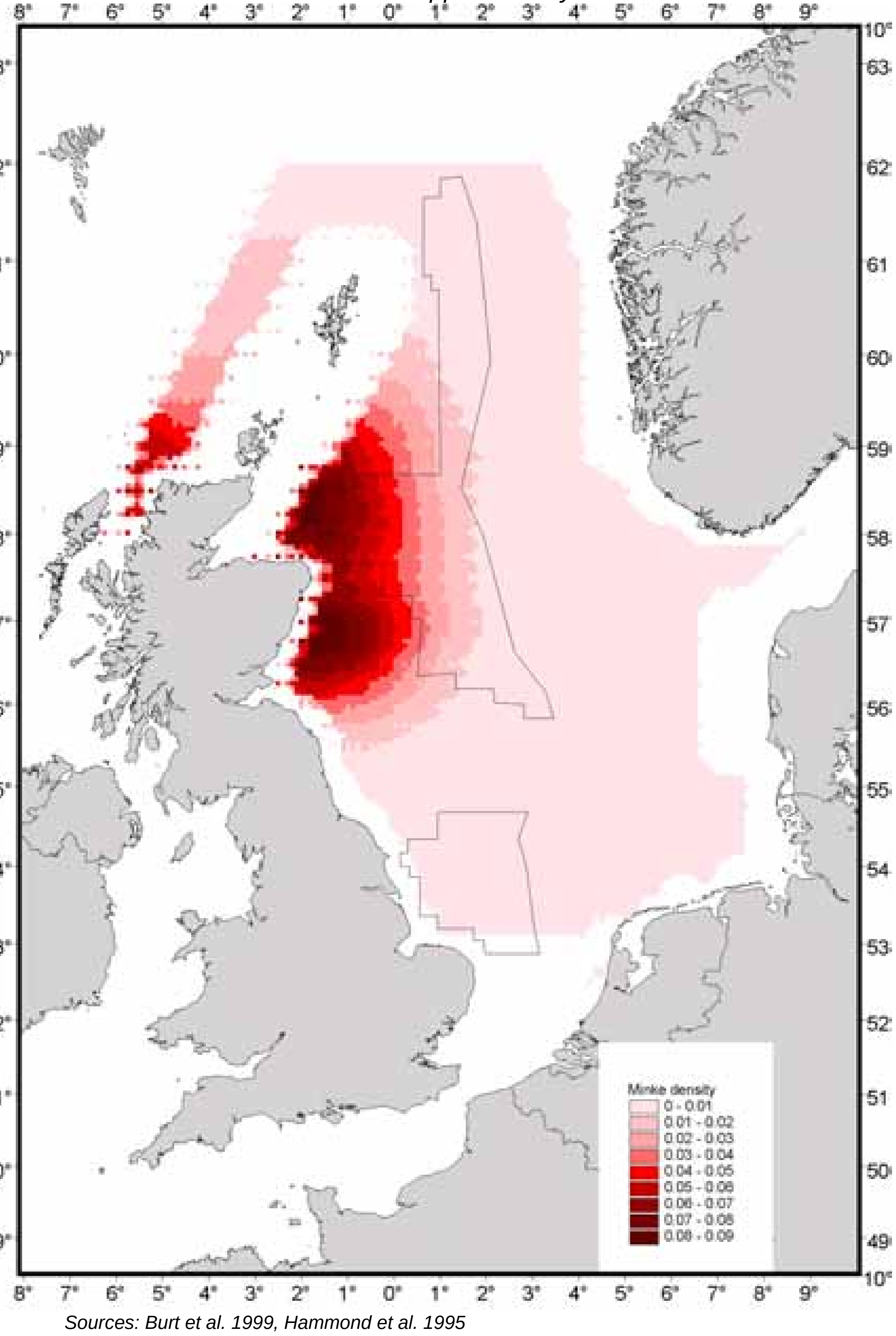
Relatively little information is available for other cetacean species. Minke whales feed on a variety of fish, including herring, cod, haddock and sandeels. White-beaked dolphins take whiting and other cod-like fish, sandeels, herring and octopus. Killer whales are known to feed on herring, mackerel and seals around haul-out sites.

6.8.4 Sensitivity to disturbance, contamination and disease

6.8.4.1 Noise

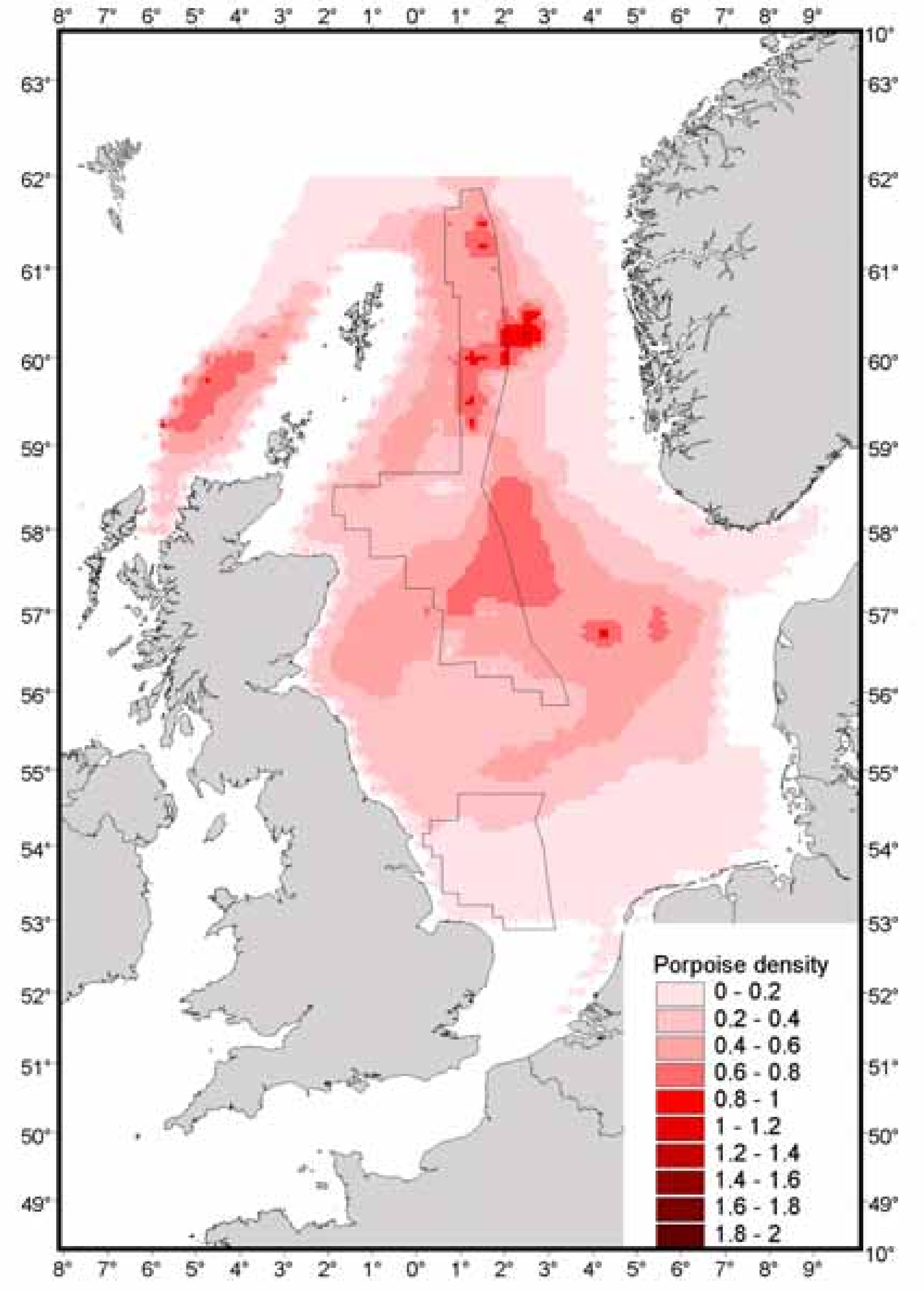
There is an increasing awareness of the importance of sound to marine mammals. Any man-made noise could potentially have an effect on a marine mammal. The effects could range from mild irritation through impairment of foraging or disruption of social interactions to hearing loss and in extreme cases may lead to injury or even death. Most of the noise generated by offshore oil operations is low frequency, mostly <1kHz, although higher frequency sounds are also generated. Seals are known to be sensitive to those frequencies whereas small (toothed) cetaceans are relatively insensitive to low frequencies. There are no direct measurements of either the frequency range or sensitivities of hearing in large whales, but circumstantial evidence suggests that they may have good low frequency hearing.

Figure 6.9 - Minke whale density (schools.km^{-2}) predicted from spatial modelling of the SCANS data. Mean school size is approximately 1.



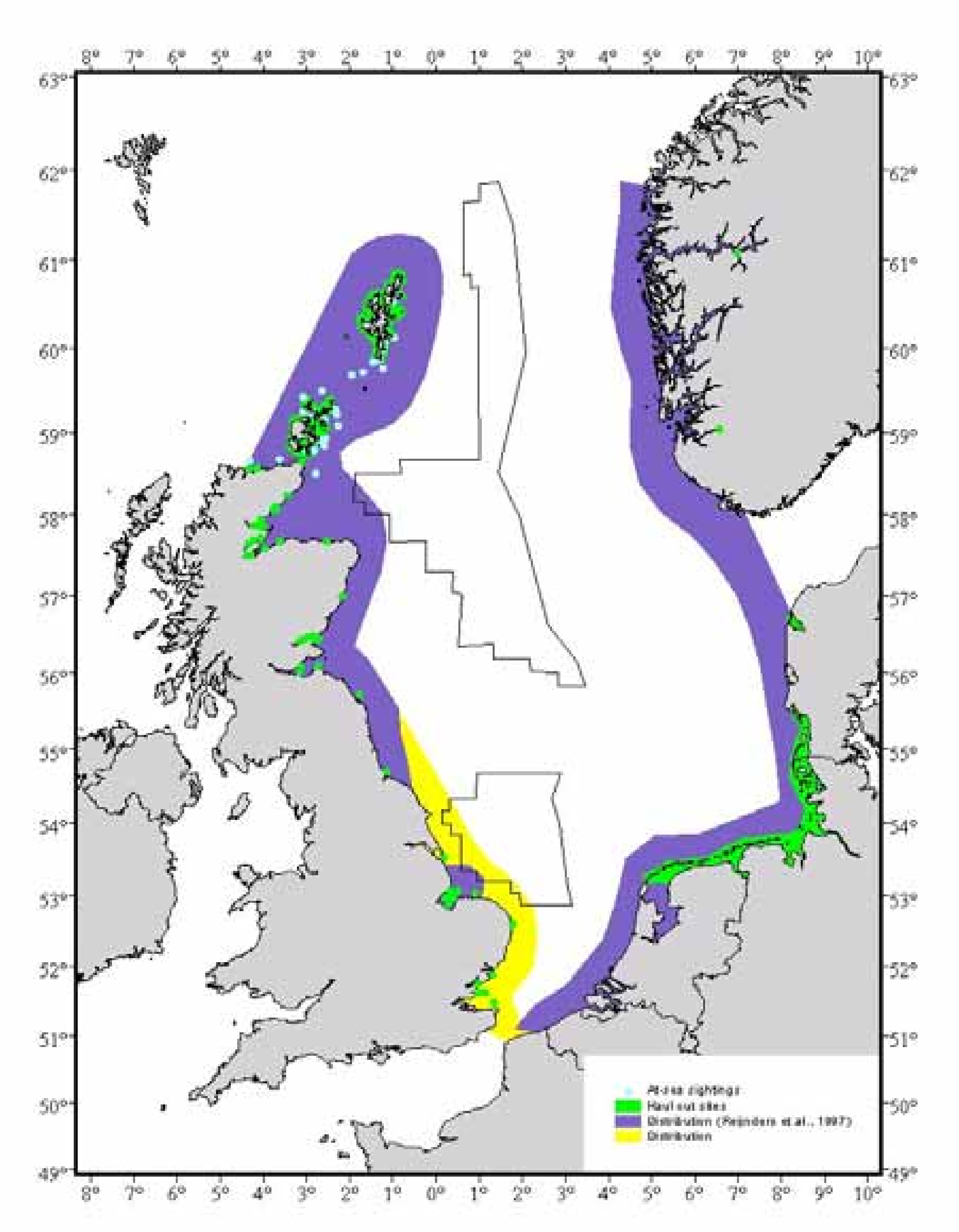
Sources: Burt et al. 1999, Hammond et al. 1995

Figure 6.10 - Harbour porpoise density (schools.km^{-2}) predicted from spatial modelling of the SCANS data. Mean school size is approximately 1.5.



Sources: Burt et al. 1999, Hammond et al. 1995

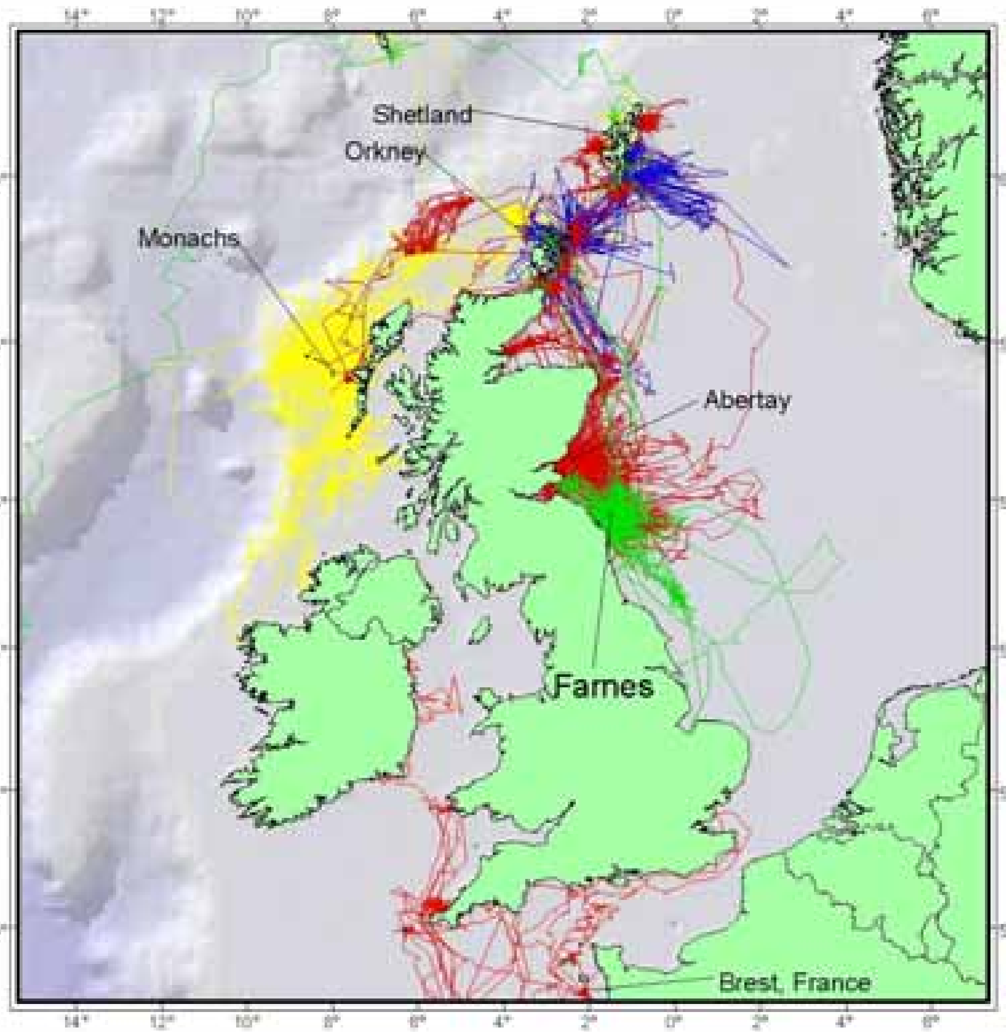
Figure 6.11 - Harbour seal distribution around the North Sea. Also shown are haul-out sites during the moult and at-sea sightings from SAST surveys.



Sources: after Bjørge 1991, Reijnders et al. 1997, Pollock et al. 2000, SMRU unpublished data

Figure 6.12 - Tracks of 108 grey seals fitted with satellite-relay data loggers over a period of about 10 years

Sources: McConnell et al. 1999, SMRU unpublished data



Seismic surveys have been shown to cause avoidance behaviour in the two seal species present in the North Sea, and in a range of large cetacean species. It is likely that seismic survey work will affect foraging behaviour by any seals and large whales in the SEA 2 areas. Current mitigation methods are probably generally effective in preventing physical damage.

There are no reliable data to suggest that vessel noise or drilling noise adversely affect seals or small cetaceans but there are indications that large whales may avoid areas of intense activity.

Decommissioning of installations and subsea structures including wellheads and pipelines can require occasional use of explosive cutting. At close range, underwater explosives could conceivably result in injury and death of marine mammals, and may cause hearing damage at greater ranges. The oil and gas industry, DTI and JNCC have collaborated to develop mitigation strategies for the use of explosives during decommissioning, including the use of acoustic techniques to detect cetaceans, and "seal scarer" devices. Mitigation strategies are at an early stage of development, since few major structures have yet been decommissioned, but would be expected to improve as a result of experience gained.

6.8.4.2 Contaminants

A substantial amount of information is available on the uptake of lipophilic contaminants by marine mammals, such as polychlorinated biphenyls, DDTs and chlorinated pesticides. Other studies on captive and wild populations have shown that these compounds probably have toxic effects on the reproductive and immune systems. Certain heavy metals such as mercury, lead, cadmium, copper and zinc are taken up by marine mammals although there is little evidence that these cause substantial toxic responses, except at high concentrations. Cetacean species which feed lower down the food chain may be at risk from exposure to polyaromatic hydrocarbons, although very little is known about current exposure levels or the effects of chronic exposure in marine mammals.

6.8.4.3 Oil spills

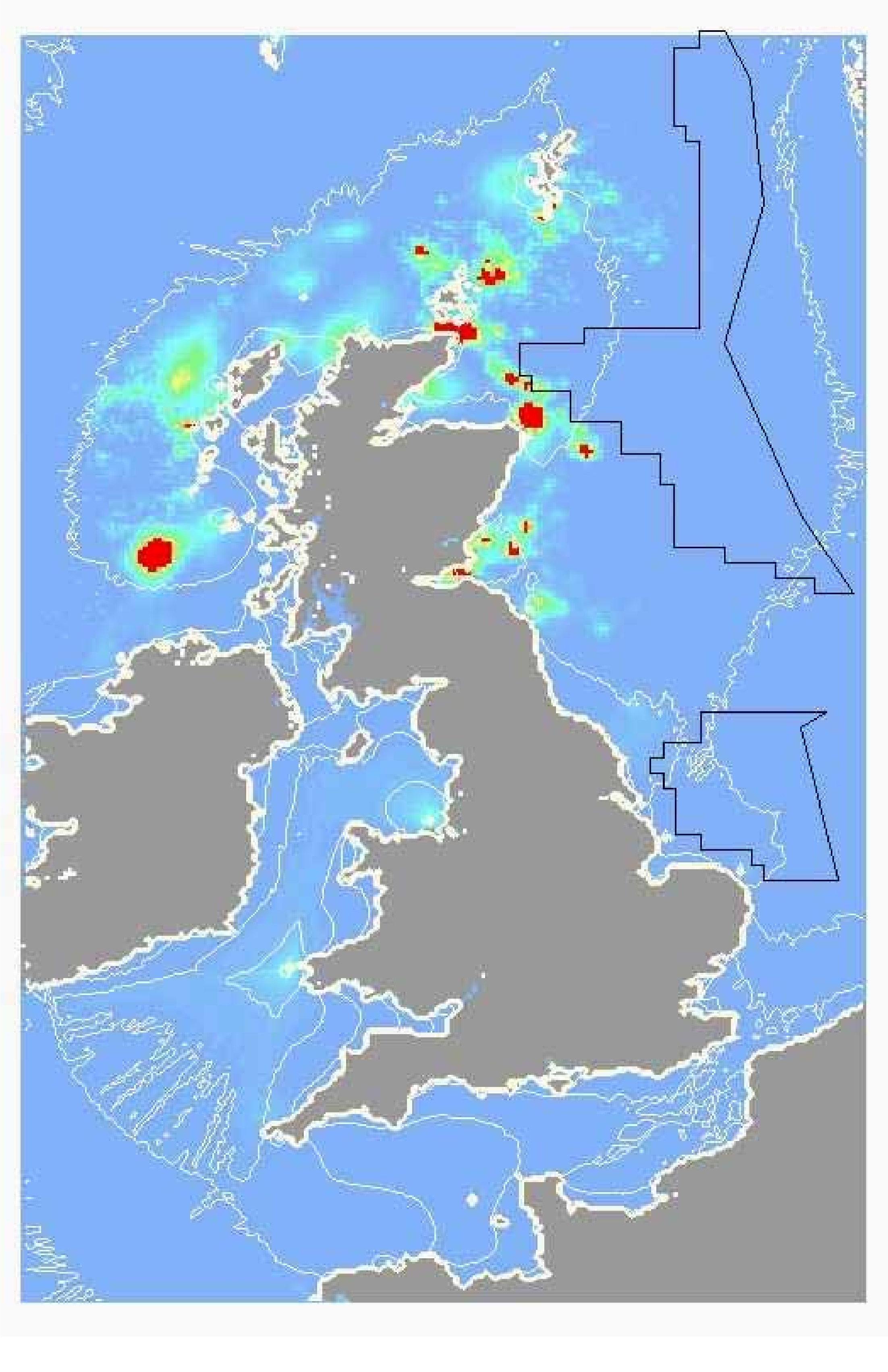
Direct mortality as a result of contaminant exposure associated with major oil spills has been reported, eg following the *Exxon Valdez* oil spill in Alaska in 1989. Many animals exposed to oil developed pathological conditions including brain lesions. Additional pup mortality was reported in areas of heavy oil contamination compared to unoiled areas.

More generally, marine mammals are less vulnerable than seabirds to fouling by oil, but they are at risk from hydrocarbons and other chemicals that may evaporate from the surface of an oil slick at sea within the first few days. Symptoms from acute exposure to volatile hydrocarbons include irritation to the eyes and lungs, lethargy, poor coordination and difficulty with breathing. Individuals may then drown as a result of these symptoms.

Grey and harbour seals come ashore regularly throughout the year between foraging trips and additionally spend significantly more time ashore during the moulting period (February-April in grey seals; August in harbour seals) and particularly the pupping season (October-January in grey seals; June-July in harbour seals). Animals most at risk from oil coming ashore on seal haul-out sites and breeding colonies are neonatal pups, which are therefore more susceptible than adults to external oil contamination.

There have been no specific studies on the direct acute or chronic toxicity of oil dispersants to seals and cetaceans.

Figure 6.13 - Distribution of where grey seals spend their time foraging around the British Isles predicted by a spatial model using the satellite-linked telemetry data and other unpublished SMRU data (Matthiopoulos et al. in preparation)



6.8.4.4 Disease

A small-scale survey of anthropogenic bacteria, including *Salmonella* and *Campylobacter*, has been conducted in seals but there is no information on the occurrence of anthropogenic viruses, such as enteroviruses.

6.8.5 Bycatch and other non-oil related management issues

The accidental capture (bycatch) of marine mammals in fishing gear is an issue of current concern throughout EU waters, and beyond. Bycatch in gill and tangle nets represents a significant source of mortality for harbour porpoises in the North Sea and elsewhere. In the North Sea, harbour porpoises are bycaught in the Danish and, to a much lesser extent, UK gill and tangle net fisheries. The total estimated mortality of around 7,200 porpoises per year in the North Sea is thought to exceed sustainable levels.

Most harbour porpoises are bycaught in Danish gillnet fisheries that operate mainly, but not exclusively, in the eastern half of the North Sea and to the east of the SEA 2 areas. It is not possible to estimate the bycatch mortality of porpoises within the SEA 2 areas but animals taken there would in any case belong to a population from a wider area.

Bycatches of other cetacean species in the North Sea have been recorded very rarely.

A potential source of mortality to cetaceans in the North Sea is through collisions with shipping. In other areas, where ships are numerous and cetacean numbers are depleted, this is a serious cause for concern. The frequency of such events in the North Sea is unknown and consequently this has not been identified as a significant source of additional mortality in this region.

6.8.6 Conservation frameworks

Marine mammals are included in a wide range of conservation legislation. All species are listed on Annex IV (Animal and Plant Species of Community Interest in Need of Strict Protection) of the European Commission’s Habitats Directive. Under Annex IV, the keeping, sale or exchange of such species is banned as well as deliberate capture, killing or disturbance. The harbour porpoise, bottlenose dolphin, grey seal and harbour seal are also listed in Annex II of the Habitats Directive. Member countries of the EU are required to consider the establishment of Special Areas of Conservation (SACs) for Annex II species. Candidate SACs have been established for the bottlenose dolphin in the Moray Firth and in Cardigan Bay. No candidate SACs have yet been established for the harbour porpoise in the North Sea. A number of candidate SACs have been established for grey and harbour seals around the coast of the UK.

Under the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS) provision is made for protection of specific areas, monitoring, research, information exchange, pollution control and heightening public awareness. Measures cover the monitoring of fisheries interactions and disturbance, resolutions for the reduction of by-catches in fishing operations, and recommendations for the establishment of specific protected areas for cetaceans.

In UK waters, all species of cetacean are protected under the Wildlife and Countryside Act 1981 and the Wildlife (Northern Ireland) Order 1985. Whaling is illegal under the Fisheries Act 1981. Guidelines to minimise the effects of acoustic disturbance from seismic surveys, agreed with the oil and gas industry, were published by the then Department of the

Environment in 1995 and revised in 1998. In 1999, the then Department of the Environment, Transport and the Regions produced two sets of guidelines aimed at minimising disturbance to cetaceans. Grey and harbour seals in the vicinity of fishing nets can be killed to prevent damage to the nets or to fish in the nets under the Conservation of Seals Act 1970. Both species are protected during the breeding season; however, licences to kill seals may be granted for any time of the year for specific listed purposes.

6.8.7 Relevance

The SEA 2 areas are important areas for the three most abundant cetacean species in the North Sea: minke whale, harbour porpoise, and white-beaked dolphin. However, all are also distributed in surrounding areas. Only for the harbour porpoise is there evidence that the SEA 2 areas (northern and central) are particularly important areas.

Grey and harbour seals do occur in the SEA 2 areas but the populations as a whole spend a very small proportion of their time in these areas. Activities in the SEA 2 areas are unlikely to result in a population effect for seals in the North Sea.

The most abundant marine mammal species in the North Sea (grey and harbour seals, minke whales, harbour porpoises and white-beaked dolphins) are important predators in this region feeding on a wide range of prey types including a number of important commercial species. The abundance and availability of fish prey is clearly of prime importance in determining the reproductive success or failure of marine mammals in this area, as elsewhere. Changes in the availability of principal prey species may be expected to result in population level changes of marine mammals but it is currently not possible to predict the extent of this.

Seals are sensitive to the low frequency sounds generated by oil exploration and production. Small cetaceans are relatively insensitive to low frequencies. Circumstantial evidence suggests that large whales may have good low frequency hearing.

It is likely that seismic survey work will affect foraging behaviour by any seals and large whales in the SEA 2 areas. Current mitigation methods are believed to be generally effective in preventing physical damage.

There are no reliable data to suggest that vessel noise or drilling noise adversely affect seals or small cetaceans but there are indications that large whales may avoid areas of intense activity.

Contaminants, such as polychlorinated biphenyls, DDTs and chlorinated pesticides probably have toxic effects on the reproductive and immune systems of marine mammals. There is little evidence that heavy metals cause substantial toxic responses, except at high concentrations. Cetacean species which feed lower down the food chain may be at risk from exposure to polyaromatic hydrocarbons, although very little is known about current exposure levels or the effects of chronic exposure in marine mammals.

Major oil spills are likely to result in direct mortality. More generally, marine mammals are less vulnerable than seabirds to fouling by oil, but they are at risk from chemicals evaporating from the surface of an oil slick at sea within the first few days. Individuals may drown as a result of associated symptoms. Neonatal seal pups are at risk from oil coming ashore.

Bycatch in gill and tangle nets represents a significant source of mortality for harbour porpoises in the North Sea and the total estimated mortality per year is thought to exceed sustainable levels. It is not possible to say how many porpoises may become bycaught in the SEA 2 areas; animals bycaught there would in any case belong to a population from a wider area. Bycatch is not a significant issue for other species.

6.8.8 Implications for Strategic Environmental Assessment

In conclusion, although there are relatively few species of marine mammal present in important numbers within SEA 2 areas, in comparison to areas of the UKCS West of Britain (eg SEA 1 area); these species may be vulnerable to the effects of oil and gas activities (specifically seismic noise). This issue is therefore addressed further in Section 10.5.1.

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7 POTENTIAL OFFSHORE CONSERVATION SITES

7.1 Overview

The Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001, came into force on 31 May 2001, and implement with respect to UKCS offshore oil and gas activities only, the European Council Directive on the conservation of natural habitats and of wild fauna and flora, and the European Council Directive on the conservation of wild birds. The UK Government is, through the Joint Nature Conservation Committee, currently identifying possible Special Areas of Conservation (SACs) for offshore areas beyond territorial waters (12 nautical miles). The *Interpretation Manual of European Union Habitats Eur. 15/2, October 1999. Natura 2000, European Commission DG Environment* defines three "Coastal and Halophytic Habitats in Open Sea and Tidal Areas" which are potentially relevant to the UKCS:

Sandbanks which are slightly covered by seawater all the time - described as "Sublittoral sandbanks, permanently submerged. Water depth is seldom more that 20m below Chart Datum. Non-vegetated sandbanks or sandbanks with vegetation belonging to the *Zosteretum marinae* and *Cymbodoceion nodosae*."

Reefs - described as "Submarine or exposed at low tide, rocky substrates and biogenic concretions, which arise from the sea floor in the sublittoral zone but may extend into the littoral zone where there is an uninterrupted zonation of plant and animal communities. These reefs generally support a zonation of benthic communities of algae and animal species including concretions, encrustations and corallogenic concretions."

Submarine structures made by leaking gases – described as "Spectacular submarine complex structures, consisting of rocks, pavements and pillars up to 4m 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 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."

7.2 Potential for sites within the SEA 2 areas

7.2.1 Sandbanks

Shallow sandbank features in the SEA 2 area are confined to the southern North Sea, and comprise both active and relict (moribund) linear sandbanks, and shoal areas including the Dogger Bank (Section 5.2.2, Figure 7.1). The structure and hydrodynamics of linear bank formation have been studied on the Norfolk Banks, although relatively little information was previously available on their biology. In particular, it was unclear whether there were differences in the fauna and relative importance of banks in different areas. In support of the SEA 2 process, therefore, survey work has been commissioned which included high-resolution multibeam bathymetry, photography of sediment features and epifauna and seabed sampling (see discussions in Sections 5.2 and 6.3). In contrast to the Norfolk Banks, the ecology of the Dogger Bank was extensively investigated during the 20th century and Kröncke and Knust (1995) concluded that the area was a special ecological region, unlike anywhere else in the North Sea. This conclusion was used to support a proposal from the Worldwide Fund for Nature that the Dogger Bank should be made a Marine Protected Area on account of its year round productivity, importance for commercial fisheries and potential for restoration. To allow strict comparisons with other shallow sandbanks, parts of the Dogger Bank were included in the DTI 2001 Survey.

Preliminary results from the DTI 2001 Survey are available and on the basis of the animals retained on a 5mm sieve at each sampling station some initial conclusions can be drawn (see also Section 6.3 – SNS seabed fauna). The Norfolk Banks appear to all have a similar and unremarkable fauna, which in terms of species composition is typical of other sandy sediments in the southern North Sea. Two species of sandeels were noted to be widespread and common in the area. The shallow banks in the approaches to the Wash are distinct in both sediment (stony with numerous shells) and fauna (extensive epifaunal growth and including the potentially habitat modifying, introduced slipper limpet *Crepidula fornicata*). The Dogger Bank was also distinct and the sediments (sandy) and fauna (higher densities of larger animals) corresponded to previous descriptions.

7.2.2 Reef structures

There are no known reef structures within the SEA 2 area which would be likely to qualify for designation in the sense defined by the European Commission Interpretation Manual.

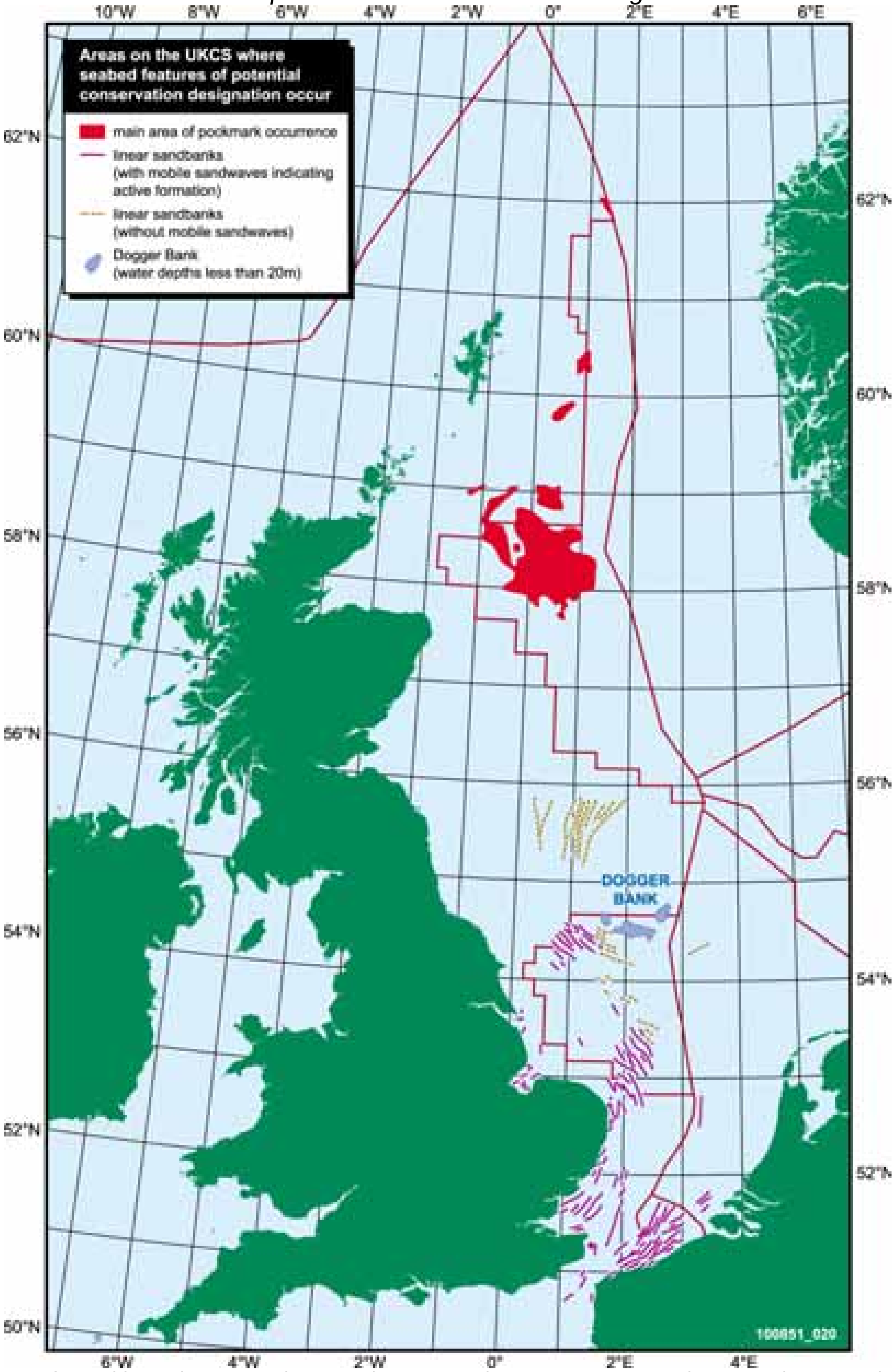
7.2.3 Submarine structures made by leaking gases

Pockmarks are widespread in the North Sea and other sedimentary basins throughout the world; and are believed to result from gas or fluid release, causing suspension and winnowing of sediments (see also Section 5.2.2).

Continuing release of gas has previously been recorded from three Fladen Ground pockmarks in block 15/25 (named Scanner, Challenger and Scotia, after the vessels used in their study) (Hovland and Judd 1988, Judd *et al.* 1994). The whole of Block 15/25 was previously been licensed for oil and gas exploration (although part is now relinquished) and it was through oil industry surveys that the pockmarks were discovered and subject to initial study. These pockmarks are large eg 450m wide, 700m long and 17m deep although only one (Scanner) has been visually investigated. This pockmark was found to contain areas of carbonate-cemented sediments (aragonite and calcite, apparently formed by bacterial metabolism of seeping methane). ROV observations show that these hard substrate areas have associated epifaunal and seston assemblages (but see below). Bacterial mats have also been observed and may be indicative of a chemoautotrophic food chain (Hovland and Judd 1988).

Pockmarks in the Witch Ground Basin show considerable variability with respect to their size and shape. Whilst it is evident that seabed sediment type influences their character, this alone does not explain the asymmetry of the pockmarks of several areas. Clearly the large pockmarks in UKCS Block 15/25 are anomalous. However, several other pockmarks larger / deeper than the norm were identified in other areas. The new data, acquired during the DTI 2001 Survey, has revealed the true extent of the gas escapes that created these large features, although not whether gas release is ongoing.

Figure 7.1- UKCS areas of potential conservation site designation.



Sources: after Stride et al. 1982, Andrews et al. 1990, Pantin 1991, Cameron et al. 1992, Johnson et al. 1993, Gatliff et al. 1994, Holmes et al. 1993, 1994

During the DTI 2001 Survey active gas seeps were identified only in UKCS Block 15/25. However, gas seeps have been reported from several other locations in the Witch Ground Basin. Some of these reports are evidently erroneous; shipwrecks having been mistaken for gas seep plumes and 'carbonate reef' during at least two commercial rig site surveys. Pockmarks are widespread in the North Sea, particularly in the Witch Ground Basin, but there is very little reliable evidence (in the public domain) of methane-derived authigenic carbonate (MDAC). This does not necessarily indicate that MDAC is very rare because of the difficulty in detecting MDAC remotely. The widespread availability of gas in the seabed, and evidence of gas seeps over much of the North Sea suggest that MDAC, and benthic communities associated with gas seeps and MDAC, are more widespread than has been realised hitherto. Certainly, gas seeps (and MDAC) are not confined to pockmarks; it is probable that, in addition to active pockmarks, further occurrences are present, particularly in the central North Sea associated with salt diapirs.

Shallow inactive pockmarks, without hard grounds, in the UKCS sector of the North Sea are unlikely to have a fauna that differs in species composition from that of the surrounding sediment (Dando, SEA 2 commissioned study). Preliminary results from the DTI 2001 Survey are consistent with this conclusion. In deeper pockmark depressions with fine-grained sediment, the faunal composition (in terms of the dominance of feeding guilds) may differ from that of the surrounding sediment if the pockmark topography is such that it acts as a sediment trap.

Inactive pockmarks may be used by fish, especially ling, for shelter. Seabed features and structures, including boulders and oil/gas pipelines, are commonly used by a variety of fish species in this way.

Shallow active pockmarks may differ in faunal composition from the surroundings and from each other, depending on the degree and the effects of the seepage. Deep pockmarks with cemented sediment in their base provide both a refuge for fish, especially large gadoids such as cod, torsk and ling, and as a site for colonisation by hard-bottom epifauna such as various sea anemones. Such epifauna is much less common in the sedimentary basins where such pockmarks are found, although the rapid development of fouling communities on fixed installations suggests that local populations provide dispersal centres of larvae which colonise available hard substrates (Forteath *et al*. 1982).

Deep active pockmarks, such as the three studied in UKCS block 15/25, additionally contain species dependent on high sulphide concentrations originating from seepage or enhanced sedimentation. The Dando commissioned study notes that the bivalve species *Thyasira sarsi* and *Lucinoma borealis* are not found elsewhere in the open North Sea, with the exception of recent colonisation of *T. sarsi* around some oil platforms. However, there are a number of offshore records of *Lucinoma borealis* (see for example Seaward 1982 and Hartley 1984) and the taxonomy of *Thyasira* in the North Sea is so confused that the distributions of the various species cannot be inferred from past records (Graham Oliver pers. comm.). Natural scattered habitats such as seeping pockmarks are almost certainly responsible for the dispersal of species like these to man-modified habitats where they can play an important role in re-oxygenation of sediments (Dando and Spiro 1993). Seeping pockmarks are likely to contain potentially interesting bacterial associations which have been little studied but which could have industrial potential eg for bioremediation. The Scanner pockmark in UKCS block 15/25 is unique in that it is the only known habitat of the gutless nematode roundworm *Astomonema southwardorum* - although this perception of uniqueness is tempered by the comments of Heip and Craeymeersch (1995) on the number of undescribed meiofaunal species in the North Sea. Further novel species may be discovered with more detailed investigations. It has been suggested (the Dando commissioned study) that consideration be given to designating the “best” examples of seeping pockmarks, as Special Areas of Conservation (SACs), because of their biological interest, as well as for their roles as fish refugia and dispersal centres for otherwise less common species in the central North Sea.

Based on the above, and the results of the DTI 2001 Survey it seems likely that only the three studied pockmarks in UKCS block 15/25 could currently be considered as “submarine structures made by leaking gases” in the sense defined by the European Commission Interpretation Manual. The responsibility for identifying offshore sites as potential SACs rests with the JNCC with the European Commission accepting (or modifying/rejecting) such proposals as Natura 2000 sites.

7.2.4 Special Protection Areas

Council Directive 79/409/EEC 1979 (the EC Birds Directive) is aimed at the protection of all species of naturally occurring birds in the territory of the member states. According to the Bird Directive, member states shall classify the most suitable territories for the conservation of these species, including migratory species, as special protection areas (SPAs).

A large number of coastal SPA sites have been classified by EU member states with North Sea coastlines (see section 9.5, Table 9.7), in many cases coincident with designated Ramsar sites. Coastal SPAs have been designated mainly in relation to seabird breeding colonies, and estuarine and wetland areas important as breeding and feeding areas for migrant waders and wildfowl.

To date, no EU member states have classified offshore areas as SPAs, although collaborative work has been undertaken to identify areas holding internationally important numbers of birds (Skov *et al*. 1995, see Section 6.7).

In the event of offshore SPAs being designated, project-specific assessment and permitting procedures available to the DTI under existing legislation, including *The Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001*, are considered to provide adequate control over exploration and production activities (including management of oil spill risks).

7.2.5 Implications for Strategic Environmental Assessment

It is a requirement of the SEA Directive that any existing environmental problems which are relevant to the proposed plan or programme are identified, for example, those relating to any areas of a particular environmental importance, such as areas designated under Directives 79/409/EEC and 92/43/EEC.

Therefore, although neither offshore SPAs or SACs have been proposed or designated in the SEA 2 areas, potential environmental effects associated with the proposed licensing are assessed in Section 10.4 (Consideration of the effects of licensing). The identified potential effects include:

- noise effects on marine mammals (Section 10.4.1.3) and possible conservation sites (Section 10.4.1.4)
- physical damage to biotopes including possible seabed SACs (sandbanks and pockmarks, Section 10.4.2.3)

- effects of discharges on seabed habitats considered as possible SACs (Sections 10.4.4.4, 10.4.4.5 and 10.4.4.7)

- oil spill risks in relation to vulnerable concentrations of seabirds (Section 10.4.7.4)

In the event of offshore SPAs or SACs being designated, under the requirements of *The Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001*, project-specific assessment and permitting procedures must include an appropriate assessment of the potential effects of the project on the site. The appropriate assessment must be carried out by the competent authority (DTI) and taking due account of advice from the relevant statutory conservation agency - JNCC outside territorial waters.

8 EXISTING HUMAN ACTIVITY IN THE SEA 2 AREA

8.1 Introduction

On the basis of archaeological data, North Sea coastal waters have supported human populations for at least 8,500 years, and human exploitation of North Sea ecological resources probably pre-dates deglaciation and inundation of the southern North Sea via the Calais-Dover Strait (around 9,000 BP, Jelgersma 1979).

The intensity and ecological consequences of direct human exploitation have steadily increased, ranging from hunting to extermination of several species of whale (European grey whale and probably European right whale) to the present situation where removal of target species impacts the whole North Sea ecosystem and catch levels for many fish stocks are almost certainly not sustainable (see Section 8.3.7).

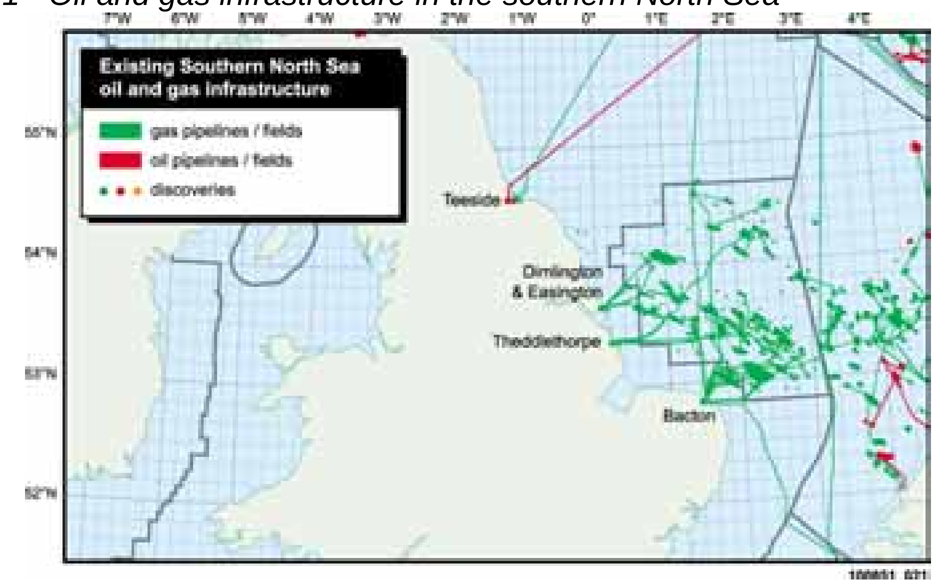
A variety of other human pressures on the North Sea environment were reviewed by OSPAR (2000), the most significant of which were inputs of trace organic contaminants from land, seabed disturbance by fisheries, inputs of nutrients from land, effects of discards and mortality of non-target species by fisheries, and input of TBT and other antifouling substances by shipping. The effects of the offshore oil and gas industry, including input of oil and physical disturbance, were considered to be relatively lower.

8.2 Oil and gas

8.2.1 Overview

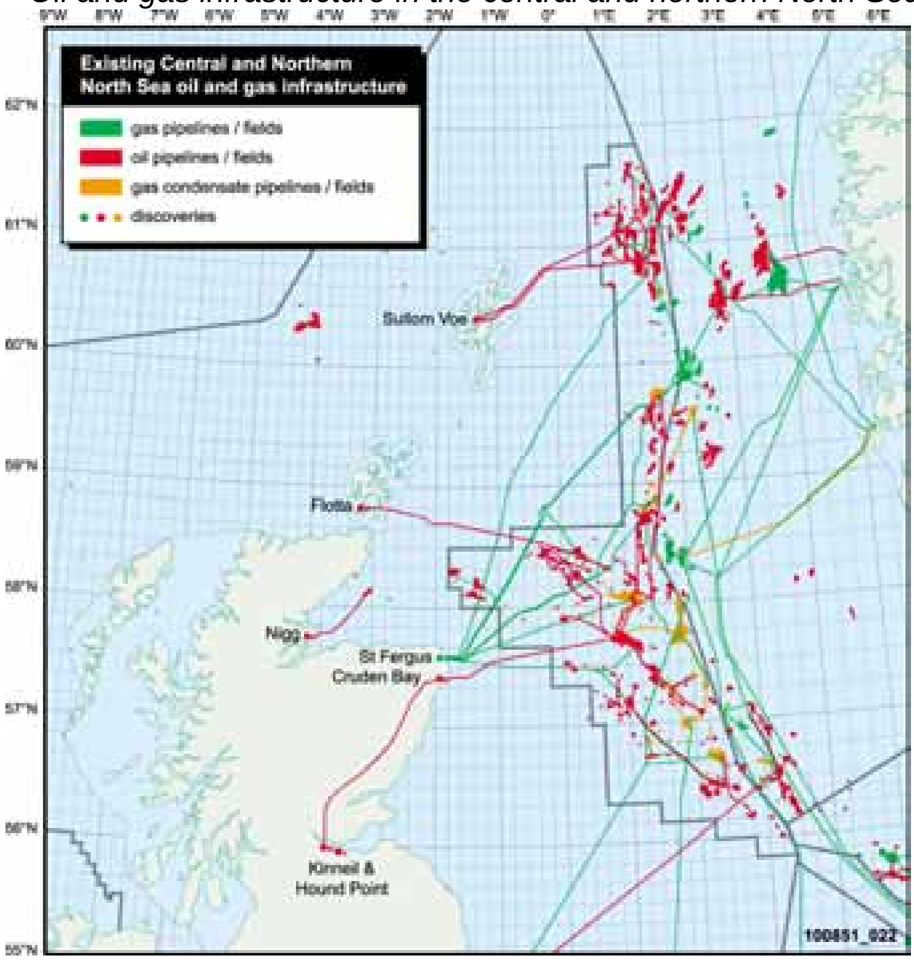
The offshore oil and gas industry has developed into an important economic activity since the 1960's. Gas developments predominate in the southern North Sea (see Figure 8.1) whilst the northern and central North Sea contain major oil and gas developments (see Figure 8.2).

Figure 8.1 - Oil and gas infrastructure in the southern North Sea



(Source: DTI 2001)

Figure 8.2 - Oil and gas infrastructure in the central and northern North Sea



(Source: DTI 2001)

Installations and a comprehensive pipeline infrastructure have developed to process the hydrocarbons, with most feeding into the main pipelines exporting the hydrocarbons to onshore terminals. The largest, and most easily developed fields have now been discovered, and with decreasing existing reserves, the number of installations facing decommissioning will increase. A more in depth consideration of oil and gas related activity in the SEA 2 areas is given in Section 4.

8.3 Fisheries

8.3.1 Introduction

The Centre for Environment Fisheries and Aquaculture Science (CEFAS), working in collaboration with the Fisheries Research Services (FRS), was commissioned to review fisheries information relevant to the SEA 2 process. The report describes the fish resources of the region and intensity and distribution of commercial fishing activity. It describes those fisheries management measures which recommend seasonal closures of parts of the North Sea to protect spawning or juvenile fish. The report also summarises the most important consequences of oil and gas exploration for fish populations and commercial fisheries, such as the use of seismic surveys and the placement of structures on the sea bed.

8.3.2 Data sources

Descriptions of major North Sea fisheries were prepared from official landing statistics, anecdotal information from local ports, and over-flight surveillance data. Official landing statistics of the major species by ICES rectangle are available for UK fleets, but only for cod and sandeel have international landings by rectangle been prepared.

8.3.3 Demersal fisheries

The North Sea is one of the world's most important fishing grounds. Major UK and international fishing fleets operate in the southern, central and northern North Sea and target both pelagic and demersal fish stocks (Figure 8.3). One of the most important fisheries in the North Sea is the mixed demersal fishery that targets cod, haddock and whiting in the central and northern parts of the region. Otter trawl and seine net vessels catch cod as part of a mixed fishery in which haddock and whiting form an important component of the catch. Otter and pair trawling accounts for most of the fishing effort in the northern North Sea, where beam trawls are rarely used, but in central and southern SEA 2 regions otter trawls are less common. Most effort is confined to the northeast coast of the UK, northeast of Scotland and east of the Shetland Islands. Parts of the Norwegian Deep and the central North Sea are relatively lightly fished. Recent overflight data showed that most otter trawl effort was concentrated to the west of Orkney and east of Shetland throughout the year, near the Fladen Ground and the northeast coast of England in the 1st and 4th quarters of the year, and during the spring and summer months near the Dogger Bank and the Silver Pit.

North Sea plaice and sole are taken in a mixed flatfish fishery by mainly Dutch and UK registered beam trawlers in the southern and southeastern North Sea. There are also directed fisheries for plaice carried out with seine and gill nets and by beam trawlers in the central North Sea. The distribution of the international beam trawl fleet indicates that most trawling activity is concentrated in the Southern Bight of the North Sea, particularly along the Continental coast from Denmark to the Straits of Dover, and is high in the offshore part of the southern SEA 2 region. Inshore fleets are heavily dependent on sole, especially during the second half of the year.

8.3.4 Pelagic Fisheries

Herring is one of the most important species landed by the UK pelagic fleet. During the 1970s there was a decrease in their spawning stock biomass, largely caused by over-exploitation and poor recruitment, and in 1977 the North Sea herring fishery was closed. The North Sea fishery reopened in 1983. Fishing for herring is mainly undertaken with purse seines and trawls offshore and to a smaller extent by fixed nets in coastal waters. While North Sea stocks are fished throughout the year, landings are greatest in the third quarter of the year, predominantly from the Orkney/Shetland area, Buchan, northwest of the Dogger Bank and in coastal waters of eastern England.

The other major North Sea pelagic fishery is for mackerel, which supports an extensive, directed fishery by pelagic trawlers in the northern North Sea, taking advantage of the migration of the western stock to this feeding area. This is a very important species for the Scottish fleet, and by weight it is one of the most abundant pelagic species landed. Fishing in the North Sea occurs throughout the year with peak landings in July to September, and moderate levels of fishing activity take place between the Faeroe Islands and the Norwegian coast during the first half of the year.

8.3.5 Shellfisheries

Crustacean fisheries are generally of high value and target specific grounds at different times of the year. A range of gears, such as bottom trawls, prawn trawls, seines, pots and dredges are used in these fisheries. Norway lobster (*Nephrops*) are landed from the north and west of the Dogger Bank, along the northeast coast of England, the eastern coast of Scotland, and on the Fladen ground in the central SEA 2 region. The pink shrimp fishery is also concentrated in the deep muddy areas of the Fladen Ground. The edible crab fishery is an important source of income to UK shellfishers, and the fishery is now conducted throughout the year by many fishermen, supplying both the live continental market and the home processing market. Crabs are captured in traps (pots or creels), which are baited with fresh fish, and larger vessels will work up to 1000 traps. Crab fisheries occur on coarse grounds in coastal UK waters, and in the south these can extend eastwards into the gas fields of the southern SEA 2 region.

Finally, important scallop fisheries occur on suitable sand and gravel sediment around Shetland and Orkney, and along the east coast of Scotland, exploited by vessels using heavy, wide toothed dredges. Most landings are taken from inshore areas, but some grounds are over 60 miles offshore, and can extend into the oil fields in the northern North Sea.

8.3.6 Cephalopod fishery

Cephalopods include squid, octopus and cuttlefish and the main species of economic importance in the SEA 2 areas is the squid, *Loligo forbesi*. The related species, *L. vulgaris,* increases with importance to the south. A review of fisheries statistics indicates that the highest concentrations of squid probably occur outside the SEA 2 areas.

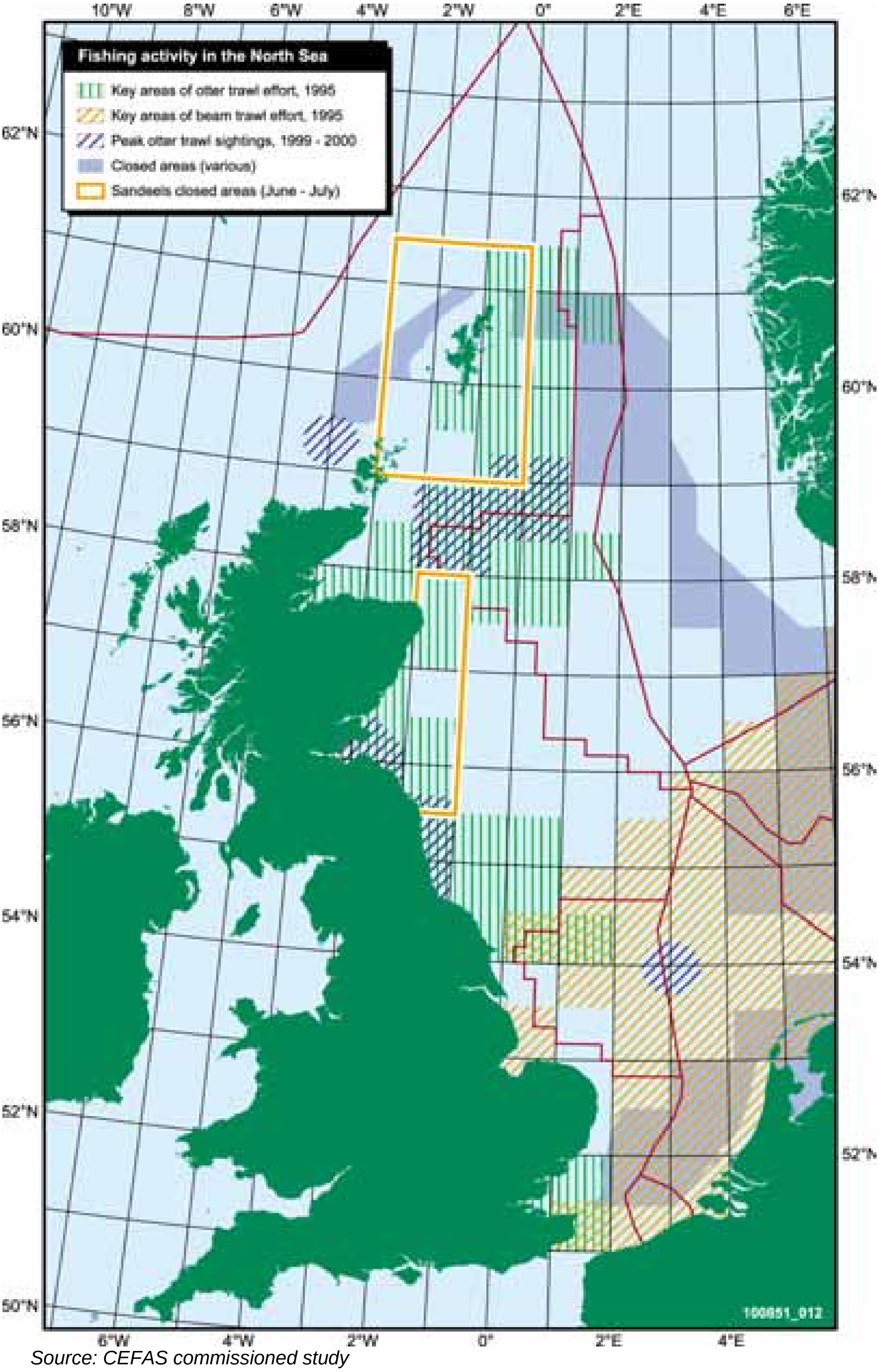
Squid catches tend to be a by-catch of demersal trawl and seine net fisheries, although a limited amount of directed squid fishing does occur close inshore in the Moray Firth. The main Scottish fishery for *L. forbesi* shows a seasonal peak around September to November.

8.3.7 Fisheries management

The effects of these fish and shellfish fisheries are widespread and ecologically important, and the removal of target and non-target species impacts the whole North Sea ecosystem. There is concern about the stocks of herring, cod, haddock, whiting, saithe, plaice and sole which are close to or outside Safe Biological Limits. Catch levels for many fish stocks are almost certainly not sustainable.

To ensure the sustainability and recovery of these fisheries, a range of fisheries management measures have been implemented by the European Commission, including area and seasonal closures that restrict access to specific fleets in order to offer protection to juveniles and spawning adults and encourage stock recovery (Figure 8.3). For example, during spring 2001, a large closed area was implemented in the North Sea which restricted access to cod fisheries. The closure covered the main spawning area and season for mature cod. Similarly, in the southern North Sea a permanently protected area (the plaice box) was established to reduce the mortality of juvenile plaice in the beam trawl fishery.

Figure 8.3 - Fishing activity in the North Sea. Stock management areas are also shown.



Source: CEFAS commissioned study

Sandeel fisheries at Shetland and off the east coast of Scotland are also closed seasonally. Both the cod closure and plaice box have caused the displacement of fishing activity away from traditional grounds and towards the oil and gas fields of the North Sea. For the otter trawl fleet this represents an increase in existing levels of local effort in regions where the two industries already co-exist. There is some evidence of a slight increase in beam trawl activity in the central and northern SEA 2 regions, since the gear was first used in the southern North Sea during the 1960s. This may have implications for the safety of both the fishing vessels and underwater structures associated with the hydrocarbon industry when they come into contact. Some form of spatial exclusion during the spawning season is likely to be retained for both cod and plaice.

8.3.8 Implications for Strategic Environmental Assessment

In conclusion, considerable information is available concerning the intensity and economic importance of fisheries within SEA 2 areas of the North Sea. The accuracy of the reported landings of commercial species is a source of considerable debate in the UK and Europe, and is governed by a number of complex and interrelated factors (CEFAS commissioned study). Firstly, the catches of species that are controlled by quota management may be under-reported or mis-reported by area so that a fishery does not exceed its quota in a particular year. Secondly, those species which are not controlled by quotas may be under-reported because there is no legal requirement to record landings, or several species may be grouped together as historically there was little interest in collecting data by species. However, these concerns apply principally to the reliability of stock assessments and are not considered to represent a data gap in terms of assessment of the potential effects of licensing.

Potential interactions between fisheries and exploration and production activities are considered in Section 10.

8.4 Other uses of the marine environment

8.4.1 Introduction

A synthesis of human activities in the North Sea has been compiled by Cordah. The report provides information on shipping, energy, telecommunications, military and ordnance disposal sites, waste disposal sites, dredging and aggregate extraction, marine archaeological sites and wrecks. Various sources of information have been used including published charts and literature, UK Hydrographic Office, Ministry of Defence and COAST (a database containing information on shipping routes).

8.4.2 Shipping

Some of the busiest shipping lanes in the world are found in the North Sea. The central and northern North Sea have relatively moderate traffic with an average of 1 to 10 vessels passing through each route per day. The southern North Sea is busier, with a number of international ports (including Rotterdam) located in this region. This area sees a high number of oil tankers, cargo vessels and ferries passing through.

8.4.3 Cables

In addition to the oil and gas infrastructure, there are presently 10 operational telecommunications cables which cross the SEA 2 areas. There has been a rising demand for telecommunications cable capacity with the increase in the use of the Internet and the growth in e-commerce which may lead to further cables being installed in the future.

8.4.4 Military exercise areas

Areas of the North Sea are used as military exercise areas for the countries bordering the sea. There are four charted areas within the SEA 2 areas designated for UK military use.

8.4.5 Disposal sites

Several licensed waste disposal sites are located in the North Sea for the disposal of dredged material, industrial waste and until the end of 1998, sewage, when an OSPAR agreement to cease such dumping came into effect. The majority of the sites were used for the disposal of dredging waste, primarily from navigation channels and coastal construction. These sites are all in coastal waters.

There are no recorded historic ordnance disposal sites in the SEA 2 areas.

8.4.6 Aggregate extraction

Marine aggregate extraction occurs at licensed areas in the North Sea. The main region in the North Sea is the Humber Region and some of these sites fall within the SEA 2 area. No maintenance dredging is undertaken in the SEA 2 areas.

8.4.7 Wrecks

There are numerous wrecks within the SEA 2 areas although only a proportion of these are charted. Records from the UK Hydrographic Office reveal 1,157 confirmed wrecks within the SEA 2 area, the majority in the central and southern areas. In addition, records of non-wreck debris (lost cargoes, anchors, cables, large boulders) indicate 151 items within the area. Historic wrecks are protected under the Protection of Wrecks Act, 1973. There are 46 in the North Sea and although none lie in the SEA 2 areas, two are located close of the western boundary of the northern North Sea area.

8.4.8 Other energy

With increasing pressure to increase renewable energy, sources of power are being examined (none of these are within the SEA 2 areas). In future, renewable sources of energy from the North Sea could be obtained from wind, wave and tidal power.

8.4.9 Implications for Strategic Environmental Assessment

In conclusion, available information concerning other users of the marine environment within SEA 2 areas is adequate to support assessment of the potential effects of licensing. Potential interactions between other users and exploration and production activities are considered in Section 10.

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9 COASTAL RESOURCES POTENTIALLY RELEVANT TO THE SEA 2 AREAS

9.1 Introduction

The following sections provide an overview of coastal conservation, economic and other human interests in the coastal areas most at risk should an environmental incident occur in the SEA 2 areas. Areas of particular interest for their bird life are designated as Special Protection Areas and Ramsar sites. These are explained in more detail below, but Table 9.7 at the end of this section provides a complete listing of sites located along the North Sea coastline.

9.2 Northern and eastern Scotland

9.2.1 Overview

The nearest westward landfall from the SEA 2 areas of the northern North Sea and central North Sea are the islands of Shetland and Orkney, and the east coast of the mainland of Scotland.

The northern isles of Shetland and Orkney, with their many islands and skerries, have more than 2,000km of coastline. The Islands are characterised by a highly indented coastline with sheltered inlets as well as very exposed headlands. The result is a natural environment of contrasts which include cliffs, stacks, caves, and current swept channels between the islands, as well as voes, brackish tidal ponds, sand dunes, shingle beaches, and a few small areas of mud and sandflats. Shetland, in particular, has many kilometres of cliffs and their extensive use by breeding seabirds means that a large number are of international importance. Its shingle shorelines with features such as tombolos, spits and barriers are of particular geomorphological importance. Orkney has important areas of sand dunes with species-rich grazed dune grassland as well as wet dune vegetation. Its shingle beaches are important for migrant and wintering waders (Barne *et al.* 1997a & b).

The nearshore waters around Shetland and Orkney are used extensively by both common and grey seals as well as having some of the richest cetacean fauna around the coast of the UK. Eighteen species of cetacean have been recorded around the Shetland islands since 1980 and eight of these are either present throughout the year or are recorded annually. Otters also frequent the coast as well as the inland waters on many of the islands.

The east coast of mainland Scotland is dominated by the large embayment of the Moray Firth, but also has extensive stretches of open coastline and the estuaries of the inner Moray Firth, Dornoch Firth, Cromarty Firth, Firth of Tay and Firth of Forth. The sheltered shorelines of the firths, with their saltmarshes, sand dunes, mudflats and sandflats, support internationally important numbers of wintering waterfowl, while the non-estuarine shores have nationally and internationally important examples of sea cliffs, sand dunes and shingle structures. The scenery of the open coast is one of cliffs, rocky shores, sand dunes and shingle shores which support some rich vegetation types and are used by seabirds as well as waders and wildfowl. The adjacent waters support seal colonies as well as cetaceans, the best known of which are the resident bottlenose dolphin population of the Moray Firth.

9.2.2 Nature, landscape and heritage conservation

The impressive landscapes and significant wildlife interest of these parts of the Scottish coastline has led to the establishment of international, European and nationally recognised conservation areas.

The principal European designations are SPAs established under the 1979 EC Directive on the Conservation of Wild Birds, and SACs under the 1992 EC Habitats & Species Directive. Current SPAs along these coasts are listed in Table 9.1 but it should be noted that the Joint Nature Conservation Committee are reviewing this list at the present time.

Table 9.1 - Sites of international importance for birds in Scotland

Area	Site	Status	Conservation Interest
Shetland	Hermaness & Saxa Vord	**SPA**	Breeding seabirds
	Fetlar	**SPA**	Breeding seabirds and waders
	North Roe & Tingon	**SPA & Ramsar**	Great Skua
	Noss	**SPA**	Breeding seabirds
	Mousa	**SPA**	Breeding seabirds
	Sumburgh Head	**SPA**	Breeding seabirds
	Ramna Stacks & Gruney	**SPA**	Breeding seabirds
	Foula	**SPA**	Breeding seabirds
	Fair Isle	**SPA**	Breeding & migratory seabirds, endemic population of Fair isle wren
Orkney	Papa Westray	**SPA**	Breeding seabirds
	West Westray	**SPA**	Breeding seabirds
	Eday	**SPA**	Breeding seabirds
	East Sanday	**SPA & Ramsar**	Wintering and breeding waders
	Copinsay	**SPA**	Breeding seabirds
	Marwick Head	**SPA**	Breeding seabirds
	Sule Skerry & Sule Stack	**SPA**	Breeding seabirds
	Auskerry	**SPA**	Breeding seabirds
	Pentland Firth Islands	**SPA**	Breeding seabirds
NE Scot	Caithness cliffs	**SPA**	Breeding seabirds
	Moray Basin, firths & bays	**SPA & Ramsar**	Wintering and passage wildfowl
	Troup, Pennan & Lion Heads	**SPA**	Breeding seabirds & waterbirds
	Loch of Strathbeg	**SPA & Ramsar**	Wildfowl and wintering waterfowl
	Buchan Ness to Collieston coast	**SPA**	Breeding seabirds & waterbirds
	Ythan estuary, Sands of Forvie & Meikle Loch	**Ramsar**	Breeding seabirds and wintering waterbirds
	Fowlsheugh	**SPA**	Breeding seabirds & waterbirds
SE Scot	Montrose Basin	**SPA & Ramsar**	Wintering Waterfowl
	Firth of Tay	**SPA**	Wintering & passage, wildfowl & waders
	Eden estuary, Tentsmuir Pt & Aberlay Sands	**SPA**	Wintering waders & wildfowl
	Firth of Forth Islands	**SPA**	Breeding seabirds
	St.Abbs Head to Fast Castle	**SPA**	Breeding seabirds

Coastal Special Protection Areas established under the EU Birds Directive and Wetlands of International Importance (Ramsar sites)

They are also investigating the possibility of boundary changes to include sea areas adjacent to breeding colonies and marine offshore SACs and SPAs. The seas around the Shetland and Orkney Islands and north east Scotland have been ranked as the second and third most important areas for seabirds in the North Sea (based on the number of species occurring in the area at internationally important levels) and may therefore include some offshore SPAs in the future.

SACs are a more recent initiative, hence their status as candidate sites at the present time. Nevertheless, UK Government policy is that they should be treated as designated sites once the details are registered with the European Commission. There are 9 marine SACs along this section of Scottish coast and 16 coastal SACs (Table 9.2). The reasons for designation are being reviewed as part of a moderation process undertaken by the European Commission and may therefore be amended. There is also the possibility that further sites will be added to the list.

Table 9.2 – Other sites of international importance on the east coast of Scotland

Area	Site	Conservation Interest
Shetland	Keen of Hamar	Grasslands, Eutric scree
	Hascosay	Active blanket bog
	Mousa	Common seal
	The Vadills	Lagoons
	Papa Stour	Reefs, sea caves
	Ronas Hill-North Roe	Alpine & subalpine heaths, active blanket bog
	Tingon	Blanket bog
Orkney	Loch of Stenness	Lagoons
	Stromness Heaths & Coast	Dry heaths, vegetated sea cliffs
	Hoy	Alpine & subalpine heaths, wet heaths
NE Scot	Invernaver	Decalcified dunes
	Dornoch Firth & Morrich More	Atlantic salt meadows, decalcified fixed dunes, dune slacks, shifting dunes
	Conon Islands	Residual alluvial forests
	Moray Firth	Bottlenose dolphin
	Culbin Bar	Vegetation of stony banks
	Lower River Spey/Spey Bay	Vegetation of stony banks
	Sands of Forvie	Dune habitats
SE Scot	Barry Links	Dune habitats
	Berwickshire & N.Northumberland coast	Grey seal, mudflats & sandflats, reefs, sea caves

Coastal and Marine Special Areas of Conservation established under the EU Habitats & Species Directive

National conservation designations provide the underpinning protection for most of the European sites, as well as safeguarding sites of national importance. These sites are either National Nature Reserves (which extend to Mean Low Water Springs) or Sites of Special Scientific Interest (SSSIs) that have been designated for geological, botanical, entomological, ornithological and/or marine biological interest.

The nature conservation importance of coastal waters around Scotland have also been recognised by the identification of Marine Consultation Areas. These are sites “considered to be of particular distinction in respect of the quality and sensitivity of their marine environment”. Whilst not a statutory designation, Scottish Natural Heritage wish to be consulted over proposals for developments at these sites which are located on the

Berwickshire coast and four of the sheltered inlets of Shetland (in addition to north and west coast sites).

Landscape conservation is recognised at a European level by the identification of Environmentally Sensitive Areas (ESAs) which have the restoration of traditional landscapes as one of its objectives. National recognition is given through the definition of National Scenic Areas (NSA) and Regional Landscape Designations (RLD). The whole of Shetland is an ESA and there is one NSA which covers Foula, Fair Isle and most of the south west coast of mainland Shetland as well as parts of some of the other islands. Most of Orkney is covered by Regional Landscape Designations and the west coast has NSA status. Landscape designations on the east coast of Scotland are a NSA at Dornoch Firth and RLDs around the Montrose basin, the Fife coast and the Borders.

Archaeological evidence of human settlement on the east coast of Scotland and the Northern Isles goes back many thousands of years. There are more than 1,000 Scheduled Ancient Monuments at the coast as well as archaeological evidence in the intertidal zone and nearshore waters. There are a considerable number of shipwrecks in these waters, particularly around Shetland and Orkney, and several historic wrecks that are designated under the Protection of Wrecks Act, 1973. The large number of shipwrecks in Scapa Flow are the result of military activity in both the First and Second World Wars and some are war graves protected under the Protection of Military Remains Act 1986.

9.2.3 Coastal uses

The coastal environment of the Northern Isles and the east coast of Scotland is of considerable economic importance. The major centres of population are concentrated in the sheltered areas of the firths. Apart from the capital, Edinburgh, and the large cities such as Dundee, Aberdeen and Inverness there are numerous towns and small settlements along both the mainland and island coastlines.

9.2.3.1 Tourism and leisure

Tourism and leisure activities are major activities along the coast. In the Northern Isles the outdoor environment with its dramatic scenery, abundant wildlife and considerable historic interest is a major attraction. Visitors come to view the seabird colonies and the archaeological sites, to walk the coast, to sail in the surrounding waters and to take part in activities such as golf, sea angling, wildfowling and watersports. Caravan and camping sites, marinas, harbours and golf courses support these activities. Annual visitor numbers for Orkney are regularly above 100,000.

All of these tourism and leisure activities also take place on the east coast of mainland Scotland although the emphasis may be different. Golf is particularly popular, encouraged by the many international standard golf courses on the coast. Camping and caravan parks, golf courses, car parks, and coastal footpaths are some of the land-based infrastructures supporting these activities. Much is concentrated on the more sheltered firths with the Moray Firth a focus for watersports. Facilities can be found at North Kessock, Inverness, Nairn, Findhorn, Findochty, Peterhead and Stonehaven amongst others. Waterfront developments, like those at Leith Docks in Edinburgh and Dundee, attract people to the cities, although the small fishing ports are also an attraction for visitors.

9.2.3.2 Commercial fisheries and aquaculture

Fishing has long been an economically important activity for coastal communities on the Islands and east coast of Scotland, with the area being of national importance for both offshore and inshore fisheries and the associated fish processing industries. This is reflected in the landings statistics with the ports of Peterhead, Lerwick, Aberdeen and Fraserburgh regularly in the top 10 ports for tonnage of fish landed in the UK. In 1999, 98,496 tonnes were landed at Peterhead, with 72,651 tonnes at Lerwick, the major port in Shetland. Fish caught around Orkney tend to be landed directly to processors on the mainland with the largest landings at Scrabster. While all areas have landings of pelagic, demersal and shellfish species, the emphasis varies from place to place. Mackerel and herring caught by purse seiners and pelagic trawlers are by far the largest component of the landings in Shetland. These species are also caught by the east coast fleets but they also target cod, haddock, whiting and saithe using trawls and seine nets. The major shellfisheries are for *Nephrops* and scallops.

In addition to the large vessels, there are creel boats, some of which are launched from beaches, that work inshore setting pots on a seasonal basis to catch edible and velvet crabs, lobsters and squat lobsters. The east coast of Scotland is famous for wild salmon and sea trout which are taken in the rivers as well as netting stations along the coast.

Aquaculture is a major industry in Scotland having developed since the early 1980's. The sheltered inlets of Orkney and Shetland are the most attractive locations in the region for this activity and the majority of the suitable locations have some facilities. The Atlantic salmon is the most widely cultivated species but there are also commercial operations farming sea trout, turbot and halibut. Shellfish farming is mostly concerned with the edible mussel, native and pacific oysters, scallops and queen scallops, which are grown on rafts or in suspended bags and cages on the seabed.

9.2.3.3 Ports and shipping

The firths and inlets on both mainland Scotland and the islands have provided a natural focus for port and harbour developments. Much of the activity used to be centred around fishing, but nowadays they have a much broader function, supporting the movement of oil-related cargos, ferry traffic, container-based trade and cruise liners. The large volume of trade handled by some of the ports, such as Lerwick on Shetland, Kirkwall on Orkney and Peterhead on the east coast of Scotland make these some of the most important ports in the UK. Smaller scale traffic between the many islands of Shetland and Orkney also provide a vital service in the movement of provisions, livestock and the local population. On the mainland there is considerable shipping movement in the Firth of Forth which has many small harbours, mostly used by recreational craft, as well as the large ports of Grangemouth and Leith and the naval docks at Rosyth.

Given the large number of vessels using these waters, the potentially hazardous cargos being transported and the likelihood of severe weather conditions in some difficult waters, a variety of management measures have been introduced to minimise the risk of shipping accidents. These include Areas To Be Avoided, Precautionary Areas and Traffic Separation Schemes. Discussions are underway about the identification of Marine Environmental High Risk Areas with the waters around Shetland one of the sites under consideration.

9.2.3.4 Energy industries

Oil and gas related industries are of major importance to the economy of the region. Both Shetland and Orkney have major facilities for transhipment at Sullom Voe and Flotta. They support production from fields that lie to the east and west of the islands. Production platforms in the Beatrice field are the most inshore in the North Sea at present and are visible from the shore.

There are also oil and gas related facilities on the east coast of Scotland. In the Inner Moray Firth the Nigg terminal receives oil from the Beatrice field and elsewhere in the North Sea and the Cromarty Firth is used for oil rig construction, conversion, inspection and repair, as well as oil field support. Other terminals on the mainland can be found at St Fergus and Kinneil on the Firth of Forth.

9.3 Northern and eastern England

9.3.1 Overview

The coastline of eastern England is mostly low-lying with estuaries characterising this coast particular in the central and southern sections where the Humber, the Wash, the Thames, the Tyne, and the Tees, as well as numerous smaller estuaries along the coasts of Suffolk and Essex fringe the North Sea. These estuaries include extensive areas of intertidal mud and sandflats, which are important feeding grounds for waders and wildfowl, as well as nursery areas for juvenile fish. At Maplin, deposition of sediment has created the largest single unit of continuous intertidal flat on the British coast and possibly Europe. The estuaries are also fringed by extensive areas of saltmarsh including some that are considered to be the finest in Britain and among the best in Europe. Other coastal habitats include the sand dunes, shingle shores and brackish lagoons, such as Salthouse Broad, which is one of a series of lagoons behind the Blakeney and Scolt Head Island spits on the north Norfolk coast. Cliff coastline is also present in certain sections. At Flamborough Head and along the Thanet coast these cliffs form the most extensive chalk exposures in northern Europe, while soft cliffs back the sandy shores in other places.

The Farne Islands are the main group of islands off Eastern England, consisting of more than 20 small islands and rocky outcrops between 2-6km offshore. They support the largest colony of grey seals in England with numbers estimated to be around 2,800 in 1999. The shallow sandbanks in the area of the Wash are more favourable for common seals, also the largest population in England with numbers estimated to be nearly 2,400 in 1999 out of around 3,600 for the entire coast of eastern England. The low-lying island of Lindisfarne, just north of the Farne Islands, encloses extensive mud and sandflats between it and the mainland with large beds of eelgrass on the intertidal areas.

9.3.2 Nature, landscape and heritage conservation

The nature conservation importance of the coast of Eastern England is acknowledged through the designation of international, European and nationally recognised conservation areas. The coastline has numerous Special Protection Areas (SPAs) established under the 1979 EC Directive on the Conservation of Wild Birds and candidate Special Areas of Conservation (SACs) under the 1992 EC Habitats & Species Directive (Table 9.3).

SACs are a more recent initiative, hence their status as candidate sites at the present time. Nevertheless, UK Government policy is that they should be treated as designated sites once the details are registered with the European Commission. There are eight marine SACs along this section of the English coast (Table 9.4). The reasons for designation are being reviewed as part of a moderation process undertaken by the European Commission and the list may therefore be amended. Sites such as the Humber estuary have been proposed as part of this process and there remains the possibility that further sites will be added to the list.

Table 9.3: Sites of international importance for birds in eastern England

Site	Status	Conservation Interest
Thanet coast & Sandwich Bay	SPA & Ramsar	Wintering & passage waders
The Swale	SPA & Ramsar	Wintering wildfowl
Medway estuary & marshes	SPA & Ramsar	Wintering & passage wildfowl
Thames estuary & marshes	Ramsar	Waders & wildfowl
Benfleet & Southend marshes	SPA & Ramsar	Wintering geese & waders
Mid-Essex coast	SPA & Ramsar	Wintering & passage waders & wildfowl, and breeding terns
Hamford water	SPA & Ramsar	Wintering waders & wildfowl, and breeding terns.
Alde/Ore estuary	SPA & Ramsar	Breeding & wintering waterbirds
Stour & Orwell estuary	SPA & Ramsar	Wintering waders & wildfowl
Deben estuary	SPA & Ramsar	Wintering wildfowl & waders
Minsmere-Walberswick	SPA & Ramsar	Breeding, wintering and passage species
Benacre to Easton Bavents	SPA	Diverse assemblage of breeding & wintering species
Breydon Water	SPA & Ramsar	Wintering & passage wildfowl & waders
Great Yarmouth North Denes	SPA	Little tern
North Norfolk coast	SPA & Ramsar	Breeding species, wintering wildfowl and migrating waders.
The Wash	SPA & Ramsar	Passage & wintering waders & wildfowl
Gibralter Point	Ramsar	
Humber flats, marshes & coast	SPA & Ramsar	Breeding raptors and waders, and wintering wildfowl and waders.
Horsea Mere	SPA	Breeding & wintering wetland birds
Flamborough Head & Bempton Cliffs	SPA	Breeding seabirds and waterbirds
Teesmouth & Cleveland coast	SPA & Ramsar	Breeding terns & wintering wildfowl
Coquet Island	SPA	Breeding seabirds
Northumbria coast	Ramsar	Breeding terns and wintering waders
Farne Islands	SPA	Breeding seabirds & waterbirds
Lindisfarne	SPA & Ramsar	Breeding terns & wintering wildfowl

Coastal Special Protection Areas established under the EU Birds Directive and Wetlands of International Importance (Ramsar sites)

Table 9.4 – Other sites of international importance in eastern England

Site	Marine Conservation Interest
Berwickshire & N.Northumberland coast	Mudflats, reefs, caves, grey seal
Flamborough Head	Reefs, caves
The Wash & N.Norfolk coast	Sandflats, mudflats, inlets, common seal
N.Norfolk coast & Gibraltar Point Dunes	Lagoons
Benacre to Easton Bavents	Lagoons
Orfordness-Shingle Street	Lagoons
Essex estuaries	Estuaries, mudflats
Thanet coast	Reefs, caves

Candidate Marine Special Areas of Conservation that have been proposed under the EU Habitats & Species Directive

National conservation designations provide the underpinning protection for most of the European sites, as well as safeguarding sites of national importance. These sites are National Nature Reserves (which extend to MLWS) or Sites of Special Scientific Interest (SSSIs) that have been designated for geological, botanical, entomological, ornithological and/or marine biological interest.

The nature conservation importance of coastal waters around England have also been recognised through the identification of Sensitive Marine Areas. These areas were identified by English Nature in the early 1990's "to trigger interest and awareness of important wildlife areas and to stimulate discussion of management issues". Twenty-seven of these nationally important marine wildlife areas were identified around England, seven of which are on the east coast of England. They are Holy Island & the Farnes, Robin Hood's Bay and associated coast, Flamborough Head, The Wash & North Norfolk, Orfordness, Colne/Blackwater to Maplin Sands and the Thanet coast.

The landscape value has also been recognised with the designation of sections of coast as Heritage Coast extending along nearly 300km of the coastlines of Northumberland, Yorkshire, Humberside, Norfolk, Suffolk and Kent; as Areas of Outstanding Natural Beauty along more than 200 kms of Northumberland, Norfolk, Suffolk and Kent coasts; and the North York Moors National Park which abuts around 42km of coast.

There are numerous sites of heritage importance along this coast dating from the Neolithic period to the Second World War. They include "Woodhenge", a possible ritual site off the Norfolk coast, medieval buildings such as Bamburgh castle (which is a Grade I listed building as well as a Scheduled Ancient Monument), the remains of a major medieval port at Boston in Lincolnshire, the sites of Roman military signal stations, shipwrecks and defences from both World Wars. Early Christian settlements include significant sites such as Lindisfarne and the Abbey at Whitby. Evidence of mans activity from the industrial period can also be seen along the NE coast and include alum works along the Yorkshire coast and the 18th port associated with them.

Coastal erosion is both revealing settlements as well as destroying known sites. At Spurn Head the coastline is known to have been more than 1km further offshore during the Roman period while remains of Saxon settlements were only found on the headland at Whitby earlier this year. These two examples also emphasise that there is undoubtedly much more to be discovered about the heritage importance of the coast of eastern England.

9.3.3 Coastal uses

The major centres of population and commerce along the coast of eastern England include the capital city London, and large cities such as Newcastle, Hull, and Norwich, as well as numerous towns. There are also sections of relatively undeveloped coast which provide a contrast and a focus for other coastal uses.

9.3.3.1 Tourism and leisure

The varied attractions of the east coast of England support a significant tourism and leisure industry. In terms of outdoor attractions the Norfolk Broads are especially popular because of the opportunities for boating along its sheltered waterways. East coast beaches are also used extensively for leisure activities and have supported the growth of seaside towns such as Southend and Scarborough. Small fishing villages such as Seahouses, in Northumberland and Robin Hoods Bay on the Yorkshire coast are more likely to be supported by visitors rather than the fishing industry these days. Cultural heritage, even on a small scale is also an attraction. The lighthouse at St Mary's Island on the north Tyneside coast is an example which attracts around 100,000 visitors a year to the museum, interpretation and education centre. The island is also the only voluntary marine conservation area in north east England.

9.3.3.2 Commercial fisheries

The east coast of England acts as a base for both offshore and inshore fisheries. Hull is the most important centre in terms of landings as well as seafood processing, much of which takes place in the north-east. Whitby, Scarborough, Bridlington, Grimsby and Lowestoft are the other significant areas for fish landings, the majority of which are demersal fish with the exception of Bridlington where about half the landings are from shellfish, particularly whelks, crabs and lobsters.

Vessels also operate from many smaller bases with traditional ‘cobles’ being used out of places like Craster, Newton and Newbiggin on the Northumberland coast and beach boats (known locally as longshore boats) operating off the Lincolnshore and north Norfolk coast. This area is important for mussels, cockles and oysters with the nearshore areas supporting crab, lobster and whelk fisheries. The Wash, was historically important for eels, shrimps, oysters, smelt and anchovies, while today the catch is mainly cockles, mussels and pink and brown shrimps.

Other more fundamental changes in the scale and target of the North Sea fisheries operating out of these ports have also taken place. The most memorable is perhaps the herring drift net fishery of the 19^{th} and early 20^{th} centuries which supported many North Sea towns but which has since gone into decline.

9.3.3.3 Ports and shipping

The east coast has some of the UK’s largest ports taking advantage of their location to trade with mainland Europe and Scandinavia as well as other parts of the world.

The Port of London, which covers the tidal Thames from Teddington to the outer Thames, a distance of 155 km, has more than 100 wharves and terminals and includes the Port of Tilbury complex as well as the Shellhaven oil terminal. Trade in non-fuel traffic includes significant volumes of aggregates, unitised cargo, timber, cereals, iron and steel, coal, paper and sugar. Cruise liners are also catered for with the London International Cruise terminal at Tilbury. Felixstowe and Harwich are also important east coast ports.

Further north, the ports of Grimsby and Immingham on the south bank of the Humber handled just over 47 million tonnes of cargo in 1999. Grimsby has developed into northern Britain’s major vehicle-handling centre while Immingham handles more dry-bulk cargoes than any other UK port. It is also one of the largest steel-handling ports in the country.

9.3.3.4 Energy industries

The offshore gas fields of the southern North Sea are the main focus of the energy industries off the east coast of England but there are more recent developments as well. Energy generation from offshore wind farms, although at an early stage of development, has gathered pace in recent years. The first offshore wind turbines were commissioned off Blyth on the Northumberland coast in 2000. The Crown Estate has since invited options for areas of seabed up to $10km^2$ for the construction of further wind farms. Options have been submitted for 13 locations around the coastline of England and Wales, six of which would lie off the east coast of England (off the northeast coast around Teesmouth and Redcar, the

Lincolnshire coast near Ingoldmells, Foulness, Caister, Clacton-on-Sea and Whitstable/Herne Bay).

9.4 South-western Norway

9.4.1 Overview

The nearest eastward landfall from the SEA 2 areas of the Northern North Sea and Central North Sea is the south-western coast of Norway. This section of coast is covered by the four counties of Rogaland in the south, Hordaland, Sogn og Fjordane and Møre og Romsdal.

The coastal scenery is dominated by the numerous fjords and valleys cutting inland to the mountains. At the coast there are a large number of skerries and island groups, particularly off Møre og Romsdal. On the mainland coast raised beaches and sand dune systems grade into wetlands and coastal meadows. The largest fjord on this section of coast is Sognefjorden, which is also the longest fjord in the country, extending inland for 204km to the mountains of Jotuneheimen. Other major fjords are Lysefjorden with Stavanger at its gateway, Hardangerfjorden, Sognefjorden, Nordfjord, Storfjorden, Moldefjorden and Tingvollfjorden with the city of Kristiansund at its entrance.

An assessment carried out in 1998 revealed that 34% of southern and central Norway could be classified as being more than 1km away from major infrastructure development. This was a reduction of 4% since 1988, revealing a pattern of gradual development which is not just typical of this area but also other parts of Norway. A small but significant part of the land area of southern and central Norway (5.1%) was more than 5km from major infrastructure development and therefore considered to be “wilderness-like”.

9.4.2 Nature, landscape and heritage conservation

Four types of protected area can be established under Norwegian conservation legislation at the present time, all of which are found in south-western Norway. The most numerous are Nature Reserves with several hundred on the islands, fjords, open coast and adjacent land. The region of Møre og Romsdal is most significant for areas of Biotope Protection with 12 sites having this status along its coast. The island of Runde, offshore from Ålesund, can also be found in this county. It supports around 170,000 pairs of breeding seabirds making it the third largest seabird cliff nesting site in Norway.

Most of Norway’s National Parks and Landscape Protected Areas are found inland but they do extend to the shore around Sauda at the innermost extent of Lysefjorden on the south shores of the Sognefjorden west of Vanganes, and adjacent to part of the inland reaches of the Tingvollfjorden near Sunndalsøra. The country also has several Important Bird Areas (IBAs) along this section of coast (Table 9.5) and a number of Wetlands of International Importance that have been defined under the Ramsar Convention (Table 9.6).

Table 9.5 - Important Bird Areas (IBAs) on the coasts of south western Norway that fulfil criteria for their global or European importance (categories A & B)

Area	Site	Area (ha)
Møre og Romsdal	Gaulosen	20,000
	Runde	640
	Skejnøy, South Skerries	100
Rogaland	Kjørholmane seabird reserve	600
	Vorma-Andelva	40
	Lake Styorsjøen	4,400
	Nordre Øyeren and Sørumsneset	7,504
	Lake Hemnessjøen	160

Source: Heath & Evans 2000

Table 9.6 - Wetlands of international importance (Ramsar sites) in south-western Norway

Area	Site	Status	Conservation Interest
Møre og Romsdal	Mellandsvågen	Ramsar + Nature Reserve	Coastal fjordic wetland. Feeding & resting site for migratory and wintering birds.
	Sandblåst/Gaustadvågen	Ramsar + Nature Reserve	Estuarine system at the end of a coastal plain. Large numbers of migrating and wintering birds.
	Harøya wetlands system	Ramsar + 4 Nature Reserves	Bays, mud and sandflats, sand dune systems wet meadows. Important for wintering and migrating waterbirds as well as a breeding site for many species.
	Giske Wetlands System	Ramsar + 6 Nature Reserves	Bays, mud & sandflats, pebble shores, dunes and wet meadows. Important for migratory and wintering birds. Breeding site for globally threatened corncrake, *Crex crex*.
Rogaland	Jæren Wetland system	Ramsar	Shallow wetland system important resting sites for ducks, swans and waders during migration. Most important waterbird wintering site in southwest Norway. Several nationally threatened species breed and rest in the area.

A programme of work on Marine Protected Areas carried out in 1996 identified a number of sites of marine biological value that are examples of areas worthy of protection in a Nordic context. Twelve of these sites were in Norway, four of which are on the south-west coast (Framvaren, Lindespollene, Utvær/Indrevær and Skorpo/Nerlandsøy). A more recent development has been the identification of 41 potential Marine Protected Areas as part of a national conservation programme. Fifteen of these are on the south-west coast of which five have been identified as possible "transect sites" that may extend offshore to cover a range of marine habitat types out from the coast. An expert working group, appointed by the

Norwegian government, will be reviewing this list as part of their work to draw up a marine conservation plan for the country by 2004.

At the present time, the only area in Norway that is protected specifically because of its marine life are the Froan Skerries. These lie beyond the islands of Froya and Hitra at the entrance to Trondheimfjord and are an archipelago of shallow water dotted with hundreds of rocky islands and skerries. Forty-six species of birds nest in the area including shag, cormorant, black guillemot and kittiwake. It is also important as a wintering site for birds and nationally important for the large numbers of common and grey seals that use the area.

The importance of Norway's coastal culture and maritime history has been recognised but is not, as yet, reflected in the number of protected sites and monuments in the country. Two projects have therefore been set up to target the conservation of coastal heritage. The first concerns the Conservation of Monuments and Sites along the Coast and the second is the Lighthouse Preservation Plan.

Work on the Conservation of Monuments and Sites along the Coast was initiated to protect a representative selection of the coastal environments and to combine protection orders with restoration and plans for new use of the environments if necessary. The project is limited to the monuments and sites that are connected with everyday life and activities along the coast. All the Norwegian counties, including the four in south-western Norway, are participating in the project.

The Lighthouse Preservation Plan was set up in response to the deterioration of many of the country's old lighthouses that have been replaced by unmanned facilities. The plan has been drawn up to protect a representative sample of these features. Twenty-seven of these are on the coast of south-western Norway. The protection of underwater cultural heritage is less advanced, however, the Directorate for Cultural Heritage has started to define priority areas that will be investigated.

Norway has four cultural heritage sites that have international recognition under the UNESCO World Heritage Convention. The old wharf in Bergen (Bryggen) that was the centre of international commercial activity, with each property having its own dock area and store house, is the only coastal example.

9.4.3 Coastal uses

The Norwegian economy is inextricably linked to its coastal and marine resources and this is reflected in the activities and uses of the coast and waters of south-western Norway. Major hubs of activity can be found at Bergen, the second largest city in Norway, with a population of just over 227,000 in 1999, and Stavanger, which has a population of around 108,000. The main coastal towns along this part of the coast are at Ålesund, Molde and Kristiansund but there are also many smaller villages. All take advantage of the fact that the Gulf Stream keeps the seaward harbours ice-free in winter. Along the south and west coast most industries are in the innermost part of the fjords.

9.4.3.1 Tourism and leisure

Given its dramatic scenery, it is hardly surprising that outdoor recreation is central to leisure activities in Norway. For the local population walking, sunbathing, cycling, swimming, sailing, mountaineering, skiing, white-water canoeing, and fishing for wild salmon and sea trout are all popular. Visitors enjoy the same activities as well as supporting a thriving cruise ship and leisure craft business. These take people on short journeys up some of the fjords as well as on longer trips along the coast and up to the Arctic Circle. The many sheltered harbours provide ideal stopping off points and towns such as Haugesund and Florø provide berthing facilities for many small craft.

Bergen is an important urban centre of the tourist industry in southern Norway. The remains of the first city with its wharf and preserved wooden houses have made it a UNESCO World Heritage Site. The waterfront is a particular attraction. Maritime heritage is also an attraction elsewhere from the canneries at Stavanger that show the importance of the sardine industry in the 19th century to the old fishing and shipping centre of Haugesund which is a busy seaway today between Stavanger and Bergen and to the islands.

9.4.3.2 Fisheries and aquaculture

The produce of the fisheries and aquaculture industries of Norway are the country's second largest export, going to more than 150 countries around the world. The city of Kristiansund, for example, has been a centre for the export of Norwegian dried cod for some 300 years. Ålesund in Møre og Romsdal is the country's biggest fishing community both for offshore fishing as well as fish farming and associated processing industries.

More than 2.6 million tons of fish were landed in 1999 and the value of these exports amounted to 3.3 billion US$ of which export of farmed salmon and trout accounted for 1.9 billion US$. Fish are landed by anything from one-man sjarks (small inshore fishing vessels) to large trawlers and purse seiners. Cod, mackerel and herring are also landed by foreign fleets for processing in Norway.

The onshore component of the industry consists of many small and medium sized companies spread up and down the coast. Over the past 20 years the number of fish processing companies has declined from 860 to about 500. In the year 2000 there were 12 herring meal and oil plants along the coast. Much of their yield is fish meal used for fish farming.

Fish farming takes place at over 3,000 sites spread along the entire coast of Norway. The industry employs more than 21,300 people in the fishing fleet, 12,500 in the fish processing industry and over 3,700 in farming of fish and shellfish. The south-west makes a major contribution to the aquaculture industry with its sheltered inlets making the area particularly well suited to fish farming. The industry is dominated by production of Atlantic salmon and secondly, trout. Other species, which are more at a developmental stage, are halibut, Atlantic wolf-fish and cod. New methods of fish rearing, such as ranching rather than enclosing the fish in pens, are also being investigated.

Figures for farmed Atlantic salmon production in 1999 for the four counties of south-western Norway were 16,989 tonnes for Rogaland, 92,737 for Hordaland, 36,907 in Sogn og Fjordan and 35,801 for Møre og Romsdal. Hordaland accounts for the largest production of farmed salmon in Norway and Møre og Romsdal for sea trout, with 1999 production figures of 18,519 tonnes.

Kelp, *Laminaria hyperborea*, is also harvested for the chemical industry in southern Norway from Lista in the south to a little north of Trondheim. The annual harvest is around 160,000 tonnes. The coastline is divided into 1 nautical mile broad sections and each section is harvested every 5th year, leaving 4.5 years (on average) for the sections to regrow. Around 30,000 tonnes of *Ascophyllum nodosum* is also harvested every year in mid-Norway.

9.4.3.3 Ports and shipping

The coastal cities and towns in south-western Norway owe much of their development and wealth to maritime trade although the emphasis has changed over the years. In the case of Stavanger the city depended on shipping and sea trade for many centuries. In the mid-19th century the emphasis shifted to fisheries with the city a focal point for sardine canneries. Since the 1960s this has been superseded by the importance of the oil industry. The same pattern can be seen in many of the smaller towns such as Haugesund, and Florø in Sognefjorden that expanded on the basis of its trade in herring but is better known today for its role in the offshore oil industry.

Bergen is a major commercial port and hub for shipping lines operating from the major European ports. In 1995 around 19,000 vessels passed through the port, not only for trade, but to provide services for cruise ships and ferries to other ports in Norway.

9.4.3.4 Energy industries

The offshore oil industry has been important to the Norwegian economy since the early days of production from North Sea wells. In 1999 Norwegian oil exports amounted to NOK 168 billion and the petroleum industry generated around 14.6% of Norway's state revenues. The oil and gas is brought ashore through pipelines or by tankers before onward distribution to refineries.

Stavanger is regarded as the oil capital of Norway. The deep waters at its northern entrance provide anchorages for large ships as well as oil rigs. There are also lay-up areas for rigs and deep water locations which can be used for the construction of large offshore structures. The port is important for the import and export of goods as well as transhipment associated with the offshore oil and gas industry.

It is likely that the development of Norway's oil and gas resources will continue for the next few decades.

9.5 Denmark, Germany and the Low Countries

As the risk of oil spillage from the SEA 2 areas reaching the coastlines of Denmark, Germany and the Low Countries is extremely low, a high level summary of the key coastal resources of these areas is provided. Sites of international importance are listed in Table 9.7.

9.5.1 The Wadden Sea

The Wadden Sea is undoubtedly the main feature of conservation interest in the area. It comprises an extensive area of shallow seas and low-relief coastline stretching from Den Helder in the western Netherlands to Esbjerg in western Denmark.

Protection at the national level and cooperation between the three Wadden Sea countries on the protection of the Wadden Sea developed in parallel. The first comprehensive protection schemes were introduced in 1979-1980 in all three countries. The trilateral Wadden Sea Cooperation has developed to constitute as the overall framework for the protection of the Wadden Sea as one entire, shared ecosystem.

The trilateral Wadden Sea conservation area consists of:

- In The Netherlands, the areas under the Wadden Sea Memorandum including the Dollard
- In Germany, the Wadden Sea national parks and protected areas under the existing Nature Conservation Act seaward of the main dyke and the brackish water limit including the Dollard
- In Denmark, the Nature and Wildlife Reserve Wadden Sea

The majority of the Wadden Sea will be included in Natura 2000 sites network (as both SACs and SPAs), in addition, parts of the area are designated as Ramsar sites or Biosphere Reserves and the area has been proposed as a World Heritage Site.

The Wadden Sea and adjacent coasts are important for shipping, commercial fishing (primarily shellfish within the Wadden Sea), tourism and recreation, energy (both natural gas and wind power), sand extraction and military exercises.

Several major ports are situated in or at the borders of the Wadden Sea. The main ports are Harlingen, Delfzijl/Eemshaven, Emden, Wilhelmshaven, Bremerhaven, Bremen, Hamburg and Esbjerg. There is intensive traffic between the Wadden Sea ports and harbours outside the area. The shipping lanes of Hamburg, Bremerhaven and Wilhelmshaven are connected with Traffic Separation Schemes to Rotterdam and the English Channel.

9.6 Listing of SPAs and Ramsar Sites

A listing of internationally important conservation sites for birds around the North Sea margins is tabulated below.

Table 9.7 - Listing of Special Protection Areas and Ramsar Sites along the North Sea Coastline

	IBA No.	Site No.	Site Name	SPA	Ramsar
UK					
	74	1	Thanet coast & Sandwich Bay		
	68	2	The Swale		
	40	3	Medway estuary & marshes		
	73	4	Thames estuary & marshes		
	7	5	Benfleet & Southend marshes		
	42	6	Mid-Essex coast		
	29	7	Hamford water		
	2	8	Alde/Ore estuary		
	66	9	Stour & Orwell estuary		
	16	10	Deben estuay		
	43	11	Minsmere-Walberswick		
	6	12	Benacre to Easton Bavents		
	10	13	Breydon Water		
	27	14	Great Yarmouth North Denes		
	47	15	Northumberland coast		
	77	16	The Wash		

	IBA No.	Site No.	Site Name	SPA	Ramsar
UK					
		17	Gibralter Point		
	32	18	Humber flats, marshes & coast		
	31	19	Hornsea Mere		
	24	20	Flamborough Head & Bempton Cliffs		
	71	21	Teesmouth & Cleveland coast		
	15	22	Coquet Island		
	50	23	Northumbria coast		
	23	24	Farne Islands		
	37	25	Lindisfarne		
	237	26	St.Abbs Head to Fast Castle		
	148	27	Forth Islands		
	133	28	Eden estuary, Tentsmuir Pt & Aberlay Sands		
	143	29	Firth of Tay		
	204	30	Montrose Basin		
	150	31	Fowlsheugh		
	270	32	Ythan estuary, Sands of Forvie & Meikle Loch		
	112	33	Buchan Ness to Collieston coast		
	181	34	Loch of Strathbeg		
	259	35	Troup, Pennan & Lion Heads		
	207	36	Moray basin, firths & bays		
	115	37	Caithness cliffs		
	226	38	Pentland Firth Islands		
	124	39	Copinsay		
	105	40	Auskerry		
	197	41	Marwick Head		
	131	42	East Sanday		
	132	43	Eday		
	223	44	Papa Westray		
	267	45	West Westray		
	138	46	Fair Isle		
	253	47	Sumburgh Head		
	208	48	Mousa		
	220	49	Noss		
	141	50	Fetlar		
	159	51	Hermaness & Saxa Vord		
	228	52	Ramna Stacks & Gruney		
	215	53	North Roe & Tingon		
	149	54	Foula		
NORWAY					
	32	55	Froan		
	38	56	Havmyran		
	39	57	Smola archipelago		
		58	Sandblast/Gaustadvagen		
		59	Haroya Wetlands System		
		60	Giske Wetlands System		
	40	61	Runde		

	IBA No.	Site No.	Site Name	SPA	Ramsar
NORWAY					
	43	62	Kjorholmane seabird reserve		
	44	63	Jaeren wetland system		
	45	64	Lista wetland system		
	46	65	Skjernoy, South Skerries		
DENMARK					
	22	66	Hanstholm Reservatet		
	18	67	Vangsa Hede		
	17	68	Alvand Klithede & Forby So		
	23	69	Agger Tange & Kirk Vig		
	28	70	Nissum Bredning		
	39	71	Harboore Tange, Plet Enge & Gjeller So		
	38	72	Nissum Fjord		
	41	73	Stadil Fjord & Veststadil Fjord		
	43	74	Ringkobing Fjord		
	56	75	Fjilso		
	50	76	Kallesmaersk Hede, Graerup Langso & area		
	53	77	Fano		
	55	78	Skallingen & Langli		
	51	79	Ribe Holme & meadows		
	52	80	Mando		
	57	81	Vadehavet		
	65	82	Romo		
	67	83	Ballum og Husum Enge, Kamper strandenge		
	60	84	Tonderrmarsken, Magisterkog & Rudbol So		
	23	85	Agger Tange & Krik Vig		
GERMANY					
	2	86	Schleswig-Holstein		
	1	87	Heligoland island		
	34	88	Neuwerker & Scharhorner Watt (Hamburgisches Wattenmeer)		
	107	89	Elbmarsch from Stade to Otterndorf (Niederelbe, Barnkrug-Ottendorf)		
	65	90	Lower Weser		
	90	91	Wattenmeer, Jadebusen		
	58	92	Wattenmeer Elbe-Weser-Dreieck		
	63	93	Ems valley from Leer to Emden		
NETHERLANDS					
	17	94	Dollard		
	12	95	Rottumeroog		
	11	96	Rottumerplaat		
	10	97	Schiermonnikoog		
	9	98	Engelsmanplaat		
	8	99	Ameland:Duinen-Oerd		
	7	100	Terschelling: Dunes & Noordvaarder		

	IBA No.	Site No.	Site Name	SPA	Ramsar
NETHERLANDS					
	6	101	Terschelling: De Boschplaat		
	1	102	Wadden Sea		
	5	103	Griend		
	4	104	Vlieland		
	2	105	Texel: Schorren & Zeeburg		
	3	106	Texel: Dunes & Hors		
	18	107	N.Sea north of Waddensea		
	13	108	Balgzand		
	19	109	Zwanenwater		
	92	110	Dunes of Schoorl		
	21	111	Westplaat		
	24	112	Haringvliet		
	25	113	Hollands Diep		
	23	114	Kwade Hoek		
	27	115	Grevelingen		
	20	116	Voordelta		
	26	117	Lake Volkerak		
	28	118	Oosterschelde		
	29	119	Zoommeer		
	30	120	Markiezaat		
	32	121	Westerschelde & Saeftinghe		
	33	122	Zwin (Dutch part)		
	16	123	Groningen Wadden Sea coast		
	15	124	Lauwersmeer		
	14	125	Frisian Wadden Sea coast		
	35	126	Makkumer and Kooiwaard		
	36	127	Workumerwaard		
	37	128	Steile Bank & Mokkebank		
	34	129	Lake Ijsselmeer		
	38	130	Lake Markermeer		
	66	131	Oostvaardersplassen		
	67	132	Lepelaarplassen		
	69	133	Polder Zeevang		
BELGIUM					
	1	134	Vlaamse Banken		
	2	135	Westkust		

10 CONSIDERATION OF THE EFFECTS OF LICENSING

10.1 Introduction

The overall process adopted for this strategic environmental assessment is described in Section 2. The approach and methods used to identify the potential effects that could follow from SEA 2 licensing, and to assess them for significance are outlined below.

10.2 Approach

The assessment for this SEA was a staged process which has incorporated inputs from a variety of sources (outlined below). The initial stage was the identification of interactions between the activities that might follow from licensing of the SEA 2 areas and receptors within the environment (both the natural environment and human uses of the area). The interactions and implications considered include positive, negative, direct, indirect, cumulative, synergistic and transboundary effects. This initial step drew on published descriptions of the effects of oil and gas activities, the first DTI SEA of the former White Zone, the EU SEA Directive, and the report of the stakeholder dialogue session.

The next stage was screening of the range of potential interactions to identify those which might potentially have effects of a scale which should be considered further in the SEA. This was achieved through a workshop with the SEA steering group held on July 16th 2001. The process followed is illustrated in Figure 10.1 which includes the input information and outputs. Prior to the workshop, a provisional environmental interactions matrix was developed and circulated along with a summary of generic oil and gas activities (see SD-002 on the SEA website), and scenarios of potential activity in the SEA 2 area (see Section 4.3).

The provisional interactions matrix was reviewed in detail at the workshop using indicative criteria (both revised at the workshop and taking into account the criteria for determining the likely significance of effects included as Annex 2 to the SEA Directive, see Appendix 2). The steering group members and the SEA team used expert judgement to identify those interactions which should be considered further in the SEA – see Table 10.1. The criteria used in the screening included the scale, severity and duration of effects on the environment, human health and socio-economics, together with issues of public concern. In this way the screening attempted to ensure balanced consideration of scientific and perception issues.

The final stage was detailed consideration of the interactions agreed at the workshop. This stage is documented in Sections 10.4-10.7 and included quantification of the scale and magnitude of the potential activities and interactions, consideration of the sensitivity and ability to recover of the receptor(s), existing controls and agreements in place, information gaps, and a conclusion regarding the potential effect of further licensing in the SEA 2 areas.

For completeness a brief consideration of the more minor issues is included in Table 10.2.

Figure 10.1 – Summary of the assessment process

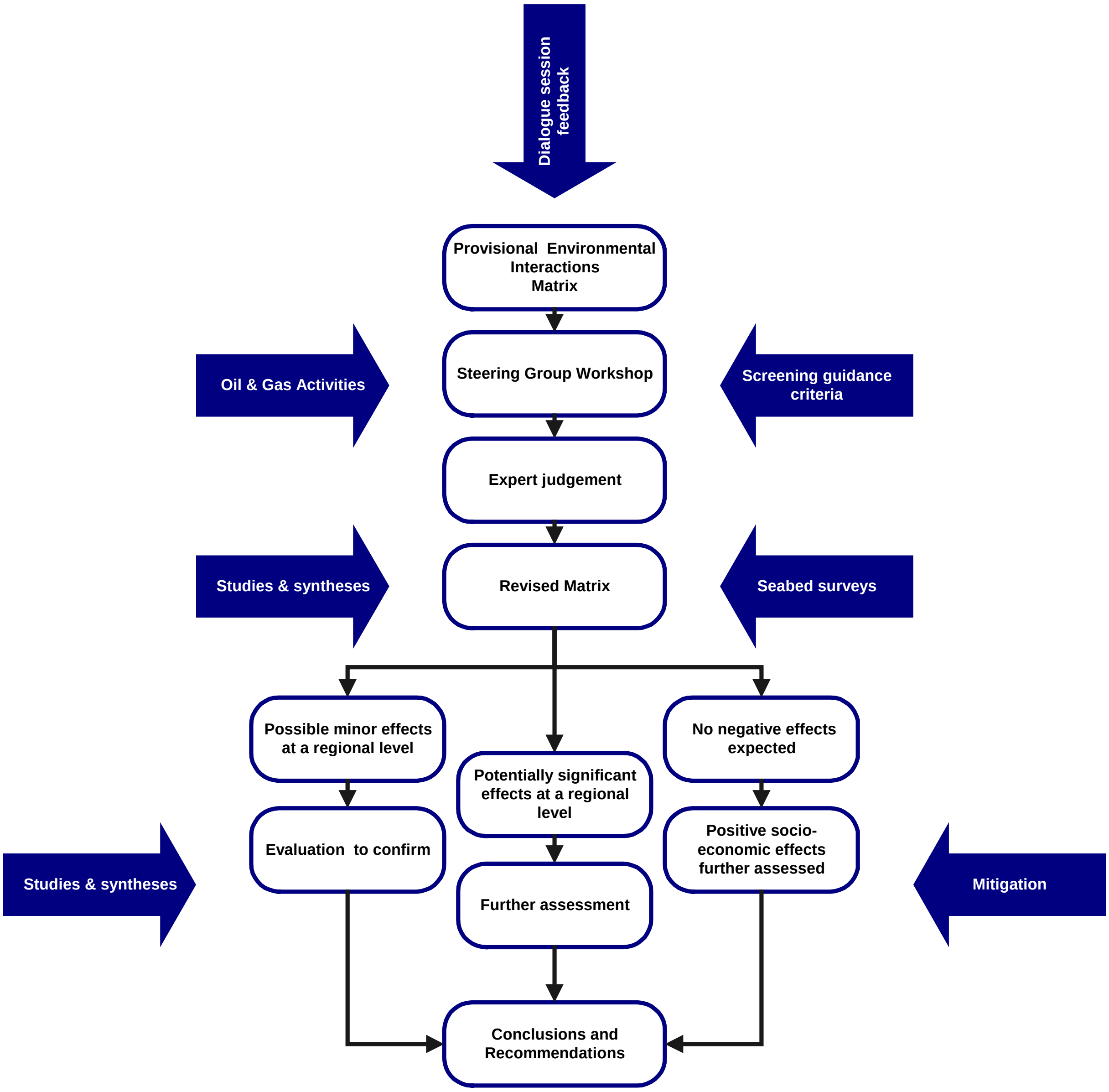


Table 10.1 – Summary of interactions identified for SEA 2 at the Assessment Workshop

Source of Potential Impact	Minor interactions with the listed receptors (See Table 10.2)	Interactions with receptors considered further in SEA 2 (See Section 10.4 – 10.7)
UNDERWATER NOISE		
Seismic	Plankton Other water column invertebrates Benthic fauna Fish & shellfish Seabirds Fisheries	Marine mammals Conservation sites Cumulative effects Transboundary effects
Drilling		Marine mammals Cumulative effects
Offshore Construction		Marine mammals Cumulative effects
Production operations		Marine mammals Cumulative effects
Decommissioning		Marine mammals Cumulative effects
PHYSICAL DAMAGE TO BIOTOPES		
Seismic (dragged array only)	Seabed Benthic fauna Fish & shellfish Conservation sites	Cumulative effects
Drilling (rig anchoring)	Fisheries	Seabed Benthic fauna Fish & shellfish Conservation sites Cumulative effects
Drilling (rock dumping for jack-ups)	Seabed Benthic fauna Fish & shellfish Fisheries	Conservation sites Cumulative effects
Construction (anchoring of lay barge)	Benthic fauna Fish & shellfish Fisheries	Seabed Conservation sites Cumulative effects
Construction (pipelay, trenching & rockdumping)		Seabed Benthic Fauna Fish & shellfish Conservation sites Fisheries Coastal features & amenity Cumulative effects
PHYSICAL PRESENCE		
Seismic survey (towed streamers)	Fisheries Shipping Recreation	

Source of Potential Impact	Minor interactions with the listed receptors (See Table 10.2)	Interactions with receptors considered further in SEA 2 (See Section 10.4 – 10.7)
Drilling (rig & anchors)	Fisheries Shipping	Conservation sites
Production (installations and pipelines	Benthic fauna	Fish & shellfish Conservation sites Fisheries
Depletion of reservoir (seabed subsidence)	Seabed Benthic fauna Fish & shellfish Conservation sites	
MARINE DISCHARGES		
Drilling (muds and cuttings)	Plankton Other water column invertebrates Seabirds Marine mammals Fisheries Health/nuisance	Seawater quality Seabed Benthic fauna Fish & shellfish Conservation sites Cumulative effects Transboundary effects
Construction (hydrotest and pipeline drying)	Seawater quality Plankton Other water column invertebrates Fish & shellfish Seabirds	
Production (produced water)	Seabirds Marine mammals Fisheries Health/nuisance	Seawater quality Seabed Plankton Other water column invertebrates Benthic fauna Fish and shellfish Cumulative effects Transboundary effects
Ballast water (exotics)	Plankton Benthic fauna	Cumulative effects
Low specific activity scale	Plankton Benthic fauna Conservation sites	Cumulative effects
SUBSURFACE DISCHARGES		
Drilling (muds and cuttings injection)	Freshwater aquifers	
Production (produced water injection)	Freshwater aquifers	
ATMOSPHERIC EMISSIONS		
Drilling (well test/clean-up)	Climate	Air Quality Cumulative Transboundary
Production (power generation)		Climate Air Quality Cumulative Transboundary

Source of Potential Impact	Minor interactions with the listed receptors (See Table 10.2)	Interactions with receptors considered further in SEA 2 (See Section 10.4 – 10.7)
Production (flaring/venting)		Climate Air Quality Cumulative Transboundary
Production (tanker loading - VOCs)		Climate Air Quality Cumulative Transboundary
Production operations		Climate Air Quality Cumulative Transboundary
Support vessels		Climate Air Quality Cumulative Transboundary
WASTES TO SHORE		
Drilling (muds and cuttings)		Air quality Onshore land use
Low specific activity scale	Onshore land use	
General oil field waste	Air quality Onshore land use	
ACCIDENTS		
Oil spills	Shipping	Air quality Seawater quality Seabed Plankton Other water column invertebrates Benthic fauna Fish & Shellfish Seabirds Marine mammals Conservation sites Fisheries Recreation Coastal features and amenity Onshore/Land use Transboundary effects Health/nuisance
Chemical spills	Seabed Benthic fauna Fish & Shellfish Seabirds Marine mammals Fisheries	Seawater quality Plankton Other water column invertebrates Conservation sites Health/nuisance
Gas releases		Climate Air quality Transboundary effects Health/nuisance

10.3 Evaluation of minor effects

Table 10.2 – Evaluation of minor effects

Nature of impact	Source of potential impact	Receptors in question	Consideration, Controls & Mitigation	Consider Further?
Underwater noise	Seismic	Plankton Other water column invertebrates Benthos Fish and shellfish Seabirds Fisheries	Except in the immediate vicinity of airgun arrays, seismic noise is considered to have minor or moderate direct effects on plankton, pelagic and benthic invertebrates or seabirds (eg McCauley 1994) and effects at a population level (or indirect effects at ecosystem level) are therefore unlikely. Most studies of fish in response to seismic have focused on catchability (e.g. Skalski *et al*. 1992, Turnpenny and Nedwell 1994, Engås *et al*. 1993). Behavioural studies have investigated the effects of seismic sound in experimental systems (Pearson *et al*. 1992) and in the field (Wardle *et al*. 1998). Although fish show a distinctive startle response, the latter study using electronic tagging showed no change in the location of fish. Seismic surveys must be carried out under the terms of an exploration or production licence, and proposed surveys notified to Government through submission of a PON14. Where required, JNCC must be consulted and an effects assessment submitted.	**No**
Physical damage to biotopes	Seismic (dragged arrays)	Seabed Benthic fauna Fish & shellfish Conservation sites	This method of seismic survey is relatively infrequent and unlikely to be used in SEA 2 areas, although moderate effects are possible on seabed and benthic organisms (including commercially exploited shellfish). Proposed surveys must be notified to Government through submission of a PON14. Where required, JNCC must be consulted and an effects assessment submitted.	**No**

Nature of impact	Source of potential impact	Receptors in question	Consideration, Controls & Mitigation	Consider Further?
Physical damage to biotopes	Drilling rig anchoring	Seabed Benthic fauna Fish & shellfish Conservation sites Fisheries	The total spatial extent of physical effects of rig anchoring are of negligible extent in the context of other activities at a regional scale, but are considered potentially significant to seabed habitats and benthic communities at a local scale (Section 10.4.2). Indirect effects of physical damage on fishing, through impacts on commercial species, are of minor or moderate significance (although negligible in comparison to direct fishing mortality). Rig locations in the vicinity of conservation sites would require Appropriate Assessment under the relevant legislation.	**No**
Physical damage to biotopes	Drilling (rock dumping for jack-ups)	Seabed Benthic fauna Fish & shellfish Fisheries	The potential significance of this activity to seabed habitats, benthic communities, demersal fish and shellfish in terms of habitat modification is considered minor or moderate, in view of the forecast number of SEA 2 wells to be drilled with jack-up rigs and resultant spatial extent of disturbance (Section 10.4.2).	**No**
Physical damage to biotopes	Construction (anchoring of lay barge)	Seabed Benthic fauna Fish & shellfish Fisheries	The spatial extent of this activity is likely to be very small in a regional context, in view of the forecast extent of pipelay activities (Sections 4.3 and 10.4.2) and likely use of dynamically positioned pipelay vessels. However, potential effects to seabed habitats, benthic communities, demersal fish and shellfish are considered to be moderate. The effects of laybarge anchoring would be evaluated through the project environmental assessment process.	
Physical presence	Seismic survey (towed streamers)	Fisheries, Shipping Recreation	The extent of interference with other users, including fisheries, shipping and recreational vessels, is considered likely to be minor or moderate, in view of the forecast extent and locations of activities. Existing consultation, notification and management procedures will mitigate effects.	**No**

Nature of impact	Source of potential impact	Receptors in question	Consideration, Controls & Mitigation	Consider Further?
Physical presence	Drilling (rig anchors)	Fisheries Shipping	Interference with other users due to the presence of rig anchors is considered to be of moderate significance, in view of the forecast extent and locations of activities. At water depths in the North Sea, anchors will be deployed within 500m exclusion zones around rigs. Existing consultation, notification and management procedures will mitigate effects.	**No**
Physical presence	Production (installations and pipelines)	Benthic fauna	The spatial extent of habitat modification, in terms of availability of hard substrate for epifaunal colonisation, is minor or moderate at a regional population level. Indirect effects at an ecosystem level are very unlikely.	**No**
Physical presence	Depletion of reservoir (seabed subsidence)	Seabed Benthic fauna Fish & shellfish Conservation sites	It is considered unlikely that seabed subsidence will occur as a result of chalk reservoir depletion in SEA 2 areas (see BGS report). This effect is considered to be of minor or moderate significance at a regional scale.	**No**
Marine Discharges	Drilling (muds and cuttings	Plankton Other water invertebrates Seabirds Marine mammals Fisheries Human health	Significant direct effects of drilling discharges on pelagic species, including turbidity and toxicity effects on birds, marine mammals and plankton are to be minor or moderate (mud toxicity is reviewed in Section 10.4.4). Chemical selection and potential environmental effects are effectively regulated (Section 3). Human health effects are minor or moderate due to low exposure of general public through the food chain.	**No**
Marine Discharges	Construction (hydrotest and pipeline drying)	Seawater quality Plankton Other water invertebrates Fish and shellfish Seabirds,.	The quantitative effects of pipeline construction discharges from SEA 2 E&P are considered moderate in view of the forecast scale of activities (Section 10.4.4), and chemical composition and toxicity of discharges. Chemical selection and proposed operations are effectively regulated under Pipeline Works Authorisation system (Section 3).	**No**

Nature of impact	Source of potential impact	Receptors in question	Consideration, Controls & Mitigation	Consider Further?
Marine Discharges	Production (produced water)	Seabirds Marine mammals Fisheries Human health	Potential effects of produced water discharges on seabirds, marine mammals and fisheries are minor or moderate in view of forecast scale of discharges (Section 10.4.4), rapid dispersion and limited direct exposure. Indirect effects through food chain biomagnification have not been detected. Human health effects are minor or moderate due to low exposure of general public through the food chain.	**No**
Marine Discharges	Ballast water (exotics)	Plankton Benthic fauna	The probability of exotic introduction through ballast water discharges from rigs and vessels is considered minor or moderate in view of the forecast scale of effects, water treatment, and likely origin of ballast water (most rig and vessel transits will be within the North Sea). Incremental effects of SEA 2 production on downstream tanker movements will not be significant.	**No**
Marine Discharges	Low specific activity scale	Plankton Benthic fauna Conservation sites.	Low specific activity scale discharges, in particulate form, have not been found to result in detectable accumulation in sediments or biological effect. The likely scale of incremental discharge is minor in the context of current North Sea activity.	**No**
Subsurface Discharges	Drilling (muds and cuttings reinjection)	Freshwater aquifers	Barium mobility in aquifers is likely to be limited because of the insolubility of sulphate and carbonate salts. Therefore it is unlikely that these would be transported in significant concentrations even after the infrequent event of a reversal of the hydraulic gradient in permeable rock formations towards the land (BGS commissioned study)	**No**

Nature of impact	Source of potential impact	Receptors in question	Consideration, Controls & Mitigation	Consider Further?
Subsurface Discharges	Production (produced water reinjection)	Freshwater aquifers	The potential risk to aquifers or to granular sediments in the Palaeogene, from the injection of formation brines from Triassic or Permian hydrocarbon reservoirs is considered to be very low. The reinjection of produced formation water into low circulation zones in the producing reservoirs themselves should also present little risk (BGS commissioned study)	**No**
Atmospheric emissions	Drilling (well test/clean-up)	Climate	The scale of emissions from potential well test and clean-up in SEA 2 blocks (around 5 exploration wells leading to discovery; 5 appraisal wells and 24 development wells, see Section 10.4.5) is minor in the scale of regional emissions from other sources.	**No**
Wastes to shore	Low specific activity scale	Onshore land use	Disposal of low specific activity waste to landfill is strictly regulated under the Environmental Protection Act, 1990 and Radioactive Substances Act, 1993. Significant environmental effects are therefore unlikely to occur and are considered to be of moderate significance.	**No**
Wastes to shore	General oilfield wastes	Air quality Onshore land use	Disposal of returned waste to landfill or incineration is strictly regulated under the Environmental Protection Act, 1990 and subsidiary legislation. General oilfield wastes returned to shore include scrap metal, plastics and paper with a limited quantity of Special Wastes comprising waste oils, paints etc. Offshore and onshore waste handling is controlled by waste management systems which emphasise reduction, segregation for appropriate disposal and safe transport. The incremental contribution to land take and combustion emissions resulting from SEA 2 activities will be negligible. Significant environmental effects are very unlikely to occur and are considered to be of moderate significance.	**No**

Nature of impact	Source of potential impact	Receptors in question	Consideration, Controls & Mitigation	Consider Further?
Accidents	Oil spills	Shipping	Potential effects of oil spills on a range of physical and biological receptors are considered in Section 10.4.7. It is possible, although with an overall low risk that an oil spill associated with SEA 2 activities would have a detrimental effect on the free movement of shipping.	**No**
Accidents	Chemical spills	Seabed Benthic fauna Fish & shellfish Seabirds Marine mammals Fisheries	Although overall usage of chemicals offshore involves substantial quantities (Section 10.4.8), the methods of transport and quantities associated with forecast levels of activity in SEA 2 E&P, together with low toxicity of the majority of chemicals used, indicate that the likelihood of a large spill with significant effects is unlikely. Possible direct effects on seawater quality, plankton, pelagic invertebrates and conservation sites are considered potentially significant and are considered further in Section 10.4.8. Direct and indirect effects of chemical spills on seabed, benthic fauna, fish and shellfish, seabirds, marine mammals and fisheries are considered to be minor. Chemical selection, transport and use is strictly regulated under environmental and health & safety legislation. The incremental risk associated with SEA 2 activity (in the context of bulk carrier transport of chemicals to UK and mainland European ports) is small.	**No**

10.4 Consideration of effects

10.4.1 Noise

10.4.1.1 Introduction

The SEA 2 Effects Workshop identified the effects of seismic and drilling noise on marine mammals as a potentially significant issue. Potential effects of offshore exploration and production on marine mammals result primarily from acoustic disturbance (eg McCauley 1994, Richardson *et al*. 1995, Evans and Nice 1996, Moscrop 1997, Gordon *et al*. 1998, Stone 1998), with seismic sources generally regarded as the most significant.

10.4.1.2 Sources and propagation

Sources of underwater noise associated with E&P include seismic, other geophysical surveys, drilling, construction, production and decommissioning.

Predicted activity scenarios for potential licensed blocks suggest a total of 5-10 seismic surveys in the NNS, 5-18 in the CNS and 6-18 in the SNS. In addition, a total of 31 site surveys would be required for exploration, appraisal and development locations (assuming no well re-entries). Seismic surveys are listed by the DEAL (Digital Energy Atlas and Library, http://www.ukdeal.co.uk/) from UKCS blocks in the North Sea. The SEA 2 areas have been extensively surveyed with 2D and 3D seismic.

Sound pressure in water is usually defined in logarithmic units (dB) against a reference pressure (e.g. p_{ref} = 1µPa). In addition to relative sound pressure, the frequency distribution of propagated noise has a major influence on transmission and effects on receptors. Source levels associated with seismic airguns, vessels, drilling and explosives are reviewed in the context of marine mammal disturbance by SMRU. Airgun arrays are the commonest high energy source; by 1985 more than 97% of marine seismic surveys used airguns (Turnpenny and Nedwell, 1994). Airgun arrays are towed behind purpose built survey vessels, with guns suspended at depths of 1 to 10 m and fired at intervals of a few seconds.

With the exception of explosives, airgun arrays are the highest energy man made sound sources in the sea; broadband source levels of 248-259 dB re 1µPa-m are typical of large arrays (Richardson *et al*. 1995). Apparent source level of a surface-towed airgun source is dependent on the relative position of the receptor; for example a receiver to the side of an array will receive a signal of longer duration but lower maximum amplitude (Gordon *et al*. 1998). Received bandwidth and apparent source level are also strongly dependent on deployment depth, due to destructive interference from the reflected “ghost” array effect. Most of the energy produced by airguns is below 200 Hz. Barger and Hamblen (1980) reported a bandwidth of 40Hz centred about 120 Hz. The peak spectral level (the SPL in 1Hz steps) occurred between 35 and 50 Hz, and decreased monotonically with increasing frequency; spectral level at 200Hz was 48dB down on the peak at 40Hz. Source levels at higher frequencies are low relative to that at the peak frequency but are still loud in absolute terms and relative to background levels. Goold and Fish (1998) recorded 8 kHz sounds above background levels at a range of 8km from the source, even in a high noise environment.

Broadband source levels of ships between 55 and 85m in length are around 170-180 dB re 1 µPa-m (Richardson *et al*. 1995), with most energy below 1 kHz. Use of bow thrusters increases broadband sound levels, in one case by 11 dB and includes higher frequency tonal components up to 1 kHz (Richardson *et al*. 1995). Drilling noise is generally low frequency, with highest levels being recorded from drill ships. Conventional drill platforms produce very low frequency noise, with strongest signals at around 5 Hz whereas drill ships produce noise with tonal elements up to 600 Hz (Richardson *et al*. 1995, Greene, 1987). Operational noise associated with drilling rigs and the Foinaven and Schiehallion FPSO facilities has recently been monitored using pop-up hydrophone instruments (Swift and Thompson 2001), although there have bee no detailed studies around North Sea installations.

Most environmental assessments of noise disturbance use simple spherical propagation models of the form **SPL = SL – 20log(R)**, where SL = source level, R = source-receiver range, to predict sound pressure levels (SPL) at varying distances from source. However, several workers have measured or modelled additional signal modification and attenuation due to a combination of reflection from sub-surface geological boundaries, with sub-surface transmission loss due to frictional dissipation and heat; and scattering within the water column and sub-surface due to reflection, refraction and diffraction in the propagating medium (Etter 1991, Gausland 1998, VerWest and Bremner 1998, Ward *et al*. 1998). In shallow water, reflection of high frequency signals from the seabed results in approximately cylindrical propagation and therefore higher received spectrum levels than for spherically propagated low frequency signals (which penetrate the seabed). However, the sub-surface attenuation of signal with distance is frequency dependent, with stronger attenuation of higher frequencies with increasing distance from the source. Frequency dependence due to destructive interference also forms an important part of this weakening of a noise signal. Simple models of geometric transmission loss may therefore be unreliable in relatively shallow water; in areas of complex seabed topography and acoustic reflectivity; where vertical density stratification is present in deep water; and where the noise does not originate from a point source. The first two of these factors will apply particularly in the Norfolk Sandbank areas considered by SEA 2.

Few data are available regarding ambient (background) noise in the North Sea, although ambient noise in the Foinaven area west of Shetland has been measured (Swift and Thompson 2001). Data from three recovered pop-ups were characterised by high and variable levels of noise in three noise bands 1-10Hz, 10-30Hz and 30-100Hz, with the middle band selected to represent the frequency range of baleen whale vocalisations. Mean received spectrum levels (105-120 dB re 1 μPa^2 / Hz) exceeded the predicted upper limit of prevailing ambient ocean noise in all noise bands, except in the low frequency band where received levels were close to the predicted upper limit of ambient ocean noise.

10.4.1.3 Potential effects on marine mammals

In general, environmental assessment of the noise effects of UKCS offshore operations (in particular, seismic surveys) has been limited by a lack of relevant, reliable data and may be characterised by considerable speculation. Threshold peak impulse sound pressure for direct physical trauma in marine mammals, birds and fish is generally considered to be >200 dB (review sources cited above), although conclusive studies are limited by ethical considerations. Behavioural and physiological responses to experimental noise occur at received levels of 150-170 dB in bottlenose dolphins (e.g. Tyack *et al*. 1993) and seals (Thompson *et al*. 1998), although the response may vary from avoidance to investigation. Behavioural disturbance by underwater noise would therefore be expected within a “zone of effect” typically 1-2 km from a seismic airgun array. Non-observable behavioural effects, such as auditory masking (interference with the ability to detect other sounds) have been proposed for marine mammals (Richardson *et al*. 1995), although any assessment of the significance of such effects must be speculative.

Gordon *et al*. (1998) reviewed potential effects in terms of physical damage, noise-induced hearing loss (temporary and permanent threshold shifts), behavioural responses (auditory masking, disruption of behaviour, habituation, sensitisation and individual variation in responsiveness), zones of influence (*sensu* Richardson *et al*. 1995), chronic effects and stress, long term behavioural responses and exclusion, and indirect effects. The most likely physical/physiological effects were considered to be shifts in hearing thresholds and auditory damage. Behavioural responses including fright, avoidance and changes in behaviour and vocalisation have also been observed in baleen whales, odontocetes and pinnipeds, in some cases at ranges of tens or hundreds of kilometres, although it is difficult to interpret these responses in terms of ecological significance.

Potential effects of E&P activities in the SEA 2 areas, in terms of acoustic disturbance, were considered by SMRU in a commissioned report. Their conclusions were:

- The SEA-2 blocks are important areas for the three most abundant cetacean species in the North Sea: minke whale, harbour porpoise, and white-beaked dolphin. However, all are also distributed in surrounding areas. Only for the harbour porpoise is there evidence that the SEA 2 areas (northern and central) are particularly important areas
- Grey and harbour seals do occur in the SEA 2 areas but the populations as a whole spend a very small proportion of their time in these areas. Activities in the SEA 2 areas are unlikely to result in a population effect for seals in the North Sea
- Seals are sensitive to the low frequency sounds generated by oil exploration and production. Small cetaceans are relatively insensitive to low frequencies. Circumstantial evidence suggests that large whales may have good low frequency hearing
- It is likely that seismic survey work will affect foraging behaviour by any seals and large whales present in the SEA 2 areas. Current mitigation methods are probably generally effective in preventing physical damage
- There are no reliable data to suggest that vessel noise or drilling noise adversely affect seals or small cetaceans but there are indications that large whales may avoid areas of intense activity
- Decommissioning work that involves the use of explosives is likely to impact animals in the vicinity, potentially causing injury and death at close range, and causing hearing damage at substantial ranges. Difficulties in observing and monitoring behaviour and the apparent attractiveness of submerged structures means that some marine mammals, especially seals, could be damaged in blasts if effective mitigation was not instituted.

10.4.1.4 Conservation sites

Potential offshore conservation sites in SEA 2 areas, if any, would be designated primarily with regard to seabed features (sandbanks and pockmarks, SACs see Section 7) and seabird distributions (SPAs) and would not be expected to hold marine mammal populations different to surrounding areas (there is no evidence, for example, that grey seals preferentially forage over sandbanks, see Section 6.8). Although pockmarks may provide refugia for fish (Section 7), the scale and importance of this, in terms of any designated site, is unlikely to be significant.

It is possible that seismic surveys on the western fringe of central SEA 2 area could result in noise propagation into the designated Moray Firth SAC, which holds a semi-resident population of bottlenose dolphins. This potential source of effect would require assessment on a project-specific basis.

It is therefore considered unlikely that noise disturbance resulting from predicted E&P activities will have significant effect on offshore conservation sites. The potential effects of specific projects would be addressed through the established PON14 and Environmental Assessment mechanisms (see below).

10.4.1.5 Control and mitigation

Seismic surveys must be carried out under the terms of an exploration or production licence, and proposed surveys notified to Government through submission of a PON14. Where required, JNCC must be consulted and an effects assessment submitted.

In British waters, all species of cetacean are protected under the Wildlife and Countryside Act 1981 and the Wildlife (Northern Ireland) Order 1985. Guidelines to minimise the effects of acoustic disturbance from seismic surveys, agreed with the oil and gas industry, were published by the then Department of the Environment in 1995 and revised in 1998. Members companies of the UK Offshore Operators Association (UKOOA) have indicated that they will comply with these Guidelines in all areas of the UK Continental Shelf. Under the Guidelines there is a requirement for visual and acoustic surveys of the area prior to seismic testing to determine if cetaceans are in the vicinity, and a slow and progressive build-up of sound to enable animals to move away from the source.

Drilling noise has been considered in Environmental Statements for exploration wells, although noise from production facilities has received little attention. Recent observations suggest that significant noise intensities may occur, and this issue is likely to be assessed in more detail in future Environmental Statements. Project assessments will, however, continue to be limited by the uncertainties noted above.

10.4.1.6 Conclusions

SMRU conclusions indicate that seismic activities in the northern and central SEA 2 blocks could potentially affect minke whale, harbour porpoise, and white-beaked dolphin, although existing control and mitigation methods are probably generally effective in preventing physical damage. There is no evident seasonality to overall sensitivity of marine mammals in offshore areas.

Assessment of individual projects in the CNS and NNS is considered to be relatively robust, in terms of the reliability of sound propagation models and the availability of sound intensity criteria for marine mammal receptors. Although modelling in the SNS area will be less reliable, marine mammal sensitivity in this area is low due to the small population densities.

In view of the limited incremental extent of noise resulting from predicted activity levels, in relation to previous activity and activities in existing licensed acreage; together with existing control and mitigation methods; it is considered unlikely that physical damage or significant behavioural disturbance of marine mammals will result from the activity scenarios associated with proposed licensing.

10.4.2 Physical Damage to biotopes

10.4.2.1 Introduction

Physical disturbance of the seabed resulting from anchoring, pipeline trenching and other hydrocarbon exploration and production activities can result in a range of effects at various scales, many of which are analogous to natural processes associated with sediment mobilisation through wave action, tidal and surge currents, and (in the case of pockmarks) fluid release. Considerable physical disturbance of the seabed also occurs as a result of fishing activity, particularly beam trawling, and the effects of E&P operations will be cumulative to those of fishing. Trawl scarring is effectively unregulated and is a major cause of concern with regard to conservation of shelf slope habitats and species (Lindeboom and de Groot 1998, Jennings and Kaiser 1998).

In addition to potential damage to biotopes or individual organisms, a range of physical effects at the seabed may occur from anchor deployment (impact depressions), tensioning or dragging of anchors and attached cables (scars, mounds and displacement), retrieval (depressions and mounds) and pipeline trenching (spoil mounds). The creation of mounds or scars on the seabed can affect demersal fishing by snagging trawls or dredges and by contaminating the catch with clay, blocks of which can be picked up in the nets and mixed with fish in the cod end. In certain areas, trawlers are occasionally chartered to trawl the bottom with heavy gear to smooth out such mounds. The duration of such effects varies from short to long term depending on the nature of sediments and the durability of the cohesive masses at the seabed surface (Dunaway and Schroeder 1988). Such effects were not considered by the SEA 2 Effects Workshop to be significant on a regional scale.

10.4.2.2 Sources

Potential sources of physical disturbance to the seabed include rig and laybarge anchoring, wellheads and templates, jacket footings, pipelay activities including trenching, rock-dumping and jack-up rig spud cans. These sources may influence sedimentary habitats on scales from a few tens of square meters (spud cans) through several thousand square meters (infield pipelay, dependant on length and diameter), to the order of millions of square meters (trenched trunk pipelines).

Using exploration, discovery and development scenarios defined in Section 4.3, an estimate of the total extent of physical disturbance to the seabed associated with potential licensing in SEA 2 areas is shown in Table 10.3.

Table 10.3 – Area of physical disturbance

	unit area (m^2)	SNS	CNS	NNS	total no.	total area (m^2)
jack-up rigs	150	8	0	0	8	1,200
rig anchoring	1200	0	12	6	18	21,600
wellheads and templates	50	2	2		4	200
infield pipelay (10km)	5000	2	2		4	20,000
jacket piling / mud mats / risers etc	10000	0	0	1	1	10,000
export pipelay (20km to existing trunkline)	40000	0	0	1	1	40,000
					total	**93,000**

To place these sources in context, a conservative estimate of demersal otter trawling effort, at 2000 hours per year per ICES rectangle (typical over much of the North Sea, see Section 8.3, although ten times this effort takes place over much of the SEA 2 area) will result in at least 20,000km per year of trawl scar – 20 million m^2/yr (assuming average trawl speed of 4 knots, twin scars from trawl doors, 1m scar width; neglecting clump weights used in twin-trawl gears). Over the North Sea as a whole (including estuaries and fjords) this corresponds to over 4 billion m^2 per year of trawl scar resulting from otter trawling alone.

10.4.2.3 Effects

Lethal effects may result from smothering by sediment of sessile and mobile animals, if the depth of burial is beyond their powers of escape or clearance. This smothering can be direct or indirect (from winnowing disturbed material). Effects on continental shelf infauna are normally short lived and similar to those from severe storms and dredge spoil disposal where recovery is normally well underway within a year (Rees *et al*. 1977, SOAEFD 1996). Habitat recovery from the processes of anchor scarring, anchor mounds and cable scrape will depend primarily on re-mobilisation of sediments by current shear. Observations of anchor scars and mounds throughout the northern North Sea are usually attributed to semi-submersible drilling units, and suggest that anchor disturbance may persist for at least 5-10 years under northern North Sea conditions. Persistence of scars and spud can depressions in the southern North Sea will be considerable shorter, due primarily to storm wave disturbance of the seabed. (Modelling studies and flume experiments show that wave-induced near-bed currents will also exceed critical erosion velocity at annual or decadal frequency, in central and northern North Sea areas – resultant sediment mobilisation is likely to be the dominant factor in long-term stability of cuttings piles.)

Bedforms in the southern SEA 2 area indicate active sediment erosion and transport, particularly in the vicinity of sandbanks. There is limited information on the sediment clearance abilities of sessile epifauna or the effects of sedimentation on epifauna and infauna, although it is evident that the dominant epifaunal species must be tolerant of considerable sediment mobility and accretion. Smothering effects are therefore unlikely to be significant at benthic population and community levels in the southern SEA 2 area.

Muddier sediments in central and northern blocks of the SEA 2 area, particularly in the Fladen ground, support benthic communities characterised by the presence of large burrowing crustaceans (*Nephrops norvegicus* and *Calocaris macandreae*) and pennatulid sea-pens (*Virgularia mirabilis* and *Pennatula phosphorea*). *Nephrops* and *Calocaris* are able to restore burrow entrances following limited physical disturbance of the sediment surface (a few cm), and video observations of burrow and pennatulid densities on Fladen ground sediments show surprisingly little cumulative effect of fishing disturbance. It is likely, therefore, that physical effects of E&P activities in the central and northern North Sea SEA 2 area will be of local significance only.

Crushing or physical damage of biota through direct impact or dragging of cables, anchors etc is likely to be the most important source of significant effect from physical disturbance to large, long lived fragile species. The spatial extent of effects will be operation specific but even small scale disturbance of a unique or sensitive feature may result in effects considered as significant. The duration of effects is related to the life history of the species involved or to the timescale required for a biotope to become developed. The majority of seabed species recorded from the North Sea are known or believed to have short lifespans (a few years or less) and relatively high reproductive rates, indicating the potential for rapid recovery, typically between 1 to 5 years (Jennings and Kaiser 1998). There are several long lived benthic species known from the SEA 2 areas, including the bivalves *Arctica islandica* and *Modiolus modiolus* which can live for over 200 years and 50 years respectively (Ropes 1985, Anwar *et al*. 1990); both of which are widely distributed and common (see Section 6.3). It is possible that the cold water coral *Lophelia pertusa* is present in northern blocks of the SEA 2 area, since colonies have been found on jacket structures (Bell and Smith 1999) although the presence of colonies on natural substrates has not been demonstrated in the North Sea (Wilson 1979, Rogers 1999). The largest *Lophelia* colonies discovered elsewhere in the northeast Atlantic are believed to be several thousand years old (Bruntse and Tendal 2000). The growth rates and ages of large sponges which may also be present on northern SEA 2 blocks are essentially unknown. The distribution of these species (if present) is scattered, and at relatively low density, and significant effects of development activities are unlikely.

In addition to the potential effects of smothering, sediment plumes in the water column and settling to the seabed from construction activities and pipeline trenching activities can result in effects on biota through clogging of feeding mechanisms, temporarily altering the nature of the seabed sediments or in near surface waters, reduction of light for photosynthesis (Newell *et al*. 1998). The extent of effects will vary according to the frequency of occurrence and the tolerance of the species involved, itself a function of the average and extreme natural levels of sediment transportation/deposition experienced in an area. Near-bed concentrations of suspended particulate material (SPM) in the southern SEA 2 area are high, and the effects of anthropogenic sediment plumes are unlikely to be significant or long-term.

Localised biological effects may result from changed sediment type. Mixing of sediments can occur through anchoring and trenching activities and result in an alteration to the nature of the seabed surficial sediments and therefore the type of seabed biological community it can support. Infilled natural depressions, including pockmarks (see Section 6.3) may have different sediment characteristics (usually muddier but occasionally harder, due to carbonate formation) to the surrounding area, resulting in detectable faunal differences from surrounding sediments. Comparable effects may occur following infill of impact depressions and pipeline trenches, although the significance of such effects will be negligible on a regional scale.

Oil and gas infrastructure, together with dropped objects and construction debris if left on the seabed forms an artificial hard substratum which is rapidly colonised by a range of animals (eg Edyvean *et al.* 1985). The incremental significance of this is minor since considerable artificial substrate is already present within the SEA 2 area, see Section 6.3.8.5 (the ecological significance of which, in terms of the dispersal of epifaunal species such as the anemone *Metridium senile*, which have short duration planktonic larval stages, has not been fully assessed). Northern blocks of the SEA 2 area contain scattered glacigenic boulders and cobbles which are presumed to provide natural "stepping stones" for epifaunal dispersion.

Inversion of boulders at the seabed causes damage or death of epifauna living on the boulder surface. Some of the species involved, especially those in deeper waters can be long-lived and fragile. Physical damage to rock outcrops can occur through anchoring on, or anchor cables dragging across, fractured or friable rocks. In terms of overall surface area, rock and boulder habitats are rare in the SEA 2 areas and the effects of physical disturbance will be negligible on a regional scale.

10.4.2.4 Conclusions

The predicted spatial scale of physical disturbance of the seabed, resulting from activity scenarios for potential licensed areas, is very small in comparison to the total area of the North Sea (approximately one part in eight-million); or in comparison to the extent of physical disturbance from trawling and other activities (approximately one part in 217,000). The major sources of physical disturbance from E&P activities are predicted to be rig anchoring and pipelay activities.

Recovery of affected seabed through sediment mobility, and faunal recovery and re-colonisation, is expected to be rapid where the source of effects is transient (eg anchoring); less than five years in most cases.

Mitigation measures, principally the identification and avoidance of habitats and populations of particular sensitivity, will be implemented through established project assessment and planning controls.

It is therefore concluded that the potential incremental and cumulative effects of physical disturbance are not likely to be significant.

10.4.3 Physical presence

10.4.3.1 Introduction

The physical presence of offshore infrastructure required for exploration and production can have significant direct effects on other users of the affected areas (notably the fishing industry), in terms of:

- Loss of access due to exclusion zones and obstructions
- Safety risks associated with “fastening” of fishing gear to obstructions.

These issues were reviewed by CEFAS in a commissioned study for SEA 2, from which the following is abstracted.

10.4.3.2 Exclusion

The Petroleum Act (1987) allowed for the creation of safety zones at all offshore surface installations and subsea structures, excluding pipelines. Under this legislation, a zone of 500m radius (an area of approximately 78 hectares) is created when surface structures such as platforms become operational. All sub-sea installations can also be protected by safety zones of similar size. These zones are normally patrolled by support vessels, and the proximity of other vessels can be monitored from the installations themselves.

In the early 1980's, it was estimated that the loss of fishing area in the North Sea caused by these zones was ~0.25% of the total area of the North Sea. Although this has increased over the last decade, the maximum loss of fishing area remains less than 1%. The exclusion of fishing activity from these zones does not adversely affect fish catch rates, as fishing effort is simply diverted to adjacent areas. The loss of area does not result in a proportional loss of catch, and the individual zones themselves are so small that they do not completely obscure any one fishing ground.

It has been thought that these safety zones may act as closed areas, protecting individuals from capture by fishing gears and thereby enhancing the stock. There is little evidence to support this assertion. Regular incursions into the safety zones by trawlers occur, and these, together with fish migrations (eg to spawn) are likely to preclude the establishment of protected populations of fish.

10.4.3.3 Obstruction caused by well heads and pipelines.

The safety of all users of the sea must be of primary concern during the design and construction of sub-sea structures, particularly to ensure that they are over-trawlable and that gears do not become snagged. Where possible, vulnerable structures such as templates, wellheads, subsea valve assemblies and manifolds are placed within a safety zone and provided with further protection such as a composite structure with a steel framework, designed with sloping sides to deflect trawls. Pipelines may be protected by the addition of a protective coating or by burial. In all cases these extra measures are expensive and the offshore industry has recently revised its guidelines to take account of recent advances in technology and the changing requirements of the industry (DNV 1997). For structures designed and built 10 or more years ago, the loads determined at the time may no longer be applicable to the heavier gears used by the more powerful fleets now operating in the North Sea.

The decision as to whether a pipeline is trenched or placed on the sea bed is complex, and includes the needs for pipeline protection and to limit the obstruction it may cause to fishing gears. Although pipelines can cause accidental interference, it has been reported that they are used by some trawlers as tows, presumably on the assumption that pipelines aggregate fish and so provide greater catch rates that similar tows nearby. A recent Norwegian study involving experimental trawling of pipelines with gill nets and otter trawls concluded that they had only limited ability to aggregate fish (Valdemarsen 1993, Soldal 1997). Since the loss of the trawler *Westhaven*, however, there have been a number of initiatives to ensure that pipeline spans and sub-sea structures do not pose a threat to fishing vessels.

Traditionally, pipelines of diameter less than 16 inches were buried for their own protection, while larger diameter pipelines were left on the sea bed and were unlikely to be seriously damaged. Although there is evidence that pipelines up to a diameter of 40" (about 1m) cause only minimal gear damage, they can affect the gear geometry and efficiency once past the obstruction (Valdemarsen 1993). Even pipelines which are protected on the surface by rock dumping can also present a hazard to towed fishing gears (Soldal 1997).

It is normal practice to apply for a safety zone around all fixed installations, including subsea developments, but these are not marked with surface buoys. Without such visible markers, the offshore oil and gas industry is dependent on fishing vessels maintaining a safe distance from all sea bed structures. To ensure that the risk of fishery interactions is reduced, pipeline route and locations of subsea structures are notified to fishermen and other mariners through direct liaison with representative organisations and through established publications such as Admiralty charts, Kingfisher charts and FishSafe computer systems.

Debris outside exclusion zones, including containers lost from supply vessels in transit, and debris not recovered during decommissioning, is also of concern to fishermen. All reasonable measures are taken by the industry to prevent losses and recover debris.

10.4.3.4 Conclusions

Although exclusion can represent a significant conflict between fishing and production in intensively developed areas within established fishing grounds, including some SEA 2 areas, the spatial extent of exclusion zones is unlikely to cause significant economic impacts. The oil industry and UK fishing industry maintain consultation, liaison and compensation mechanisms, which should serve to mitigate and resolve any conflicts.

10.4.4 Marine discharges

10.4.4.1 Introduction

The SEA 2 Effects Workshop identified certain marine discharges from E&P operations as potential sources of significant environmental effect. These related primarily to produced water (dispersed and dissolved contaminants with effects principally on water quality, plankton and pelagic organisms) and drilling discharges (particulate contaminants with effects principally on benthos).

10.4.4.2 Sources – produced water and other aqueous discharges

Marine discharges from exploration and production activities include produced water, sewage, cooling water, drainage and surplus WBM, which in turn may contain a range of hydrocarbons in dissolved and suspended droplet form, various production and utility chemicals, metal ions or salts (including Low Specific Activity (LSA) radionuclides). In addition to these mainly platform-derived discharges, a range of discharges are associated with operation of subsea developments (hydraulic fluids), pipeline testing and commissioning (treated seawater), support vessels (sewage, cooling and drainage waters) and terminals (predominantly ballast water from tankers).

Produced water is derived from reservoir ("fossil") water and from breakthrough of treated water injected to maintain reservoir pressure, and is generally the largest single wastewater stream in oil and gas production (OLF 1998). Discharges of produced water in the North Sea were predicted to peak at about 340 million m^3/year in 1998 (E&P Forum 1994), followed by a levelling in discharge volumes. The most recent survey carried out by UKOOA concluded that total UKCS produced water discharges in excess of 300 million tonnes/year would probably be sustained to 2010 and beyond. Actual discharges have been consistently less than predictions and the latest reported total produced water discharge from UKCS oil production was 244 million tonnes in 2000, with an average oil in water content of 21.5 mg/kg (DTI 2001).

As the majority of produced water discharge volume is associated with oil production, a pro-rata estimate of produced water resulting from peak annual production from developments in newly licensed SEA 2 blocks is around 6 million tonnes of water, containing 132 tonnes of oil. These are likely to be considerable over-estimates, as water-cut from reservoirs at peak production is generally lower than the North Sea average. There is also a presumption against discharging produced water from new developments (Section 10.4.4.6)

Other overboard discharges are generally of much lower volumes than produced water, and are unlikely to have significant effect.

Chemical composition and effects of produced water discharges have been reviewed previously (eg Middleditch 1981, 1984, Davies *et al*. 1987, Ray and Engelhardt 1992, E&P Forum 1994, Reed and Johnsen 1996, OLF 1998). Chemical composition is strongly field-dependent, with generally little correlation between the oil-in-water content (which is used as the standard for environmental regulation) and the aromatic content (principally responsible for toxicity). Studies of acute and chronic toxicity of produced water in Norway (OLF 1998) concluded that Polycyclic Aromatic Hydrocarbons (PAH) and alkylated phenols were the major contributors, with immunotoxic, carcinogenic and teratogenic effects in the former, and possible oestrogenic effects in the latter case.

Other components of produced water include organic compounds (mainly volatile fatty acids), metals and residual process chemicals. None of these are considered likely to have significant effects (OLF 1998).

10.4.4.3 Sources – drilling wastes and other solid discharges

Drilling wastes are a major component of the total waste streams from offshore exploration and production, with typically around 1,000 tonnes of cuttings resulting from an exploration or development well. Cuttings are discharged at, or relatively close to sea surface during "closed drilling", whereas surface hole cuttings will be discharged at seabed during "open-hole" drilling (see Section 10.4.4).

Scenarios identified for exploration and development of SEA 2 licence areas predict a total of 21 exploration and 5 appraisal wells throughout the areas, together with two subsea developments in each of the southern and central areas, and a possible platform development in the northern North Sea (Section 4.3). On the assumption that southern area developments will comprise two wells each; five wells in central developments and ten in the northern development; a total of 24 development wells are forecast. Cuttings discharges from these activities would therefore total around 50,000 tonnes, assuming the use of water-based muds. (Use of oil-based mud systems, for example in highly deviated sections or in halite sections, would require the onshore disposal or reinjection of a small proportion of this material.)

Predicted drilling activity in blocks already licensed in the southern, central and northern North Sea, from DTI forecasts, suggests between 45 and 60 wells per year during the period 2002 – 2005 (ie annual cuttings discharges of around 50,000 tonnes). Forecast drilling discharges resulting from SEA 2 licence areas over the same period represent an annual increment of between 2 and 16% on predicted North Sea discharges. It should be noted that the DTI forecast of drilling activity in existing licenced blocks is conservative (1999 and 2000 drilling activities were 261 and 249 wells respectively , DTI 2001) – the actual increment resulting from SEA 2 may therefore be less than 10%.

In 1999, 157,253 tonnes of water-based drilling chemicals and additives (including some 54,000 tonnes of barite and other weighting agents) were reported as being discharged to the UKCS (CEFAS commissioned study). These discharges resulted from 36 exploration/appraisal and 225 development wells (DTI 2001) together with workovers, giving an average WBM chemicals discharge of 603 tonnes per well. The predicted incremental annual discharge of WBM chemicals from SEA 2 related drilling represents a maximum increase of 4.2% (in 2002) on 1999 values.

The contaminant composition of drilling wastes has changed significantly over the last few decades, in response to technical and regulatory developments. Previous widespread and substantial discharges of oil-based muds, and later synthetic muds, have been superseded by alternative disposal methods (either containment and onshore treatment, or reinjection) or by water-based muds. The major environmental effects of development of the North Sea in the 1970s and 1980s, i.e. the "legacy" of cuttings piles beneath platforms, are therefore not predicted to be repeated in future exploration and development.

Mud systems used in surface hole drilling for exploration wells are usually simple (seawater with occasional viscous gel sweeps) and would not result in significant contamination of sediments. However, the composition of closed drilling discharges likely to result from exploration, appraisal and development drilling (and to a lesser extent from well maintenance activities) is more complex, and will include cuttings (i.e. formation solids, in varying degrees of consolidation and in a range of particle sizes), barite, salts (sodium and potassium chloride), bentonite and a range of mud additives in much smaller quantities. Water-based mud additives perform a number of functions, but are predominantly polymeric organic substances and inorganic salts with low toxicity and bioaccumulation potential (see Sections 5.5). In addition to mud on cuttings, surplus water-based mud may be discharged at the sea surface during or following drilling operations. Due to its density, a proportion of the particulate component of the mud (including barite) may settle in the immediate vicinity of the discharge.

The major insoluble component of water-based mud discharges, which will accumulate in sediments, is barite (barium sulphate). Barite has been widely shown to accumulate in sediments following drilling (reviewed by Hartley 1996). Barium sulphate is of low bioavailability and toxicity to benthic organisms (eg Starczak *et al*. 1992). Other metals, present mainly as salts, in drilling wastes may originate from formation cuttings, from impurities in barite and other mud components or from other sources such as pipe dopes. Although a variety of metals (especially chromium) are widely recorded to accumulate in the vicinity of drilling operations (eg Engelhardt *et al*. 1989, Kröncke *et al*. 1992), the toxicity of settled drill cuttings appears to be related primarily to hydrocarbon content, even in WBM discharges (eg ERTSL 2001).

Modelling of drilling waste dispersion is frequently carried out in support of environmental assessment of specific projects under the *The Offshore Petroleum Production and Pipe-lines (Assessment of Environmental Effects) Regulations 1999*. Dispersion modelling usually focuses on physical accumulation of cuttings, although contaminant concentration can also be simulated. To date, limited calibration and validation of dispersion models has been carried out.

Sand, sludge and scale from production facilities may be discharged, as an alternative to onshore disposal, subject to regulatory controls. The effects of these discharges were not judged to be potentially significant by the SEA 2 Effects Workshop. LSA scale, removed from pipework and vessels, has been routinely discharged from North Sea installations with no observed effects.

10.4.4.4 Potential effects of produced water

Potential effects of produced water discharges include direct toxicity, organic enrichment, contaminant bioaccumulation and dissolution of particulates and precipitates. Some slight elevation in the sea temperature may occur in the immediate vicinity of the discharge. These effects may be of significance in terms of:

- chronic accumulation of persistent contaminants in the marine environment
- acute or chronic effects on biota, including effects on productivity, within the human foodchain (ie indirect effects on human health and commercial interests)
- acute or chronic effects on other biota (i.e. indirect effects on biodiversity)

The toxic effects of produced water are influenced by bulk dispersion and dilution processes following discharge, and potentially by bioaccumulation and biomagnification of individual contaminants. Direct measurement of dispersion and dilution is extremely challenging from a technical viewpoint, and most studies have focused on the use of computer models (eg Rye *et al*. 1998, OLF 1998). The majority of studies have considered single sources, although the OLF (1998) model simulates discharges from all North Sea installations (Norwegian, British, Danish and Dutch) simultaneously. Field measurements have confirmed predicted concentration fields (Johnsen *et al*. 1998). Dispersed oil and PAH concentrations in the northern North Sea (the East Shetland basin and Tampen area) were predicted to be increased approximately tenfold over background concentrations which is consistent with observations from large scale studies carried out in the 1990's (Stagg and McIntosh 1995, Stagg *et al*. 1996).

Uptake of selected PAH and phenolic compounds from water in a marine planktonic food chain may be rapid (OLF 1998), with significant bioaccumulation at the lower level of the food chain (flagellate and dinoflagellate micro-zooplankton), and to a lesser extent in the dominant copepod *Calanus finmarchicus*. The levels of PAHs observed in organisms were all much lower than literature reported No Effect Concentration (NEC) of PAH or phenolic compounds, suggesting (although final proof is lacking) that no adverse or chronic effects on marine organisms would be expected except for areas very close to the discharge points (less than 100-500m). The earlier studies reviewed by E&P Forum (1994) also concluded that the necessary dilution would be reached at 10 to 100m from the discharge point, and therefore that biological impacts would be confined to the seafloor or platform fouling community at the discharge site.

Dispersion of discharged effluents in the SEA 2 areas will be influenced by the hydrographic regime, which in central and northern areas is characterised by relatively deep water, but with vertical stratification for much of the year and relatively low tidal current amplitudes; and in the southern area by shallow water but considerably greater tidal current energy. Wave-induced turbulence will be a significant dispersion mechanism in all areas of the North Sea under typical weather conditions, particularly with respect to vertical mixing. In practice, noting the dilution ranges necessary to achieve NECs for individual produced water components, regional hydrographic considerations will be of minor relevance as extremely low contaminant concentrations are achieved through turbulent dispersion in close proximity to the discharge.

As noted above, direct measurement of dispersion and dilution of produced water components is extremely difficult, due to the low concentrations involved. Model development (eg PROTEUS in the UK, DREAM in Norway) has therefore concentrated on simulation of physical dispersion processes, in addition to more sophisticated chemical risk assessment methods than the Hazard Quotient (PEC/NEC) method used currently. However, further development and validation of dispersion modelling, including better understanding of the chemical partitioning of residual process chemicals (many of which have surfactant properties) would improve confidence in risk assessment.

The potential effects of endocrine disrupting compounds (e.g. alkylated phenols present in many produced waters) require further investigation (OLF 1998), although research is currently limited by a lack of *in vivo* and *in vitro* bioassays. In addition, current understanding of cumulative and synergistic effects of produced water components is inadequate. Improved understanding will require research on both chemical behaviour and toxicological effects.

The eventual fates of produced water discharges are poorly known. Although it might be expected that volatile hydrocarbon fractions, including some PAHs, will evaporate to atmosphere or be metabolised by marine organisms in the water column, surface adsorption onto particulates and subsequent incorporation into sediments is a more likely fate for persistent organic compounds and metals. At present, however, quantitative understanding of these processes is lacking. Widespread, low-concentration accumulation of hydrocarbons in sediments of the East Shetland Basin (including northern SEA 2 areas) has been attributed to produced water discharges (Davies and Kingston 1992).

The environmental effects of produced water discharges can be mitigated through volume reduction, improved treatment prior to discharge, and alternative disposal methods (e.g. reinjection). Produced water management and alternative disposal techniques, including reinjection, improved treatment (“polishing”), downhole separation and shut-off all tend to have significant energy requirements and therefore increase combustion emissions from power generation. At present, there are no widely accepted and robust approaches to comparative assessment of the relative effects of air emissions and discharges to water, and selection of the preferred disposal option therefore remains somewhat judgemental. Nevertheless, some operators have committed to a complete phase-out of produced water discharges in the North Sea over a short timescale.

10.4.4.5 Potential effects of drilling discharges

The past discharge to sea of drill cuttings contaminated with oil based drill mud resulted in well documented acute and chronic effects at the seabed (eg Davies *et al*. 1989, Olsgard and Gray 1995, Daan and Mulder 1996). These effects resulted from the interplay of a variety of factors of which direct toxicity (when diesel based muds were used) or secondary toxicity as a consequence of organic enrichment (from hydrogen sulphide produced by bacteria under anaerobic conditions) were probably the most important. However, through OSPAR and other actions, the discharge of oil based and other organic phase fluid contaminated material is now effectively banned and the effects of such discharges are not considered relevant to the SEA 2 process.

In contrast to oil based mud discharges, effects on seabed fauna of the discharge of cuttings drilled with WBM and of the excess and spent mud itself are subtle or undetectable, although the presence of drilling material at the seabed is often detectable chemically (eg Cranmer 1988, Neff *et al*. 1989, Hyland *et al*. 1994, Daan and Mulder 1996). Considerable data has been gathered from the North Sea and other production areas, indicating that physical disturbance is the dominant mechanism of ecological disturbance where water-based mud and cuttings are discharged (see Section 10.4.2 for review of physical disturbance effects). (Several studies, however, have noted the presence of hydrocarbons and synthetic base fluids at potentially toxic concentrations even where drilling was believed to have used exclusively WBM.)

Water based muds are of low inherent toxicity (see Ray *et al*. 1989, ERTSL 2001) and toxicological studies of the major individual constituents have reported limited or no effects (eg Tagatz and Tobia 1978, Starczak *et al*. 1992).

Seabed inspection and monitoring data from the central and northern North Sea indicate that cuttings deposition in the vicinity of single well sites is limited to the immediate vicinity (typically 10-20m) of the wellhead (eg UKOOA 2001, Cordah 1998, ALTRA 1996), and typically takes the form of an oval pile composed mainly of surface hole cuttings (surficial and shallow formation sediments with small quantities of gel sweep additives). Subsequent discharges of WBM cuttings from closed drilling are dispersed more widely in the water column, and deposition is often detectable only through chemical analysis of characteristic tracer components (eg barium). Quantities of cement may also be discharged directly to seabed during installation of casing.

Surface hole cuttings piles in the central and northern North Sea will be dispersed, typically over a time scale of 1-10 years, mainly through re-suspension and bedload transport due to wave-induced currents. At the water depths involved, wave-induced currents of the required velocity (>1 m/s) are generally associated with winter storm events during which significant transport of natural surficial sediments will also occur.

Pockmarks are widespread in the central and northern North Sea (see Section 5.2), and due to their topographic relief, it is conceivable that pockmarks could represent depositional “sinks” for contaminant accumulation. Preliminary data from studies of representative pockmarks in the Fladen Ground, being carried out on behalf of DTI, indicates no observable differences in sediment characteristics or ecology between pockmarks and adjacent seabed. The environmental risk associated with discharge of water-based mud and cuttings is therefore considered to be low.

Near-bed current velocities and sediment mobility in the southern North Sea are generally sufficient to prevent detectable local accumulation of cuttings. Significant topographic depressions (eg “Pits” present north of the Norfolk Sandbanks) could act as depositional sinks, although the majority of these features appear to be tidally scoured, with little evidence of recent deposition. Circulatory residual currents around sandbanks result in accretion over bank crests (see Section 5.4) and a proportion of WBM cuttings discharges in southern North Sea areas may be deposited over such features. Recent survey work carried out for DTI has acquired samples to test this hypothesis (sample analysis is ongoing).

Reported accumulation of barium in depositional areas of the Skagerrak (OSPAR 2000) may also be linked to wide area dispersion of cuttings from the North Sea, including southern areas from where sediment transport processes may move particulate contaminants over considerable distances.

In contrast to the general picture of limited effects of WBM discharges, Cranford and Gordon (1992) reported low tolerance of dilute bentonite clay suspensions in sea scallops (*Placopecten magellanicus*). Cranford *et al*. (1999) found that used water based mud and its major constituents, bentonite and barite caused effects on the growth, reproductive success and survival of sea scallops, which were attributed to chronic toxicity and physical disturbance. It may be that *Placopecten* is especially sensitive to drill muds (or fine sediments in general) or that in the field, water based drilling discharges very rapidly disperse to below effective concentrations.

Studies of the effects of water based mud discharges from 3 production platforms in 130-210m off California found significant reductions at some stations in the mean abundance of 4 of 22 hard bottom taxa investigated using photographic quadrats (Hyland *et al*. 1994). Hyland *et al*. (1994) concluded that these reductions reflected possible negative responses to drilling discharges, attributed to the physical effects of particulate loading, namely disruption of feeding or respiration, or the burial of settled larvae. It is unlikely that drilling over hard seabed substrates would occur in the SEA 2 areas.

10.4.4.6 Control and Mitigation

Produced water discharges are regulated under the Prevention of Oil Pollution Act 1971 with limits set for the proportion of oil in water (currently 40 mg/litre) and the daily flow which may be discharged. Through OSPAR, the UK is committed to a 15% reduction in total discharged volume of oil in produced water by 2006 and there is a presumption against discharge from new developments. Chemical use has been monitored through the OCNS which will be superseded shortly by new chemical regulations (draft *Offshore Chemicals (Pollution Prevention and Control) Regulations 2001*). These regulations are expected to introduce a new permit system for the use and discharge of chemicals offshore and include a requirement for site specific risk assessment.

The management of produced water and chemical discharges will continue to be a key issue addressed through the environmental assessment process for planned developments (under *The Offshore Petroleum Production and Pipe-lines (Assessment of Environmental Effects) Regulations 1999*).

Current technical approaches to the minimisation and management of produced water discharges include reinjection (to reservoir, or more usually to a receiving formation via a dedicated well), and improved treatment. Produced water reinjection remains technically challenging, and requires significant energy consumption, but is likely to be a preferred option for many new field developments. Future technology, including downole separation and improved reservoir management, may also substantially reduce produced water discharges in comparison to previous oilfield practice.

Solid and aqueous waste discharges from exploration and production operations are also regulated under the *Prevention of Oil Pollution Act 1971*, and are exempted (at the point of production) from the *Food and Environment Protection Act 1985*. Discharges associated with specific exploration drilling or development projects in the licensed areas require to be assessed under the *Offshore Petroleum Production and Pipe-lines (Assessment of Environmental Effects) Regulations 1999*.

Alternative disposal methods for cuttings, including onshore treatment and reinjection as currently implemented for oil and synthetic-based muds, may also be feasible for drilling with water-based mud (for example, if particular benthic biotope sensitivities were identified). However, the environmental benefit of these approaches would require detailed assessment.

10.4.4.7 Conservation sites

Potential offshore conservation sites in the SEA 2 areas, if any, would be designated primarily with regard to seabed features (sandbanks and pockmarks), and associated benthic communities (see Section 6.3). Given the dispersion of produced water discharges, effects on the benthos of designated offshore conservation sites are unlikely.

Cuttings discharges could, if a well location was sufficiently close to a designated site, disperse over or accumulate in a designated site, with potential effects on benthos as reviewed above. This is probably unlikely in view of the small number of wells forecast, and the locations of potential features of designation. However, potential effects from specific projects would require to be evaluated (through the Appropriate Assessment mechanism) and mitigation measures adopted.

10.4.4.8 Conclusions

The environmental effects of produced water discharges are limited primarily by dispersion, below NEC. Produced water discharges are, and will continue to be dominated by oil developments in the central and northern North Sea. Key concerns over produced water discharges relate to cumulative effects of oil and possible biological effects of residual process chemicals (see also Section 5.5. Produced water will remain the focus of regulatory controls, and a range of technical developments are under development which may offset the predicted increase in total volumes discharged to the North Sea, improve the quality of discharges or provide alternative disposal methods. Incremental contributions from newly licensed SEA 2 blocks would be minimal (maximum predicted 2.4% of total North Sea produced water discharge, assuming no reinjection).

Discharges of WBM cuttings in the North Sea have been shown to disperse rapidly and to have minimal ecological effects. Dispersion mechanisms could, in theory, lead to localised accumulation in relation to topographic features (pockmark basins and sandbank crests, in the central and southern North Sea respectively) although this is considered unlikely to be detectable. Forecast cuttings discharges from northern and central SEA 2 areas represent an annual increment of 2-16% of predicted discharges from existing licensed areas.

10.4.5 Atmospheric emissions

10.4.5.1 Introduction

Atmospheric emissions from offshore exploration and production of oil and gas contribute to reduction of local air quality, and to atmospheric concentrations of greenhouse and acid gases on a global scale. Following consideration of the predicted scale of emissions associated with potential activity in the SEA 2 areas, the SEA 2 Effects Workshop concluded that potential effects of emissions on local air quality may require further consideration.

The SEA 2 assessment considers the potential environmental effects of further licensing to oil and gas exploration and production activity in terms of continued or future non-oil and gas uses, environmental contamination, biodiversity and conservation of the area. The wider policy issues of continued oil and gas production from the UKCS and sustainable development of the overall national hydrocarbon reserves, specifically with regard to greenhouse gas emissions and UK commitments under the Kyoto Protocol, are not considered since these are subjects for a different appraisal forum.

10.4.5.2 Sources

The major sources of emissions to atmosphere are internal combustion for power generation by installations, terminals, vessels and aircraft, flaring for pressure relief and gas disposal, cold venting and fugitive emissions.

Power requirements for the offshore industry are dominated by production installations (typically >50MW per platform), with substantially smaller contributions from mobile drilling units (typically 10MW per unit) and support vessels. The major energy requirement for production is compression for injection and export, with power generated by gas or dual-fuel turbine. Fuel gas accounted for 59.5% of total CO_2 emissions from the UKCS in 1998 (UKOOA 1999).

Short-term trends in emissions from exploration and production are variable – from 1996-1998, CO_2 emissions increased slightly (by 5%), methane emissions decreased by more than 10%, and NOx emissions have increased by 14% (UKOOA 1999).

Flaring from existing UKCS installations has been substantially reduced relative to past levels, largely through continuing development of export infrastructure and markets, together with gas cycling and reinjection technologies. Total flaring (excluding terminals) on the UKCS averaged 4.76 million m^3/d in 2000, compared to 6.48 million m^3/d in 1991 (DTI 2001).

New developments will generally flare in substantial quantities only for pressure relief, with “zero routine flaring” now considered a realistic design target for planned developments. Other than start-up flaring, subsea tie-back developments, which are predicted to account for the majority of production from proposed licence areas (Section 4.3), will generally have little effect on host platform flaring. Further production developments on the UKCS would (at least partially) offset reduced emissions from mature areas of the UKCS, in which production of both oil and gas is expected to reach a peak at some point within the next decade, most likely between 2002 and 2004. (Note: the timing of the peak remains uncertain and is subject to a range of factors, including investment decisions and success in exploration.)

Venting and fugitive emissions account for a substantial proportion of hydrocarbon production methane and VOC emissions. Crude oil storage on FPSOs also results in methane and VOC emissions. Tank venting during tanker loading has been a particular area of concern with VOC losses from a typical shuttle tanker, with a carrying capacity of 120,000 tonnes, of the order of 85-240 tonnes per load of crude oil (OLF 1993), ie emission factor in the range 0.0007 to 0.002 tonnes VOC / tonne oil. Potential discoveries in future SEA 2 licence areas are very likely to export through existing pipeline infrastructure (Section 4.3), although the possible new platform hub in the northern North Sea western margin could export via tanker. In addition, developed reserves could have similar emission factors to the above, or may be of lighter oil or condensates, which would tend to result in higher emission factors, although improved emissions control technologies are currently under development.

Significant VOC emissions are also associated with tanker loading and offloading at oil terminals, such as Sullom Voe, Flotta, Nigg and Hound Point. Onshore emissions mainly from terminals accounted for 56% of total VOC emissions from UKCS exploration and production in 1998 (UKOOA 1999), and further developments in the SEA 2 area would be expected to contribute to this source.

Assuming that reservoir characteristics, development methods and production technology for forecast developments in the North Sea would be comparable to current developments, incremental emissions can be estimated on a pro rata basis from production forecasts (see Section 4.3, NB median values from DTI forecast oil and gas production have been used).

Using 2000 production as a baseline (DTI 2001), both oil and net gas production, and therefore emissions, are forecast to increase (13.4% and 1.8% respectively) with peak production predicted to occur in 2002. Production, and therefore emissions, in newly licensed blocks are forecast to peak in 2009 (oil) and 2010 (gas), with production rates of both oil and gas equivalent to 2.4% of 2000 production – see Table 10.4.

Table 10.4 – Predicted atmospheric emissions from SEA 2 licence area production

	1999 total (tonnes / year)	SEA 2 area forecast, peak production (tonnes/year)
Carbon dioxide	24,770,465	589,135
Carbon monoxide	43,381	1,032
Nitrogen dioxide	73,941	1,759
Sulphur dioxide	12,198	290
Methane	87,151	2,073
Volatile hydrocarbons	184,474	4,387

10.4.5.3 Potential effects

Gaseous emissions from the combustion of hydrocarbons and other releases of hydrocarbon gases contribute to atmospheric concentrations of greenhouse gases, acid gases and reduction in local air quality.

Atmospheric greenhouse gases include carbon dioxide (CO_2), methane (CH_4), and oxides of nitrogen (NO_X). Man-made emissions of greenhouses gases (particularly CO_2) are implicated in amplifying the natural greenhouse effect resulting in global warming and potential climate change (IPCC 1995). The potential effects of emissions of greenhouse gases are therefore global in scale.

Atmospheric acid gases include sulphur dioxide (SO_2) and oxides of nitrogen (NO_X). These gases react with water vapour forming acids, and increasing the acidity of clouds and rain which can result in vegetation damage, acidification of surface waters and land, and damage to buildings and infrastructure. In addition these gases can transfer directly to terrestrial surfaces through dry deposition (close to the source) causing similar damage to acid rain (UKTERG 1988). The potential effects of emissions of acid gases are considered to be most important at a regional scale.

Reduction in local air quality through inputs of contaminants such as oxides of nitrogen (NO_X), volatile organic compounds (VOCs) and particulates, which contribute to the formation of local tropospheric ozone and photochemical smogs, which in turn can result in human health effects (EPAQS 1996).

10.4.5.4 Conclusions

Potential environmental effects of acid gas and greenhouse emissions are, respectively, regional and global in nature. Local environmental effects of atmospheric emissions are not expected to be significant, in view of the high atmospheric dispersion associated with offshore locations.

Significant combustion emissions from flaring are not expected from potential development in the possible SEA 2 licence areas, in view of regulatory controls and commercial considerations, and combustion emissions from power generation are unlikely to represent a major contribution to industry or national totals. Overall, peak annual emissions from production in newly licensed SEA 2 blocks are estimated as 2.4% of current (2000) emission levels from UKCS production (including onshore terminals).

VOC emissions resulting from tanker loading are, potentially, an issue for consideration of mitigation in the event of developments involving this export option (this is not currently forecast as a development scenario).

10.4.6 Wastes to shore

10.4.6.1 Introduction

The return of wastes from offshore operations for onshore disposal involves a number of potential sources and receptors of effects, of which the air quality and land use implications of onshore disposal of mud and cuttings are considered below.

10.4.6.2 Sources

The use of oil-based mud (OBM) systems is necessary under some drilling circumstances, for example to provide lubricity in highly deviated sections or to increase hole stability when drilling through shale or halite formations. Discharge of OBM to the marine environment is now effectively prohibited in the UKCS, so that reinjection or containment with onshore disposal are the only available disposal methods for cuttings drilled using OBM.

Reinjection of cuttings to a receiving formation, either through a dedicated disposal well or via the annulus of an exploration or appraisal well, depends on a number of factors including the availability of space and power for the required equipment, suitable well design and the availability of a suitable formation. Containment and onshore disposal is therefore a preferred option for some wells, on engineering and commercial grounds.

The quantity of OBM cuttings generated from individual wells is usually minimised so far as possible, largely to minimise transport and treatment costs. Typical quantities are of the order of a few hundred tonnes per well, giving a total quantity associated with exploration, appraisal and development wells in SEA 2 licence areas of ca. 12,500 tonnes. As context, assuming an equivalent quantity of 250 tonnes OBM cuttings per well, the maximum number of UKCS development wells forecast by DTI corresponds to 65,000 tonnes of OBM cuttings.

A number of contractors provide treatment services for OBM cuttings in the UK, Netherlands and Norway, generally with the aim of recovering base fluid and producing a solid by-product with some alternative use. Treatment methods include solvent extraction and thermal desorption, and are generally energy-intensive. To date, UK contractors have not found a large-scale viable use for "clean" cuttings and material is being stored.

10.4.6.3 Potential effects

Onshore cuttings treatment will result in combustion emissions associated with power generation, and possibly in solvent vapour emissions, depending on treatment method. At present, no comparative assessment of emissions and energy consumption of alternative processes is in the public domain although individual Operators have audited contractors. The UKOOA Cuttings Joint Industry Project is currently conducting an assessment of onshore treatment options for recovered cuttings from "legacy" cuttings piles. Overall, however, emissions from this source will make a minor contribution to UKCS atmospheric emissions and atmospheric concentrations of greenhouse and acid gases.

Land use issues resulting from onshore cuttings treatment derive from the lack of a commercially viable use for processed cuttings. Although some use has been made for construction purposes, the high salt and shale content influences mechanical properties and limits the use of cuttings as structural material (eg for road bed) or as a concrete additive. Landfill may be the eventual solution if the processed material meets specifications for disposal as controlled waste. Long-term residual liability for disposal of this material under Duty of Care legislation has not been resolved.

10.4.6.4 Conclusions

Sustainable and commercially viable options for onshore disposal of OBM cuttings remains a significant challenge for the industry, while transfer between installations for reinjection would ease the situation.

However, the associated environmental effects of onshore treatment and long-term storage of processed OBM cuttings are not considered to represent significant environmental effects of E&P activities in SEA 2 areas, in the context of overall emissions and waste disposal to land.

10.4.7 Oil spills

10.4.7.1 Introduction

Environmental risk is generally considered as the product of probability (or frequency) and consequence. The environmental consequences of oil spills are associated primarily with seabirds, marine mammals, fisheries and coastal sensitivities; and are considered in Environment Description Sections 6.5 to 6.8. Additional effects, generally considered less significant (at least in terms of publicity), include those on air quality (through evaporation of volatile hydrocarbons), seawater quality (through dispersion of hydrocarbons, often chemically assisted), seabed habitats and communities including potential conservation sites, plankton and other pelagic organisms, other users including the fishing industry and recreational vessels, and human health.

The sources, frequency and scale of hydrocarbons spills are considered below.

A major feature of oil and gas production on the UKCS is the distinction between oil (and condensate) fields in the central and northern North Sea, and gas fields in the southern

North Sea (see Figures 8.1 and 8.2). Large oil spills resulting from E&P have been associated with crude oil (pipeline and tanker loading sources, with the additional potential for uncontrolled oil blowout), and significant spill risks are therefore limited to central and northern SEA 2 areas. The largest inventories of persistent oil associated with E&P in southern gas field areas are of support vessel fuel oil and oil based drilling fluids.

10.4.7.2 Spill scenarios and frequency

Hydrocarbon spills have been reported from exploration and production facilities on the UKCS since 1974 under PON1 (formerly under CSON7), with annual summaries published in the "Brown Book" series. This data – the DTI PON1 database – has been widely used for risk assessment in the preparation of Environmental Statements and Oil Spill Contingency Plans for exploration wells and developments in licensed areas west of Shetland and elsewhere on the UKCS. A geographically wider database, collated by SINTEF, includes reported well control incidents (i.e. "blowouts" involving uncontrolled flow of fluids from a wellbore or wellhead) from the North Sea and Gulf of Mexico from 1957 (Holand 1996).

The total amount of oil reported spilled during 2000 was 78 tonnes which continues the downward trend of recent years (DTI 2001). The number of reports made to the DTI increased from 372 in 1999 to 423 in 2000. It is clearly evident that the trend for reporting even the smallest of spills continues, with 405 reports for spills of less than 1 tonne; these represent 96% of reports.

Blowouts are extremely rare in modern drilling, with a range of historical frequencies quoted by previous Environmental Statements (reviewed in SEA 1). Recommended blowout frequencies as input basis data for risk analysis of North Sea installations are provided by Holand (1996, Table 12.2), based on the SINTEF database. These vary from 0.0049 shallow gas blowouts/well for exploration drilling, to 0.00005 blowouts per production well-year (equivalent to 0.00075 blowouts/well assuming a typical 15 year well life). The recommended frequencies do not distinguish between gas and oil, which makes application to spill risk assessment difficult.

The range in blowout frequencies used in oil spill risk assessments is partly due to differences in the definition of blowout (eg exclusion of shallow gas events), and to difficulties in comparing risk units (eg events per well, events per workover, events per wireline job, events per well-year). It should also be noted that the historical blowout frequency databases are dominated by conventional (overbalanced, jointed pipe) drilling, in which hydrostatic pressure from the mud column and the blowout preventer (BOP) form primary and secondary barriers respectively. Coiled tubing and underbalanced drilling are more recent technical developments, mainly used in production and workover situations, which may involve significantly different barrier philosophies and therefore different risk scenarios.

The only significant blowouts on the UKCS to date have been from *West Vanguard* (1985) and *Ocean Odyssey* (1988), both involving gas. The April 1977 Ekofisk blowout in the Norwegian sector released about 25,000 tonnes of oil, but killed relatively few birds due to the fortuitous timing (Mehlum 1980). The UK Health and Safety Executive's Offshore Safety Division (OSD) records well kicks, involving an unexpected but controlled flow of formation fluids into the wellbore, including "serious" kicks defined as those that posed a safety hazard to personnel on the installation or had the potential to cause a significant safety hazard (Hinton 1999). Between 1988 and 1998, 52 serious kicks have been recorded from 3,668 UKCS wells (an occurrence rate of 1.4%), none of which resulted in pollution (most kicks involved gas).

Seabed blowout flow rates in deeper water will be limited by hydrostatic pressure from the overlying water column. Qualitative analysis and modelling suggests that high flow rate blowout scenarios (eg to surface via drillpipe) will tend to bridge relatively quickly, however, sustained well flow at lower rates can be simulated under some circumstances, which could result in a prolonged release in the absence of intervention.

DTI PON1 data indicates that topsides and infield flowlines and risers are the most frequent sources of spills from production operations, with most spills being <1 tonne. A large proportion of reported oil spills in recent years (since about 1990) have resulted from process upsets (separation and/or produced water treatment), causing small volume sheens from oil in produced water discharges and from oily drainage (usually via caisson discharges). For example, in 2000 there were 423 reports of spills (including observations from the aerial surveillance programme) which accounted for 78 tonnes of oil (DTI 2001). The proportion of total oil spilled, due to oil-based mud, has dramatically reduced from 64.7% in 1993 to 0.6% in 2000. Major spill events from UKCS production facilities include the Claymore pipeline leak, 1986 (estimated 3,000 tonnes), Piper Alpha explosion, 1988 (1,000 tonnes) and the Captain spill, 1996 (685 tonnes). Although significant, these volumes are negligible in comparison to other E&P discharges, together with other anthropogenic sources of oil in the marine environment. For example, in 1995 a total of 11,800 tonnes of oil was discharged by the offshore oil and gas industry to the North Sea, of which 2% originated from accidental spills (OSPAR 2000). Estimates of oil inputs from other sources have not been subject to regular reporting within OSPAR, although the 1993 Quality Status Review estimated a total oil input of 85,000-209,000 tonnes per year to the North Sea, including oil-based drilling fluids, riverine sources, shipping and natural seepage (NSTF 1993).

The major types of spill from mobile drilling rigs have been organic phase drilling fluids (and base oil), diesel and crude oil. There has been a correlation between the number of reported spills and number of wells drilled, but no consistent trend in the volume of hydrocarbons spills from mobile rigs since 1984 (a marked increase between 1986-1993, with a subsequent decrease to <100 tonnes/year). Estimated spill risk from UKCS subsea facilities averaged just over 0.11 spills per year (equivalent to a risk of one spill in any one year of 0.003 from an individual facility), with almost all reported spills <5bbl in size.

Since 1986 the UK has carried out unannounced surveillance flights over offshore installations in accordance with international obligations under the Bonn Agreement. The Scottish Fisheries Protection Agency, MAFF and the Maritime and Coastguard Agency also undertake routine overflights of the UK waters. The DTI works closely with these agencies to ensure that any oil spill emanating from an offshore installation is reported, so the effective level of surveillance is significantly greater than the 300 hours currently funded. In particular, the Maritime and Coastguard Agency routinely survey the gas platforms in the Southern North Sea. In 2000, 300 hours were flown on 55 'dedicated' oil rig patrols ie those funded solely by the DTI. In total, 2,219 surveys of installations were undertaken. The total amount of oil observed from unreported spills was just over 1 tonne from 32 separate detections (DTI 2001).

The DTI uses a computer link to the aerial surveillance aircraft which transmits photographic images of pollution incidents and enables the DTI to investigate oil spill incidents as they happen. The DTI is currently upgrading the computer link to include the transmission of video imagery.

Subsea oil spills pose particular problems, both in terms of detection and reporting of actual events, and in terms of consequence prediction. Chronic leaks from pipelines, manifolds and risers may not result in surface oil, and may be very difficult to quantify. This issue will become an increasing challenge with further development using subsea facilities.

10.4.7.3 Spill fate

The fate of oil spills to the sea surface is relatively well understood, in contrast to subsea spills in deep water. Following a surface oil spill, there are eight main oil weathering processes:

Evaporation – Lighter components of an oil evaporate to the atmosphere. The amount of evaporation and the speed at which it occurs depend upon the volatility of the oil and the ambient temperature. An oil with a large percentage of light and volatile compounds will evaporate more than one predominantly composed of heavier compounds. Rough seas, high wind speeds and high temperatures tend to increase the rate of evaporation and thus the proportion of an oil lost by this process.

Dispersion – Waves and turbulence at the sea surface can cause a slick to break up into fragments and droplets of varying sizes which become mixed into the upper levels of the water column. Some of the smaller droplets will remain suspended in the sea water while the larger ones will tend to rise back to the surface, where they may either coalesce with other droplets to reform a slick or spread out to form a thin film. Small droplets have a greater surface area which facilitates other natural processes such as dissolution, biodegradation and sedimentation. The speed at which an oil disperses is largely dependent upon the nature of the oil and the sea state, and occurs most quickly if the oil is light and of low viscosity and if the sea is very rough. The use of chemical dispersants can accelerate the process of dispersion.

Emulsification – Emulsification occurs as a result of physical mixing promoted by wave action. The emulsion formed is usually very viscous and more persistent than the original oil and formation of emulsions causes the volume of the slick to increase between three and four times and slows and delays the other processes which cause the oil to dissipate. Emulsions are not normally amenable to chemical dispersants. Oils with an asphaltene content greater than 0.5% tend to form stable emulsions which may persist for many months after the initial spill has occurred. Oils with a lower asphaltene content are less likely to form emulsions and more likely to disperse. Emulsions may separate back into oil and water again if heated by sunlight under calm conditions or when stranded on shorelines.

Dissolution – Some compounds in an oil are water soluble and will dissolve into the surrounding water. The proportion dissolving depends on the composition and state of the oil, and occurs most quickly when the oil is finely dispersed in the water column. Components that are most soluble in sea water are the light aromatic hydrocarbons compounds such as benzene and naphthalene. However, these compounds are also those first to be lost through evaporation, a process which is 10-100 times faster than dissolution. In contrast to diesel, crude oil contains only small amounts of these compounds making dissolution one of the less important processes.

Oxidation – Oils react chemically with oxygen either breaking down into soluble products or forming persistent tars. This process is promoted by sunlight. This process is very slow and even in strong sunlight, thin films of oil break down at no more than 0.1% per day. The formation of tars can form an outer protective coating of heavy compounds that results in the increased persistence of the oil as a whole. Tarballs, such as found on shorelines, have a solid outer crust surrounding a softer, less weathered interior and are a typical example of this process.

Sedimentation/Sinking – Sinking is usually caused by the adhesion of sediment particles or organic matter to the oil. In contrast to offshore, shallow waters are often laden with suspended solids providing favourable conditions for sedimentation. Oil stranded on sandy shorelines often becomes mixed with sand. If this mixture is then washed off the beach into the sea it is likely to sink. In addition, if the oil is burned after it has been spilled, the tarry residues may be sufficiently dense to sink.

Biodegradation – Sea water contains a range of micro-organisms that can partially or completely breakdown the oil to water soluble compounds (and eventually to carbon dioxide and water). Many types of hydrocarbon bacteria exist and each tends to degrade a particular group of compounds in crude oil. However, some compounds in oil are very resistant to attack and may not degrade. The main factors affecting the efficiency of biodegradation, are the levels of nutrients in the water, temperature and the level of oxygen present. The creation of oil droplets, either by natural or chemical dispersion, increases the surface area of the oil and thus increases the area available for biodegradation to take place.

Combined processes – The processes of spreading, evaporation, dispersion, emulsification and dissolution are most important early on in a spill whilst oxidation, sedimentation and biodegradation are more important later. The behaviour of crude oil releases at depth will depend on the immediate physical characteristics of the release, and on subsequent plume dispersion processes.

In qualitative terms, if associated gas is released from a wellhead, manifold, flowline, pipeline or riser along with crude oil, the mixing conditions at the release point will be very intense. The pressure differential between the source and hydrostatic pressure at the release point will be a critical factor in determining the form of the oil as it is released. If the release pressure is high and the size of the escape orifice is small, the oil will be converted almost instantly into a jet or plume of small oil droplets by the effect of its escape velocity and gas expansion. The crude oil will be mechanically dispersed into the sea. These very small oil droplets will have a low buoyant ascent velocity, but will be propelled towards the sea surface by the sea water entrained by the buoyant gas plume. Because the water from the deeper layers in the possible licence area is relatively cold, the plume will tend to collapse as it mixes into warmer surface water. The entrained oil droplets may therefore be distributed into a huge volume of the water column without ever having reached the sea surface.

The normal sea surface oil weathering sequence of spreading, evaporation, natural dispersion, emulsification and drifting will be compressed into a single event of mechanical dispersion for the majority of the oil volume. The more volatile (and more toxic) oil components will not be able to evaporate; they will rapidly partition into the surrounding water. The extent of emulsification and hydrate formation is dependent on conditions at the spill site. There will be little resultant oil on the sea surface and all environmental consequences (if any) will occur in the water column (Rye and Brandvik 1997).

If there is limited or no associated gas production, the oil will be released less energetically, with less shear and immediate dispersion resulting in a larger droplet size. However, a lack of gas will also result in a less buoyant plume, and there remains a high probability of dispersion within the water column.

10.4.7.4 Spill trajectory and consequences

Oil spill trajectory modelling can be carried out deterministically (ie with defined arbitrary metocean conditions, usually "worst case") or stochastically (ie using statistical distributions for wind and current regimes). Quantitative spill trajectory modelling has not been carried out as part of the SEA 2 process, although it should be noted that modelling has been carried out in Environmental Assessments and Oil Spill Contingency Planning for exploration wells and developments in previously licensed acreage within the SEA 2 areas.

Deterministic calculations have been carried out to estimate the time to beach from the closest points to land within the SEA 2 areas (Figure 10.2). These calculations assume that a slick front will move at 3% of wind speed, and have assumed constant 30 knot wind speed (consistent with "Essential Elements" criteria for oil spill response measures used in UKCS licence conditions). Time to beach has also been calculated for summer and winter average wind speeds recorded from the area (Pilot 1997).

The shortest distance to land from any SEA 2 block is 17km, from UKCS block 42/27 to Flamborough Head, with a corresponding "Essential Elements" time to beach of 10h. Other points of closest approach to the UK mainland are from UKCS blocks 13/28 (40km from Rattray Head) and 53/01 (22km from Norfolk coast). UKCS block 2/4 is 72km from Unst in Shetland; 10/01 is 165km from the Norwegian coast; 39/02 is approximately 300km from the Danish coast; and 54/01 is approximately 100km from the Netherlands coast.

Throughout most of the SEA 2 area, with the exception of inshore parts of the southern area, tidal current velocities are relatively low and oil spill trajectory will be most influenced by wind. Most frequent wind directions vary seasonally and throughout the SEA 2 area, but are generally offshore (i.e. away from adjacent UK coastline) with the exception of the southern SEA 2 area in summer, when E / SE winds are most frequently recorded. It should be noted, however, that dominance by winds from any direction is low and wind (and therefore wind-driven oil spill track) may occur in any direction throughout the year.

The closest landfall to any part of the SEA 2 area, Flamborough Head, holds a kittiwake colony of world stature on the Bempton Cliffs accompanied by internationally important populations of guillemots and razorbills (Tasker 1995a), and is accordingly designated as a Special Protection Area. However, probable hydrocarbon reserves in the adjacent SEA 2 area are gas not oil. The risk of a significant spill of persistent oil from E&P sources is therefore low. Foreseeable oil spills which were advected into this area could be managed using chemical dispersion, subject to the agreement of conservation and fisheries agencies.

The northern SEA 2 area is within 72km (42h assuming constant 30kn wind) of major seabird breeding colonies on the east coast of Shetland, including those on Unst, Fetlar, Whalsay and the Shetland mainland Tasker 1995b). Populations of national and international importance at these east coast sites include fulmar, gannet and skuas with the exception of Noss, which also holds large numbers (ca. 40,000) of guillemots.

Offshore seabird, sea mammal and fisheries sensitivities were reviewed in Section 6. Overall seabird vulnerability to surface pollution is very high in parts of Quadrants 42, 43, 47, 48 and 49 (southern North Sea) and in coastal areas to the east of SEA 2 areas from Shetland to the Humber (Figure 6.7). Six blocks in Quadrants 20 and 21 (central North Sea) also had very high overall vulnerability. Much of the seabird vulnerability is associated with proximity of breeding colonies and post-breeding dispersal of auks and is therefore seasonal. However, vulnerability within the SEA 2 areas is very high for at least nine months of the year in the same parts of Quadrants 42, 43, 47, 48 and 49 (southern North Sea), and in all months in parts of Quadrants 42 and 47 off Flamborough Head (Figure 6.8).

Figure 10.2 - Distances and beaching times to land from SEA 2 areas

(A) Shortest distance to land: 72km (approx)

Time for oil to beach (assuming an onshore wind)

wind strength (knots)	time (hrs)	most frequent wind direction
30	42	–
17 (winter average)	80	SW (Winter)
12.5 (summer average)	103	W (Summer)

(B) Shortest distance to land: 164km (approx)

Time for oil to beach (assuming an onshore wind)

wind strength (knots)	time (hrs)	most frequent wind direction
30	97	–
17 (winter average)	182	SW (Winter)
12.5 (summer average)	234	W (Summer)

(C) Shortest distance to land: 40km (approx)

Time for oil to beach (assuming an onshore wind)

wind strength (knots)	time (hrs)	most frequent wind direction
30	24	–
10.5 (winter average)	67	S (Winter)
8.5 (summer average)	80	S (Summer)

(D) Shortest distance to land: 305km (approx)

Time for oil to beach (assuming an onshore wind)

wind strength (knots)	time (hrs)	most frequent wind direction
30	179	–
(winter average)	305	W (Winter)
(summer average)	436	W (Summer)

(E) Shortest distance to land: 17km

Time for oil to beach (assuming an onshore wind)

wind strength (knots)	time (hrs)	most frequent wind direction
30	10	–
10 (winter average)	28	SW (Winter)
9.5 (summer average)	34	E/SE (Summer)

(F) Shortest distance to land: 22km

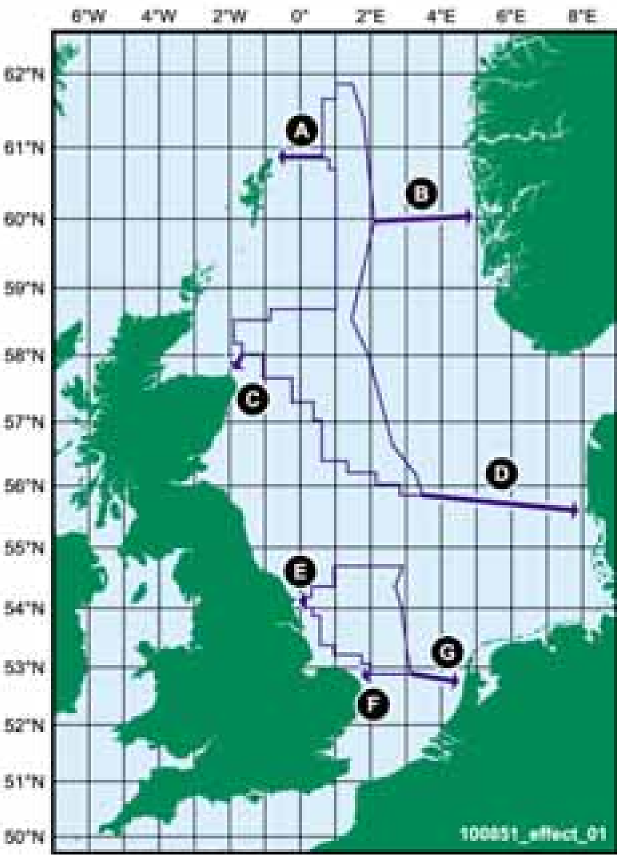
Time for oil to beach (assuming an onshore wind)

wind strength (knots)	time (hrs)	most frequent wind direction
30	13	–
12.5 (winter average)	31	SW (Winter)
9.5 (summer average)	44	SW (Summer)

(G) Shortest distance to land: 100km (approx)

Time for oil to beach (assuming an onshore wind)

wind strength (knots)	time (hrs)	most frequent wind direction
30	59	–
11.5 (winter average)	167	SW (Winter)
10.5 (summer average)	167	W (Summer)



Block 19/03, immediately adjacent to the SEA 2 area in the outer Moray Firth, is also very highly vulnerable throughout the year. A proportion of blocks within the central North Sea and southern North Sea are highly vulnerable for 6-8 months; while remaining blocks within the SEA 2 area are highly vulnerable for less than six months; ie had operational windows within which vulnerability is lower.

The most consistently vulnerable parts of the SEA 2 area are likely to contain gas reserves, from which the risk of a significant spill from E&P sources is low.

Data gaps are present for relatively few of the SEA 2 area blocks, although there are significant areas at the northern extremity of the northern North Sea area, along the Norwegian median line, and offshore from the Wash, for which vulnerability data are not available. Contingency planning for activities close to these areas should take note of these gaps, particularly with regard to the consequent difficulty in deciding whether application of chemical dispersants is appropriate.

Coastal habitats and species are also vulnerable to surface oil pollution, or to windblown oil in the case of onshore maritime habitats. After seabirds and wildfowl, seals and otters are probably the most obvious potential casualties (and certainly the most emotive in terms of press coverage), with vulnerability of intertidal habitats also high, particularly in the event of oiling of sheltered coastlines (eg Gundlach and Hayes 1978). Subtidal benthic habitats in coastal areas may be at risk more from the effects of oil spill response (i.e. dispersant application) than surface oiling.

Additional effects, listed in the introduction to this Section, were:

- Air quality
- Seawater quality (through dispersion of hydrocarbons, often chemically assisted)
- Seabed habitats and communities including potential conservation sites
- Plankton and other pelagic organisms
- Other users including the fishing industry and recreational vessels
- Human health.

Local effects on air and seawater quality have been noted in the vicinity of major oil spills, and are very dependent on physical characteristic of the oil, weather conditions and oil spill response (eg chemical dispersion). Air quality effects resulting from evaporation of volatile hydrocarbons were particularly noted during the *Braer* spill (Ritchie and O'Sullivan 1994). The *Braer* oil spill was also unusual in that almost all of the oil that was released into the sea was naturally dispersed into the water column, leading to exceptionally high concentrations of hydrocarbons in the vicinity (SOAFD 1993, Kingston *et al*. 1995).

Although a significant proportion of the total oil released from the *Braer* is thought to have accumulated in sediments (Ritchie and O'Sullivan 1994), there was no evidence from the analysis of benthic species distributions that mass mortality of the benthos took place. There were indications that a few species may have been eliminated and were recruiting at the time of the monitoring survey (Kingston *et al*. 1995). However, delayed response of benthic communities may occur where toxicity of the polluting oil is low, or initial impact sub-acute; for example following the *Florida* incident off Massachusetts when density and number of species declined over a period of 11 months before a substantial bloom of the capitellid polychaete *Mediomastus ambiseta* (Sanders *et al*. 1980). It is therefore likely that benthic community response to oil spills will be very variable.

Observed and potential effects of oil spills on planktonic communities are reviewed by the SAHFOS commissioned report.

All hydrocarbon spills can affect fish populations by tainting, caused by ingestion of hydrocarbon residues present in the water column and on the sea bed. In the event of a spill, Ministers can establish temporary fishing exclusion zones which prevent fishing for a fixed period of time to maintain public confidence in the standard of fish and shellfish as food. Recently, such fisheries exclusion zones were established after the *Braer* and *Sea Empress* oil spill incidents. The *Braer* spill had particularly severe effects on the fish farming industry in the Shetland Islands, while commercial fishing activities were only affected in a small area of the Burra Haaf. In 1997 an exclusion zone was established after a large spill at the Captain field in the outer Moray Firth. Monitoring studies conducted by FRS Marine Laboratory (SEERAD) showed a very localised area of shellfish taint that, after exhaustive chemical fingerprinting analysis, was shown not to have been derived from the spilled oil.

Human health risks associated with oil spills include direct respiratory and dermal effects of inhalation and contact with oil, and indirect effects through the food chain. Direct effects are relatively unlikely to result from oil spills in SEA 2 areas, due to limited population exposure. Indirect food chain effects would be prevented through fishery management actions, as discussed above.

10.4.7.5 Conclusion

Overall, incremental risk of oil spills associated with exploration and development in the SEA 2 area is low, particularly in the southern area where production will almost certainly involve gas. In the event of a spill of persistent oil, and in the absence of an effective response, there are possible effects of coastal oiling around much of the North Sea coastline. Offshore seabirds are also vulnerable, particularly in late summer and autumn. However, risk assessments of current activities have been carried out and established contingency measures are in place which mitigate risks.

10.4.8 Chemical spills

Although overall usage of chemicals offshore involves substantial quantities (Section 5.5), the quantities associated with forecast levels of activity in SEA 2 E&P are relatively low. In addition, process chemicals and chemical additives to drilling fluids (excluding base fluids and brines) are generally transported in small unit quantities (<1 tonne) and bulk transport, with associated risks of large-scale spillage, is rare.

The majority of chemicals used offshore are selected to be of low toxicity and bioaccumulation potential (see Section 5.5). Possible direct effects on seawater quality, plankton, pelagic invertebrates and conservation sites were identified by the SEA 2 Effects Workshop as potentially significant. In general, the fate and consequence processes which affect chemicals in the environment are comparable to those for hydrocarbon components, and are dependent on the partitioning of individual compounds between dissolved, oil and particulate phases in the water column. Persistence and biological effects of most chemicals used in the oil and gas industry are equivalent or lower than those of oil, and similar risk assessment conclusions will therefore apply.

10.4.9 Gas releases

Gas production in all three SEA 2 areas involves an associated risk of accidental gas release, at rates ranging from small (fugitive emissions) to catastrophic. Environmental and safety consequences of gas releases will depend both on scale, and on whether release gas ignites. Health and safety consequences of gas clouds and explosions are outside the scope of this assessment.

The major constituent of natural gas is the greenhouse gas methane, and gas releases on all scales will therefore contribute to global climatic effects. The significance of any foreseeable contribution, including a sustained gas blowout, to global methane emissions (which include very large fluxes through natural processes) will be negligible.

Large-scale gas releases from wellheads or trunk pipelines present a theoretical risk of effects on floating installations and vessels, through loss of buoyancy. This risk is extremely remote, as comprehensive control systems are in place to prevent and mitigate such events (including well control, pipeline integrity monitoring, depressurisation and venting systems).

10.5 Cumulative and synergistic effects

Cumulative effects are considered here as identified effects from E&P activities resulting from the proposed 20th Round licensing, which have potential to act additively with those from other oil and gas activity (including both existing activities and new activities in existing licensed areas). Synergistic effects are considered to be potential effects of E&P activities which act additively with those of other human activities (eg fishing and crude oil transport).

To some extent, all potential **sources** of effect (ie disturbance, emissions and discharges) resulting from oil and gas activity within a mature province such as the North Sea are cumulative, in so far as they are incremental to previously existing sources. Sources have therefore been quantified, based on predicted activity scenarios, and placed in the context of existing activities so far as possible throughout the assessment. However, **effects** are considered cumulative only if the “footprint” of a particular project overlaps with that of adjacent activities or if transient effects are produced sequentially.

Those potentially significant effects considered to be cumulative are tabulated below.

Table 10.5 – Potential cumulative and synergistic effects

Physical presence	Interference with other users, principally the fishing industry, was considered to result from establishment of exclusion zones and from “fastening” of gear to infrastructure or debris. There is limited potential for cumulative overlap of these effects.
Noise	The likelihood of cumulative noise effects from seismic surveys will depend on the timing and location of seismic, but is considered to be low both in terms of simultaneous surveys, and also in terms of sequential surveys affecting the same receptors (marine mammals). Seismic surveys have potential to interfere with each other and are therefore managed on a cooperative basis (“timeshared”) to avoid acoustic interference between surveys. This has the effect of substantially mitigating the probability of a single receptor receiving disturbance from

two or more sources concurrently.

Although it is likely (Section 4.3) that individual block surveys will be combined, the total duration of seismic associated with SEA2 areas will be limited (50-180 days on each area, assuming 10 day survey duration). Offshore, marine mammals are not generally confined to localised areas (eg Figure 6.12 grey seal trackplot) and it is unlikely that individuals would be exposed to the full duration of a survey. No marine mammal species are known to follow regular migration pathways in the North Sea, which could be "blocked" by cumulative seismic disturbance.

Synergistic effects of seismic in conjunction with other broadband impulse noise, for example military sonars, are possible but not considered likely.

Physical damage

Potential sources of physical disturbance to the seabed were identified as rig and laybarge anchoring, wellheads and templates, jacket footings, pipelay activities including trenching, rock-dumping and jack-up rig spud cans; of which rig anchoring and pipelay accounted for most spatial extent.

There is limited potential for cumulative overlap of these effects.

Synergistic effects of physical damage to the benthos is overwhelmingly dominated by the effects of trawling (Section 10.4.2).

Marine discharges – produced water

Produced water plumes must ultimately commingle to produce a widescale dispersion following residual circulation patterns of the North Sea. However, available evidence indicates that NECs (with reference to toxicity and other biological effect) are reached in close proximity to the point of discharge, and it is unlikely that the "effects zones" of individual discharges will overlap.

Principal synergistic sources of major contaminants, including hydrocarbons and metals, are riverine and atmospheric inputs.

Marine discharges – drilling discharges

WBM drilling discharges generally disperse widely and significant accumulations do not occur (Section 10.4.4). It is therefore likely that discharge footprints overlap, although the ecological effects will be undetectable. Potential "sinks" include pockmarks in the CNS, and sandbank accretion zones in the SNS. Both features will be subject to periodic (probably annual or less) remobilisation of sediments due to storm events.

Synergistic sources of particulate contaminants include dredge spoil disposal and coastal discharges, although these are negligible in the context of natural suspended particulate loads.

Atmospheric emissions

Greenhouse and acid gas emissions effectively contribute to a mixed regional or global "pool" and are therefore considered to be cumulative.

Emissions resulting from SEA 2 developments will be negligible in comparison to synergistic emissions from onshore sources.

Wastes to land

Emissions and landfill effects of onshore cuttings treatment will be cumulative between developments on the UKCS.

Synergistic contribution to overall effects at a regional or global scale will be minimal.

Accidental events – oil spills	Hydrocarbons from oil spills will be cumulative to produced water discharges and other (minor) offshore E&P sources; however, it is considered very unlikely that oil spill footprints will overlap given the predicted spill frequency associated with SEA 2 activities. Synergistic sources of hydrocarbons to the North Sea are reviewed in Section 5.5. Accidental spills represent a minor contribution to overall North Sea inputs.

In none of these cases of potential cumulative effects are there any known (or suspected) risks of exceeding either physiological "threshold" effects (eg with respect to toxicant burdens); population sustainability thresholds or assimilation capacity of the ecosystem. It is therefore concluded that none of the cumulative effects identified will lead to potentially severe consequences. Indeed, the QSR 2000 report concludes that the efforts of OSPAR and others have produced a significant effect in improving the protection of the marine environment of the North-east Atlantic. The trends towards worsening pollution have been reversed, and in a substantial number of significant cases the source of the pollution has been stopped.

10.6 Transboundary effects

It is a requirement for Strategic Environmental Assessment that transboundary effects are identified, under *European SEA Directive (2001/41/EC)* and the *Espoo Convention*; and this requirement also applies to project environmental assessments conducted under the *Offshore Petroleum Production and Pipe-lines (Assessment of Environmental Effects) Regulations 1999*.

Consideration of transboundary effects is intended to promote adequate consideration of, and consultation between the relevant governments, on transboundary effects where a plan or programme in one state may have significant effects on the environment of another.

The Convention on Environmental Impact Assessment in a Transboundary Context was signed in 1991, and is known as the *Espoo Convention*. This applies to various major activities with the potential to cause transboundary effects and includes offshore hydrocarbon production and large diameter oil & gas pipelines. Projects need to be screened for the potential transboundary effects and an Environmental Impact Assessment and international consultation by government conducted if necessary.

Clearly, offshore activities have a high likelihood of transboundary effects, both because of location adjacent to international boundaries and due to the unbounded nature of the marine and atmospheric environment.

The SEA 2 areas are contiguous with continental shelf areas under the jurisdiction of Norway, Denmark, Germany and the Netherlands, as defined by UNCLOS. Norway is a member of the European Free Trade Association but not a member of the European Union (EU); other contiguous states are full members of the EU. All states bounding the North Sea are members of OSPAR. Prevailing wind and residual water circulation of the North Sea will result in the transboundary transport of discharges to water (including particulates) and atmospheric emissions.

Sources of potentially significant environmental effects, with the additional potential for transboundary effects, are:

- Underwater noise
- Marine discharges – produced water
- Marine discharges – drilling discharges
- Atmospheric emissions
- Accidental events – oil spills

All of the above aspects may be able to be detected physically or chemically in adjacent state territories, particularly from activities undertaken in SEA 2 areas close to the international boundary. The scale and consequences of environmental effects in adjacent state territories will be comparable to those in UK territorial waters, and are considered in Section 10.4. There are no identified transboundary effects in which environmental consequences in a neighbouring state are overwhelmingly due to activities resulting from the proposed 20th Round licensing.

10.7 Socio-economic effects

The socio-economic implications of proposed licensing in SEA 2 areas have been assessed by the Department of Economics, Aberdeen University (Alex Kemp and Linda Stephen pers. comm.). The following section summarises the findings of their work.

The probable number and timing of exploration and appraisal wells, discoveries and developments were calculated on the basis of DTI estimates of prospects and exploration success rate. Monte Carlo techniques were used to determine the likely results of exploration in the southern, central and northern North Sea in terms of reserve size, and costs of development, operation and decommissioning. The Monte Carlo simulation gave a:

- 122 Billion cubic feet (3.66 billion m^3) field discovered in the SNS which would be developed in 2004 with development costs of $3.33/barrel of oil equivalent (boe) and a 98 Bcf (2.77 billion m^3) field discovered in the SNS which would be developed in 2005 with development costs of $2.97/boe.
- 22.8 million barrel (0.65 million m^3) oil field in the CNS which would be developed in 2006 with development costs of $4.78/barrel and a 31.8 million barrel (0.9 million m^3) oil field discovered in the CNS which would be developed in 2007 with development costs of $3.88/barrel.
- 16.2 million barrel (0.46 million m^3) oil field in the NNS which would be developed in 2006 with development costs of $4.78/barrel.

Using DTI 2001 Brown Book data for current production and forecast production for the UKCS, the contribution of predicted SEA 2 activities and production are shown in Figures 10.3 to 10.9 (assuming a $28/ barrel and 25p/therm or $20/ barrel and 18p/therm price).

Effects of resultant subsea and other tieback developments on field life of existing installations, and capacity of existing oil and gas export infrastructure (including onshore reception facilities) were also assessed on an individual Quadrant basis. The SNS is a mature area with a proliferation of infrastructure. In some cases the SEA 2 blocks or part blocks in the SNS potentially offered in the 20th licensing round are close to a number of existing installations but in other cases they are relatively remote. Existing infrastructure may be less accessible in the NNS than in the SNS. In general, predicted gas production could be handled through existing pipeline and terminal infrastructure (to St Fergus in the CNS and NNS, and to Theddlethorpe, Easington, Dimlington or Bacton in the SNS).

If the SEA 2 area is relicensed, if exploration and development is as expeditious as shown in the Aberdeen University study and if oil and gas prices remain at their current levels then more than 424 million extra barrels (67.9 million m^3) of oil and 790 extra Bcf (22.4 billion m^3) of gas may be extracted. With low oil and gas prices, less than 334 million extra barrels (53.5 million m^3) of oil and less than 392 extra Bcf (1.1 billion m^3) may be extracted. Over a ten year period almost £925 million more may be spent on development and £881 million more on operating costs than would be the case without relicensing of the SEA 2 area (assuming a $20/barrel oil price and an 18p/therm gas price. With a $12/barrel oil price and a 12p/therm gas price, development expenditure may be only £555 million and operating expenditure less than £544 million.

The $20 oil price could result in a peak of 8,977 total extra jobs in the UK in 2009, of which 858 are estimated to be direct. At $12/barrel oil price, the estimated extra total employment is 3,921 jobs, 404 of which are direct in the same year. The peak number of extra petroleum related jobs with the low oil price occurs in 2008 at 4,547. The number of employees in the petroleum industry is declining and has been for some time although there also appear to be skill shortages at the moment. The UKCS may be a mature province but the skills and expertise acquired are exportable assets. Regular and wide ranging licensing rounds could help maintain expenditure in the industry which in turn may help sustain employment levels and reverse the trend towards skills shortages by giving some security to those employed in the industry. Petroleum companies are primarily international and therefore the UK competes for funding and skilled staff with other petroleum producing provinces. If the skills base is not maintained, any competitive advantage which the UK has acquired may be lost.

Tax revenues to the UK Treasury have a complex relationship to the world market price of oil and gas. Tax revenues are calculated taking into account tax relief for exploration and appraisal activities and the fiscal regime in force at the present time. Forecast tax revenue ranges from £797 million over a 20 year period at the $28/barrel and 25p/therm case to -£23 million at the $12/barrel and 12p/therm case. Under low price conditions, Government revenues from 20th round are likely to be negative, when relief is given.

Figure 10.3 Predicted number of SEA 2 exploration, appraisal and development wells, southern North Sea. DTI 2001 Brown Book estimate for existing licensed acreage also shown.

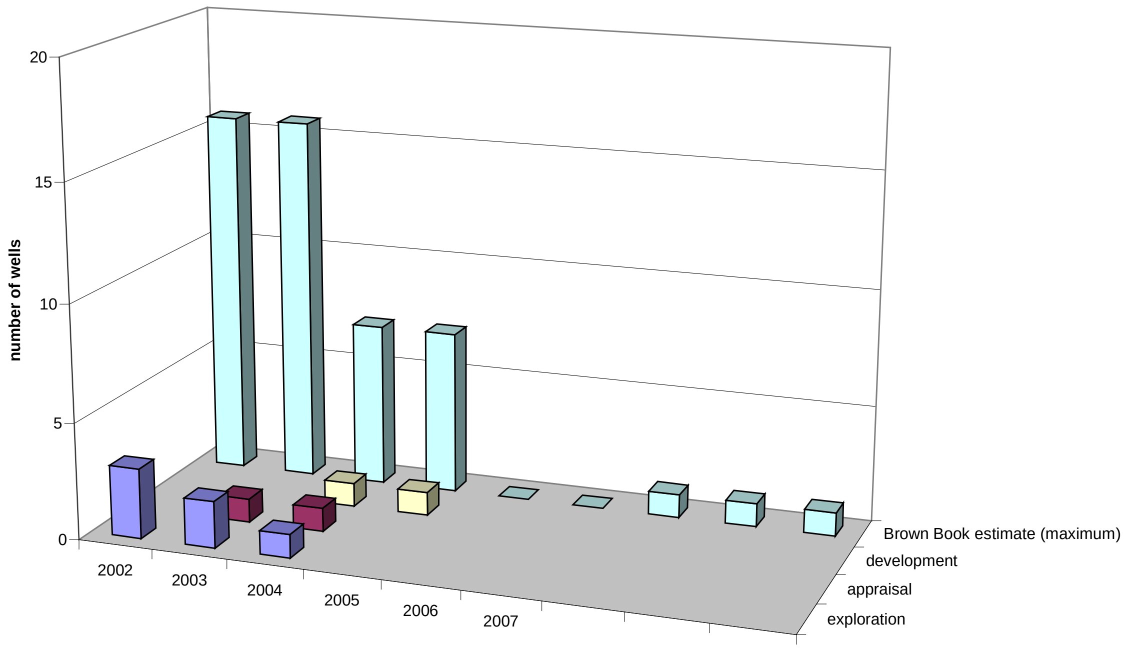


Figure 10.4 - Predicted number of SEA 2 exploration, appraisal and development wells, central North Sea. DTI 2001 Brown Book estimate for existing licensed acreage also shown.

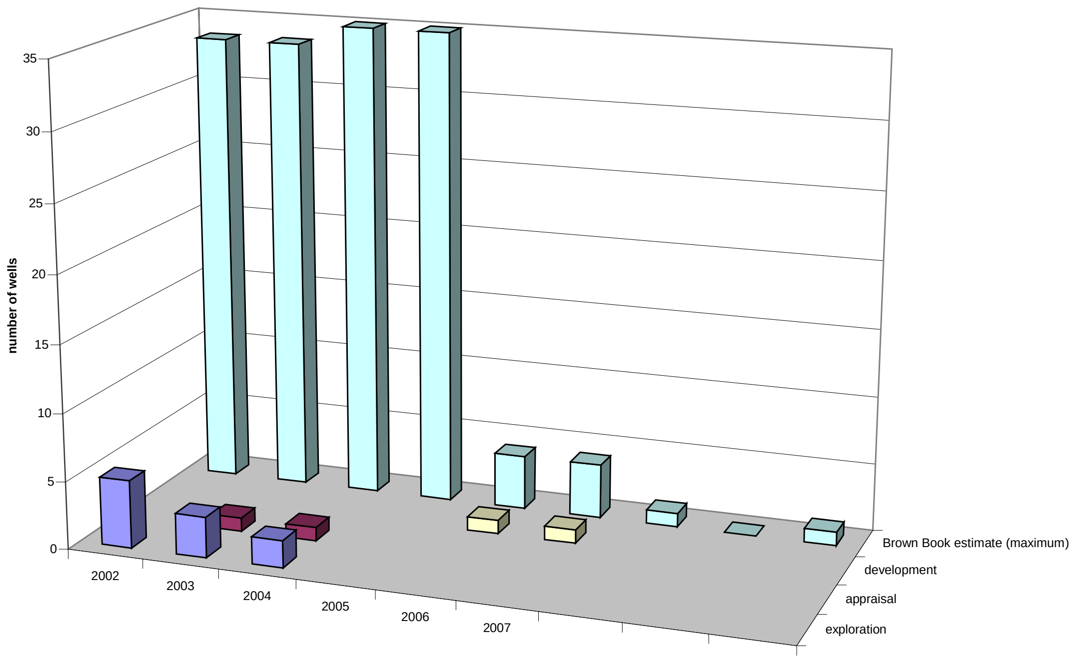


Figure 10.5 - Predicted number of SEA 2 exploration, appraisal and development wells, northern North Sea. DTI 2001 Brown Book estimate for existing licensed acreage also shown.

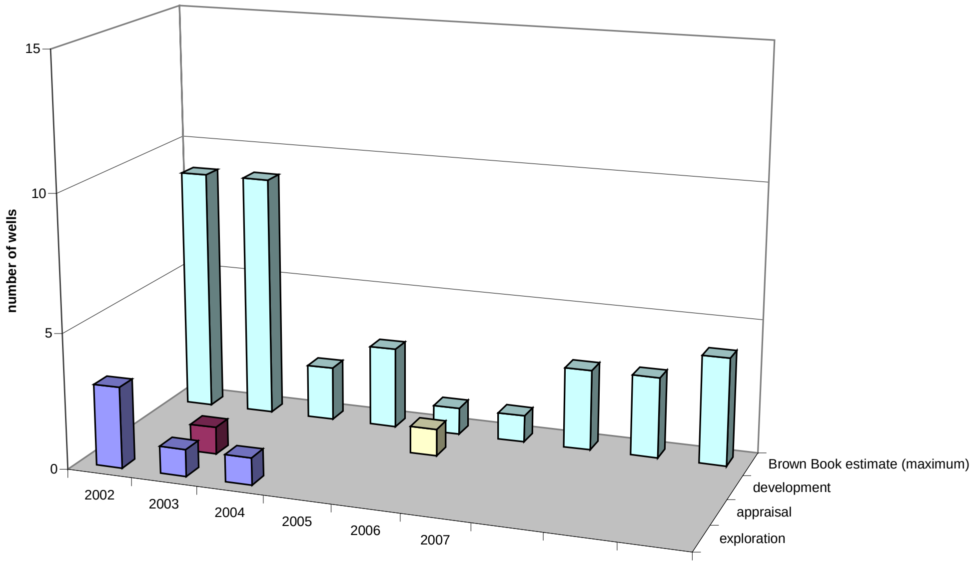


Figure 10.6 - Predicted gas production profile for additional SEA 2 developments

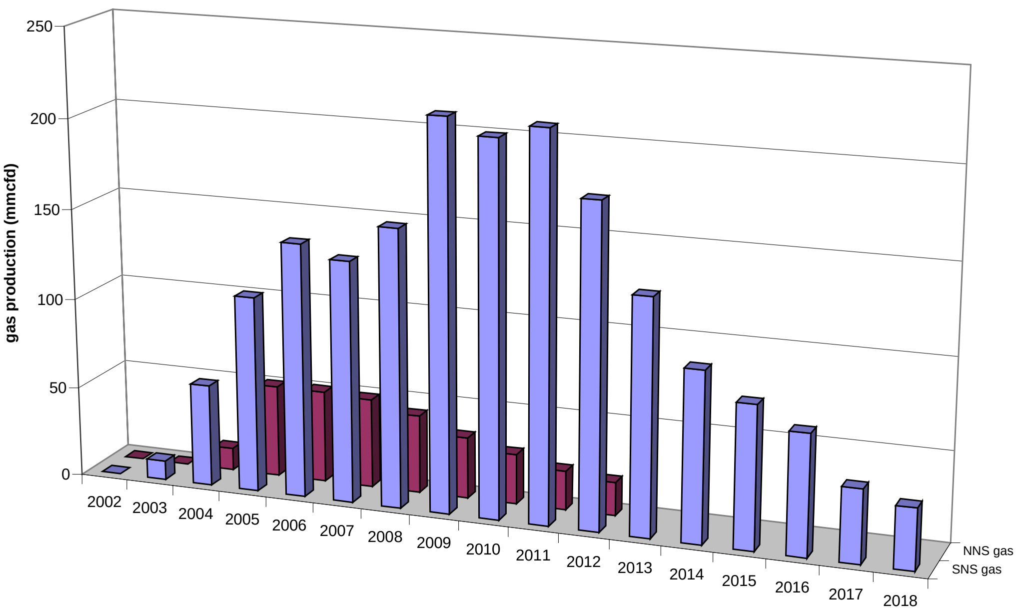


Figure 10.7 - Predicted oil production profile for additional SEA 2 developments

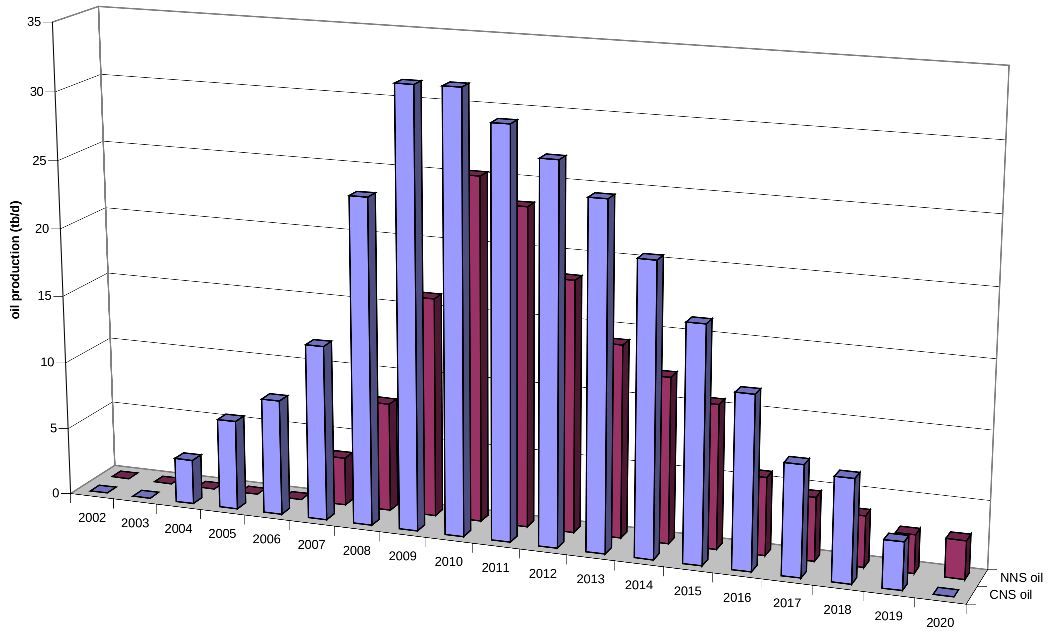


Figure 10.8 - Comparison of predicted gas production profile for additional SEA 2 developments, and DTI 2001 Brown Book forecast for UKCS (proven + possible reserves)

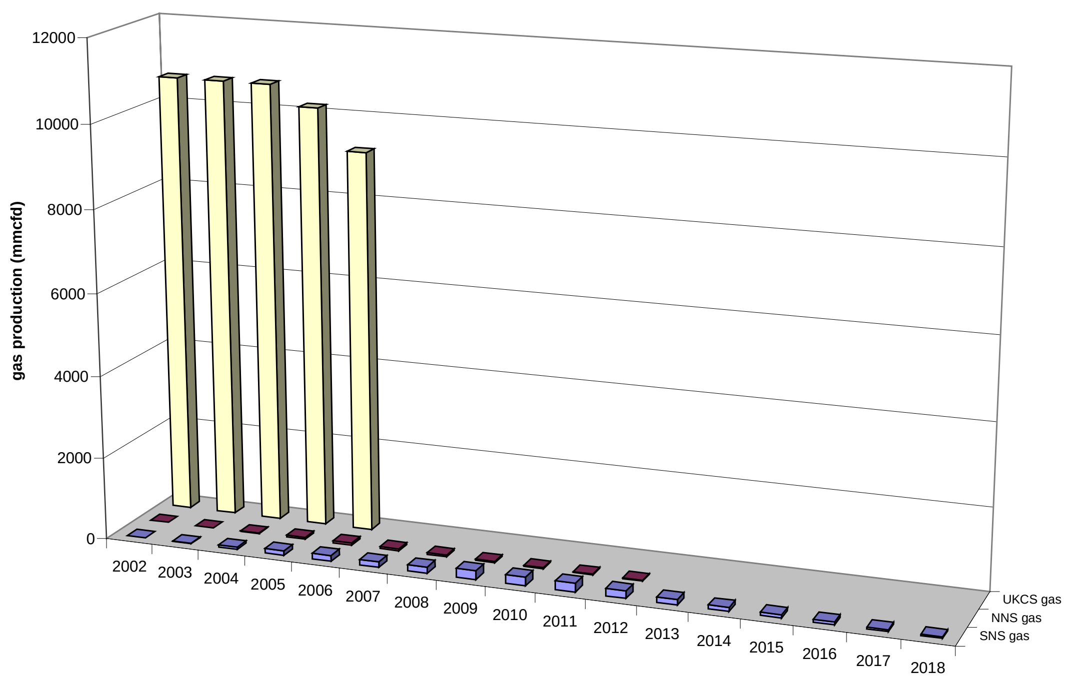
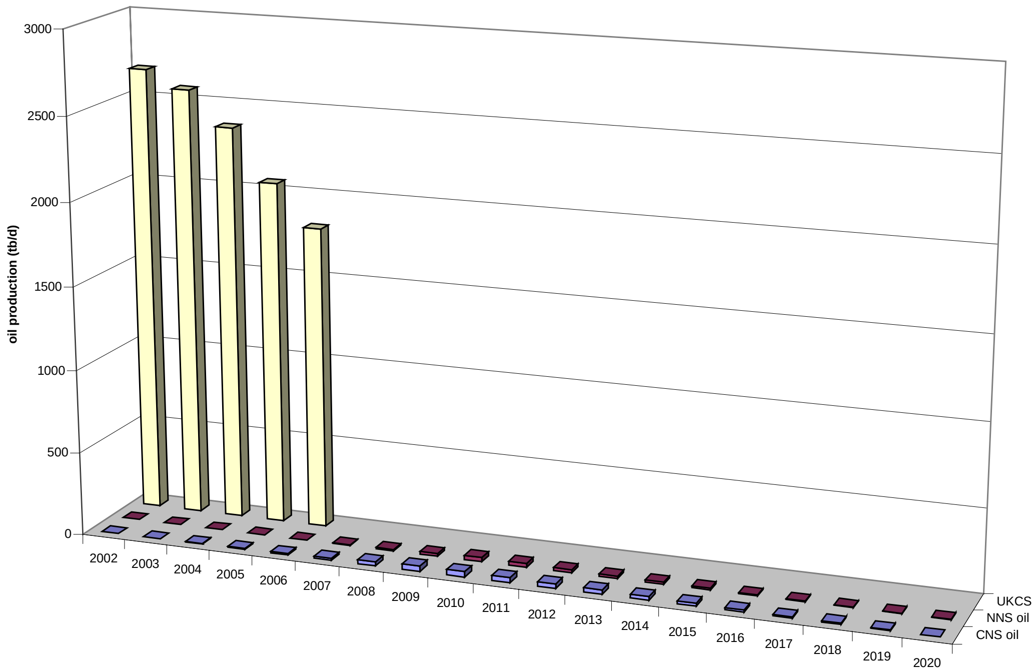


Figure 10.9 - Comparison of predicted oil production profile for additional SEA 2 developments, and DTI 2001 Brown Book forecast for UKCS (proven + possible reserves)



11 CONCLUSIONS

11.1 Conclusions

Conclusions from the consideration of potential effects of licensing the SEA 2 area in Section 10, are summarised below:

Noise - Seismic activities in the northern and central SEA 2 blocks could potentially affect regionally important numbers of minke whale, harbour porpoise, and white-beaked dolphin, although existing control and mitigation methods are generally regarded as effective in preventing physical damage. In view of the limited incremental extent of noise resulting from predicted activity levels, and in relation to previous activity and activities in existing licensed acreage, together with existing control and mitigation methods, it is considered unlikely that physical damage or significant behavioural disturbance of marine mammals will result from the activity scenarios associated with proposed licensing.

Physical damage at the seabed - The predicted spatial scale of physical disturbance of the seabed, resulting from activity scenarios for potential licensed areas, is very small in comparison with the total area of the North Sea. In terms of area, the major sources of physical disturbance from E&P activities are predicted to be rig anchoring and pipelay activities. Recovery of affected seabed through sediment redistribution and faunal re-colonisation are expected to be rapid where the source of effects is transient (eg anchoring); less than five years in most cases. It is therefore concluded that the potential incremental and cumulative effects of physical disturbance are not likely to be significant.

Physical presence - Although exclusion can represent a significant conflict between fishing and production in intensively developed areas within established fishing grounds, including some SEA 2 areas, the spatial extent of exclusion zones is unlikely to cause significant negative economic impacts. The oil industry and UK fishing industry maintain consultation, liaison and compensation mechanisms, which should serve to mitigate and resolve any conflicts.

Discharges - The environmental effects of produced water discharges are limited, primarily by dispersion, and below No Effect Concentrations (NECs). Produced water discharges are, and will continue to be, dominated by oil developments in the central and northern North Sea. Key concerns over produced water discharges relate to cumulative effects of oil and possible biological effects of residual process chemicals (see also Section 5.5). Produced water will remain the focus of regulatory controls. The recent OSPAR recommendation 2001/1 will result in reductions in both concentrations and the total amount of oil discharged from offshore installations. For new developments (including those stemming from 20th Round licensing) there will be a presumption against produced water discharge to sea. Incremental contributions from newly licensed SEA 2 blocks would be minimal (predicted 2.4% of total North Sea produced water discharges), or negligible if produced water is reinjected.

Discharges of WBM cuttings in the North Sea have been shown to disperse rapidly and to have minimal ecological effects. Dispersion mechanisms could, in theory, lead to localised accumulation in relation to topographic features (including pockmark basins and sandbanks, in the central and southern North Sea respectively) although this is considered unlikely to be detectable. The predicted incremental annual discharge of WBM chemicals from SEA 2 related drilling represents a maximum increase of 4.2% (in 2002) on 1999 values.

Emissions - Potential environmental effects of acid gas and greenhouse emissions are, respectively, regional and global in nature. Local environmental effects of atmospheric emissions are not expected to be significant, in view of the high atmospheric dispersion associated with offshore locations.

Significant combustion emissions from flaring are not expected from potential development in the possible SEA 2 licence areas. In view of regulatory controls and commercial considerations, combustion emissions from power generation are not predicted to represent a major contribution to industry or national totals. Overall, peak annual emissions from production in newly licensed SEA 2 blocks are estimated as 2.4% of current (2000) emission levels from UKCS production (including onshore terminals).

Wastes to shore - Sustainable and commercially viable options for onshore disposal of OBM cuttings remains a significant challenge for the industry, although permitted transfer between installations for reinjection would ease the situation.

However, the associated environmental effects of onshore treatment and long-term storage of processed OBM cuttings are not considered to represent significant environmental effects of E&P activities in SEA 2 areas, in the context of overall emissions and waste disposal to land.

Accidental events - Overall, incremental risk of oil spills associated with exploration and development in the SEA 2 area is low, particularly in the southern area where production will almost certainly involve gas. In the event of a spill of persistent oil, and in the absence of an effective response, there are possible effects of coastal oiling around much of the North Sea coastline. Offshore seabirds are also vulnerable, particularly in late summer and autumn. However, risk assessments of current activities have been carried out and established contingency measures are in place which mitigate risks.

In general, the fate and consequence processes which affect chemicals in the environment are comparable with those for hydrocarbon components, and are dependent on the partitioning of individual compounds between dissolved and particulate phases in the water column. Persistence and biological effects of most chemicals used in the oil and gas industry are equivalent or lower than those of oil, and similar risk assessment conclusions will therefore apply.

Environmental and safety consequences of gas releases will depend both on scale, and whether released gas ignites. The major constituent of natural gas is the greenhouse gas methane, and gas releases on all scales will therefore contribute to global climatic effects. The significance of any foreseeable contribution, including a sustained gas blowout, to global methane concentraions (which include very large fluxes through natural processes) will be negligible.

Cumulative effects - Cumulative effects are considered here as identified effects from E&P activities resulting from the proposed 20th Round licensing, which have potential to act additively with those from other oil and gas activity (including both existing activities and new activities in existing licensed areas). Synergistic effects are considered to be potential effects of E&P activities which act additively with those of other human activities (eg fishing and crude oil transport). Although there is potential for sources to be additive in some cases, (for example through mixing of sea water masses containing dispersed discharges) cumulative effects in the sense of overlapping “footprint” of detectable contamination or biological effect are considered to be limited (physical presence, noise, physical damage, emissions, discharges), or unlikely (accidental events). Synergistic effects were insignificant, either because of the scale of other sources is minimal (noise, physical presence); because effects are insignificant in the context of natural processes (cuttings discharges) or because the contribution resulting from proposed licensing is negligible in the context of other activities (physical damage, emissions, oil spills).

Transboundary effects – SEA 2 areas are contiguous with continental shelf areas under the jurisdiction of Norway, Denmark, Germany and the Netherlands, as defined by UNCLOS. Norway is a member of the European Free Trade Association but not a member of the European Union (EU); other contiguous states are full members of the EU. All states bounding the North Sea are members of OSPAR. Prevailing wind and residual water circulation of the North Sea will result in the transboundary transport of discharges to water (including particulates) and atmospheric emissions.

The environmental effects of underwater noise, produced water, drilling discharges, atmospheric emissions and oil spills may be able to be detected physically or chemically in adjacent state territories, particularly from activities undertaken in SEA 2 areas close to international boundaries. The scale and consequences of environmental effects in adjacent state territories will be comparable to those in UK territorial waters. There are no identified transboundary effects in which environmental consequences in a neighbouring state are overwhelmingly due to activities resulting from the proposed 20th Round licensing.

Socio-economic effects - Economic modelling indicates that if oil and gas prices remain at their current levels then more than 424 million extra barrels (67.9 million m^3) of oil and 790 extra Bcf (22.4 billion m^3) of gas may be extracted. With low oil and gas prices, less than 334 million extra barrels (53.5 million m^3) of oil and less than 392 extra Bcf (1.1 billion m^3) of gas may be extracted from new fields as a result of 20th round licensing. Over a ten year period almost £925 million more may be spent on development and £881 million more on operating costs than would be the case without licensing/relicensing of the SEA 2 area.

Forecast tax revenues range widely, with a maximum of £797 million over a 20 year period. However, if oil prices drop substantially, under the current fiscal regime, Government revenues from 20th Round are likely to be negative when tax relief for exploration and appraisal activities is given.

The forecast activity could result in a peak of 8,977 total extra jobs in the UK in 2009, of which 858 are estimated to be direct. The number of employees in the petroleum industry is declining and has been for some time, although there also appear to be skill shortages at the moment. The UKCS may be a mature province but the skills and expertise acquired are exportable assets. Regular and wide ranging licensing rounds could help maintain expenditure in the industry which in turn may help sustain employment levels and reverse the trend towards skills shortages by giving some security to those employed in the industry. Petroleum companies are primarily international and therefore the UK competes for funding and skilled staff with other petroleum producing provinces. If the skills base is not maintained, any competitive advantage which the UK has acquired, may be lost.

Wider policy objectives - Based on the review of potential effects, no significant effect of activities following the proposed 20th Licence Round is predicted in relation to wider UK Government policy and commitments; specifically:

- Energy Policy
- Common Fisheries Policy
- Commitments under the EU Urban Waste Water and Water Framework Directives

- National Waste Strategy
- Kyoto Agreement
- MARPOL
- OSPAR
- Natura 2000 and RAMSAR programmes
- UN Convention on Biological Diversity and UK Action Plans

At a wider scale of assessment, it is clear that the major environmental pressures on the North Sea are not associated directly with hydrocarbon exploration and production, but with trace organic contaminants from land, seabed disturbance by fisheries, inputs of nutrients from land, effects of discards and mortality of non-target species by fisheries, and input of TBT and other antifouling substances by shipping (OSPAR 2000). Fishing mortality (of both target species and by-catch), and trawling disturbance effects are probably the most significant direct anthropogenic effects on the ecology of the North Sea. In this context, the combined effects predicted as a result of routine E&P activities which may arise from 20th Round licensing are minimal. From a management perspective, although averaged hydrocarbon inputs to the North Sea from accidental releases are relatively low, the risk of major environmental damage from tanker incidents must be considered significant – it could be argued that the proposed licensing activity would have a net environmental benefit if the need for the UK to import oil by tanker is reduced or delayed. Similarly, provision of oil and gas from UK resources provides for security of national supply.

The SEA Directive requires that, in considering the likely significance of effects, the degree to which the plan or programme influences other plans and programmes should be addressed, together with the promotion of sustainable development (Section 3.1).

While current UK, and international legislation (eg OSPAR and MARPOL) have been effective in the control and continued reduction of contaminant inputs, similar controls are not in place to address other sources of ecosystem disruption. At present, there is a lack of effective mechanisms within the UK and European regulatory framework for the *integrated* management of the pressures on the North Sea ecosystem from the various human activities offshore. This lack is a challenge to the achievement of marine biodiversity and sustainable development goals. The UK Government is currently conducting two major reviews:

- The review of marine nature conservation
- The marine stewardship report

These should both contribute to improvement of the situation. Nevertheless, as stated above, with regard to this SEA, adequate controls are considered to be in place for the regulation of oil and gas activities that may follow 20th Round Licensing.

11.1.1 Consideration of the implications of alternatives

Alternatives proposed for the development of the oil and gas resources within the proposed 20th Round areas have been identified as:

1. Not to offer any blocks for Production Licence award
2. To restrict the area licensed by offering only a proportion of the blocks nominated
3. To stagger the timing of activity in the area
4. To proceed with the licensing programme as proposed.

The matrix below summarises potential significant sources/effects (see Section 10 for derivation) arising from various alternatives and possible subsequent activities (exploration and production).

Key source/effect	**Alternatives**			
	1	**2***	**3***	**4***
Underwater noise from seismic surveys / Marine mammal disturbance				
Physical presence / Exclusion of fishing and gear interactions				
Physical damage / Seabed and benthic community effects				
Marine discharges – produced water / Seawater quality and pelagic species effects				
Marine discharges – drilling discharges / Seabed and benthic community effects				
Atmospheric emissions / Greenhouse and acid gas effects				
Accidental events - oil spills / Hydrocarbon contamination; seabird oiling; impacts on coastal resources				
Socio-economic benefits				

**with appropriate mitigation and control measures*

Benefit / disadvantage
Strong benefit
Some benefit
No benefit or disadvantage
Potential, but minor environmental effect or socio-economic disadvantage
Potential significant environmental effect or socio-economic disadvantage

Potential benefits associated with alternatives to the proposed licensing programme are associated with potential effects of noise (alternative (3), staggered licensing); and physical presence / damage (alternative (2), partial licensing). Alternative (1), not licensing, would result in a definite negative socio-economic impact, and could be considered as a disincentive to continued Operator investment in UKCS operations (Section 10.7) and hence amplified socio-economic disbenefits.

The potential benefit of staggered timing of licensing, with regard to the effects of noise on marine mammals, relates to the concern that sequential seismic surveys may have a cumulative effect (Section 10.5). However, it can concluded that in view of marine mammal distributions, any cumulative effect of seismic surveys is unlikely. The concern is therefore precautionary only, and the benefit of staggered timing is not considered significant.

The potential benefit of partial licensing, with regard to the effects of physical presence on fishing activities and physical damage to seabed habitats, is related to the number and prospectivity of blocks offered. In the event that licensed blocks do not yield discoveries, the physical effects of exploration will be negligible in a regional context. In view of the low probability of a discovery in individual blocks, and of the project-specific control over development effects available through regulatory mechanisms, the benefit of withholding nominated blocks is not considered significant. No localised areas within the SEA 2 area were considered of outstanding environmental sensitivity (Sections 5 and 6). Project-specific permitting allows due attention to be given to the protection of environmental sensitivities (such as seasonal seabird vulnerability in the outer Moray Firth and Flamborough front areas, and actual or potential conservation sites), other users of the sea and other marine resources. These permits can and do where necessary specify timing, spatial and activity constraints relevant to the sensitivities of the area.

11.2 Gaps in understanding

Current understanding of North Sea habitats and ecosystems are reviewed in Sections 5 and 6, with reference to proposed 20th Round licence areas. The North Sea is a relatively well studied area, and holistic assessments of its status have been undertaken in 1993 and 2000 (OSPAR 2000). International and multi-disciplinary cooperation is also a feature of North Sea science, for example through JAMP, ESAS, SCANS programmes; and of North Sea environmental protection for example through OSPAR, Natura 2000 and ASCOBANS (see glossary for acronyms).

DTI have sponsored a recent seminar (19 June 2001) on offshore oil and gas environmental research, with the aim of identifying priorities for future work aimed at improving protection of the environment in relation to offshore activities. Four core topics were considered: marine discharges (produced water, chemicals and drilling fluids); atmospheric emissions (flaring and other atmospheric discharges); protection of species and habitats (noise and other impacts); and monitoring (compliance and effects).

Significant gaps in understanding identified during this assessment, and associated requirements for additional work, are summarised as follows:

- Long-term variability and trends in hydrographic characteristics, in relation to natural phenomena (eg the NAO) and climate change (see Section (5.4)

- Benthic communities of specific localised habitats, including pockmarks and sandbanks (see Section 6.3). Sample acquisition for this purpose and for assessment of particulate contaminants has been undertaken under the DTI's 2001 survey programme to support this assessment

- The biodiversity and distribution of smaller fauna (meiofauna including foraminifera) across the North Sea (see Section 6.3.4)

- Wide area and regular monitoring of benthic community structure, with regard to long term trends. Further development of the taxonomy of several important macrofaunal groups is also required for reliable assessment of historic and future data

- Wide area and regular monitoring of chemical contaminants with regard to long term trends. Consistent methodologies are required or intercalibration exercises to be undertaken as new techniques are adopted to ensure comparability with historic data

- Seasonal data gaps and update of seabird distribution data (see Section 6.7.5)

- Distribution of marine mammals (update of SCANS data, see Section 6.8)

- Sound propagation and effects of noise on marine mammals (see Sections 6.8.4 and 10.4.1; SMRU commissioned report Section 3.1.3)

- Fate and biological effects of organic contaminants, including residual process chemicals (see Section 10.4.4.4)

- Physical dispersion and accumulation of particulates and associated contaminants with specific reference to sink areas including pockmarks, sandbanks and other offshore conservation sites (see Section 10.4.4.5)

A scientific perspective on future priorities for North Sea research (with a strong emphasis on southern North Sea seabed issues) was presented by Gerlach (1995), who suggested seven key areas: the phenomenon of rare species; meiofauna in suboxic sediment layers; dormancy of animals and bacteria in sediment; lateral advection of organic flux to the benthos; selection of representative monitoring sites; and importance of viruses, bacteria and other parasites.

11.3 Recommendations

Further to the Strategic Environmental Review process undertaken in relation to proposed 20th Round licensing, recommendations are made in five areas:

Scientific understanding – funding and coordination of resources is needed to address data gaps identified above. This should develop and follow on from the DTI R&D Seminar (noted above) and other initiatives.

Environmental effects monitoring – a programme should be established to monitor the effects of E&P activities subsequent to the proposed 20th Licence Round. Monitoring should include specific evaluation of the quantitative predictions made in this assessment regarding source emissions, discharges and accidental events from E&P activities with data being made available through established DTI and UKOOA environmental performance monitoring systems. Field monitoring should also be undertaken with specific reference to:

- Received noise levels associated with seismic surveys in SEA 2 areas

- Behavioural responses of marine mammals to seismic noise, incorporating controlled exposure experiments where feasible

- Physical damage and recovery monitoring with specific reference to anchoring and pipelay activities

- WBM cuttings and produced water dispersion, possibly using tracer techniques

These requirements may be addressed through DTI or industry-sponsored studies.

Activity scenarios – actual exploration, appraisal, development and production activities should be monitored in relation to the scenarios used in this assessment. Consideration should be given to further development of the methods used to generate activity and economic forecasts underpinning the SEA process.

SEA process evaluation – lessons learned from SEA 2 should be captured following the public consultation phase to ensure continuous improvement of the SEA process.

Cumulative effects – a review should be undertaken of methods used to assess the cumulative effects of E&P activities consequent to individual licence rounds, with specific reference to the contribution of these activities to wider policy objectives and national targets under MARPOL, OSPAR and Kyoto commitments.

Integrated management – DTI and other Government departments should consider what, if any, additional steps might be appropriate to facilitate the objectives of integrated management of the offshore environment, towards sustainable development, both at the national and international level.

11.4 Overall conclusion

The overall conclusion of this assessment is that, given adequate subsequent control and information gathering, there are no overriding reasons why blocks within the SEA 2 areas should not be considered for oil and gas licensing as part of a 20th Licensing Round.

11.4.1 Conservation areas

Individual block licences and project-specific approvals should take account of any future designation of offshore conservation sites, under the European Council Directive on the conservation of natural habitats and of wild fauna and flora, and the European Council Directive on the conservation of wild birds. These considerations may curtail permitted activities in certain areas.

11.4.2 Cumulative effects

The potential for cumulative effects of seismic noise, emissions and discharges should also be considered prior to project-specific approvals.

11.4.3 Alternatives

While the North Sea as a whole is recognised as highly important for fish, fisheries, seabirds and certain marine mammals, on the basis of available information, no individual parts of the proposed 20th Round licence areas were identified as being so important that they should not be considered for licensing given the activity permitting controls available to the DTI.

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APPENDIX 1: GLOSSARY AND ABBREVIATIONS

Term	Definition
µg	Micrograms
µPa	Micropascal (unit of pressure)
2D	2 Dimensional (of seismic)
3D	3 Dimensional (of seismic)
4D	4 Dimensional (of seismic, includes temporal parameter)
Acute	Of relatively short duration
Amphipods	Marine crustaceans (“sandhoppers”)
Anaerobic	Used of an environment in which oxygen is deficient or absent
Anchor mound	The disturbance to the seabed caused by the movement of the anchors
Annulus	The space between the drill string and well bore
Anode	Metal fitting, commonly of zinc or aluminium alloy, that provides corrosion (cathodic) protection
Anthropogenic	Resulting from human activity
Appraisal well	Well drilled to determine the physical extent, reserves and likely production rate of a field
Aqueous discharges	Watery discharges to the sea
Artificial Lift	A method of increasing oil production rate from a well, for example by gas injection at the wellhead or electrically powered submersible pumps within the well
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (United Nations)
Barite	Barium sulphate – a naturally occurring heavy mineral added to drilling mud as a weighting agent to increase its specific gravity and thus the hydrostatic head of the mud column
Base fluid	The liquid component of drilling mud
Bathymetry	Measurement and study of ocean depth and floor
bbl	Barrel (= 0.1589m^3)
Benthic	Relating to organisms living in or on the seabed
Benthos	Organisms living in or on the seabed
Bentonite	Naturally occurring clay mineral; used in drilling fluids to increase viscosity
Bioaccumulation	The uptake of elements or compounds within organisms
Biocide	A chemical toxic or lethal to living organisms, used to inhibit microbial growth and fouling within pipelines and other equipment

Term	Definition
Biocoenoses	Association of organisms forming a closely integrated community
Biodiversity	Diversity of species
Biogenic	Produced by the action of living organisms
Biogeographic	Relating to the geographical area characterised by distinctive flora and fauna
Biomagnification	The transfer of increasing concentrations of elements or compounds up the trophic levels in the food web
Biomass	Living material; eg the total mass of a species or of all living organisms present in a habitat; usually excluding shell mass
Biosphere Reserves	Sites designated for the long-term study of ecosystems and the monitoring of environmental change
Biota	The total flora and fauna of a given area
Biotope	A physical habitat and its associated biological community
Block	Sub-division of sea for the purpose of licensing to a company or group of companies for exploration and production rights. A Block is approximately 200-250 square kilometres
Bloom	Rapid increase in concentration of phytoplankton, often dominated by one species; may be seasonal (spring bloom); natural or anthropogenic
Blow-out	The uncontrolled release of oil, gas or water from a well
Blow-out preventor	Hydraulically operated device used to prevent uncontrolled releases of oil or gas from a well
BOD	Biochemical (Biological) Oxygen Demand - The amount of oxygen required to degrade the organic material and to oxidise reduced substances in a water sample; used as an index of water pollution
BOP	Blow Out Preventor
BP	Before Present
Bunkering	Transfer of fuel from supply vessel to rig or platform
Carcinogenic	Compounds inducing cancer
Casing	Steel lining used to prevent caving of the sides of a well, to exclude unwanted fluids and to provide a means of the control of well pressures and oil and gas production
Cephalopods	Marine molluscs including squid, cuttlefish and octopus
Cetaceans	Aquatic mammals including whales, dolphins and porpoises
Christmas tree (xmas tree)	Valve assembly at the top of a well used to control flow of oil or gas
Chronic	Of relatively long duration
Clupeid	Family of fish including herring, sprat and anchovy

Term	Definition
cm	Centimetres
COAST	Computer Assisted Shipping Traffic - vessel movement database, developed by Safetec on behalf of UKOOA, DETR and HSE
Combustion emissions	Emissions of gases from the burning of fossil fuels such as oil or gas including carbon, nitrogen and sulphur oxides, and may include particulates and unburned hydrocarbons
Completion	See Well Completion
Condensate	Liquid hydrocarbons, sometimes produced along with natural gas
Contaminants	Substances which may cause impurity or pollution
Copepod	Small crustaceans, usually planktonic
Corrosion Inhibitor	Chemical formulation used to minimise corrosion; a variety of formulations use different chemical properties
Corrosion protection	Use of chemicals or sacrificial anodes to protect a structure from progressive breakdown by chemical attack (or rusting)
cSAC	Candidate Special Area of Conservation - conservation site proposed for designation by national government under the EU Habitat & Species Directive
CSON	Continental Shelf Operations Notice
Cuttings pile	Pile of mainly rock chips deposited on the seabed as a result of drilling
dB	Decibel
DDT	Dichlorodiphenyltrichloroethane (a pesticide)
Dehydration	The process of removing water from a pipeline (during pre-commissioning); removal of water from gas as part of the production process
Demersal	Living at or near the bottom of the sea
DEPCON	Deposit Consent (included in Pipeline Works Authorisation)
DETR	Department of Environment, Transport and the Regions (functions now split between the Department for Environment Food and Rural Affairs (DEFRA) and the Department for Transport, Local Government and the Regions (DTLR)
Development well	Well drilled in order to produce hydrocarbons from a proven field
DISCON	Discharge Consent (included in Pipeline Works Authorisation)
Downhole injection	Injection of gas, water or slurrified solids to a porous receiving rock formation
DP	Dynamic Positioning – active positioning of a stationary vessel or rig by thrusters (as compared to anchoring)
Drill bit	A drilling tool used to cut through rock

Term	**Definition**
Drill casing	Steel pipe cemented into a well to prevent cave-in and stop fluids from leaking from surrounding rock into the hole or vice versa
Drill cuttings	Rock chips produced as a result of drilling
Drill string	Lengths of steel tubing roughly 10m long screwed together to form a pipe connecting the drill bit to the drilling rig. It is rotated to drill the hole and delivers drilling fluids to the bit
Drilling mud	Mixture of clays, water and chemicals used to cool and lubricate the drill bit, return rock cuttings to the surface and to exert hydrostatic pressure to maintain well control
DSV	Dive Support Vessel
DTI	Department of Trade and Industry
Dynamic Positioning	Use of thrusters instead of anchors to maintain the position of a vessel
E&P	Exploration and Production
EA	Environmental Assessment - systematic assessment of the environmental effects a proposed project may have on its surrounding environment
EC	European Community
EEC	European Economic Community
EMAS	Eco Management and Audit Scheme
EMS	Environmental Management System
Endocrine disrupting compounds	Compounds which have an effect on the hormonal systems of organisms
Environmental Aspect	An activity that causes an environmental effect
Environmental Effect	Any change to the environment or its use
Environmental Impact Assessment	Systematic review of the environmental effects a proposed project may have on the surrounding environment
Environmental Management System	System established to manage an organisation's processes and resultant environmental impacts
Environmental Statement	Formal document presenting the findings of an EIA process for a proposed project. Issued for public consultation in accordance with *The Offshore Petroleum Production and Pipe-lines (Assessment of Environmental Effects) Regulations, 1999*
EPAQS	Expert Panel on Air Quality Standards (See References)
Epifauna	Organisms living on the surface of the seabed
Epipelagic	Relating to towards the surface of the water column
ES	Environmental Statement

Term	**Definition**
ESA	Environmentally Sensitive Area
ESAS	European Seabirds At Sea
ESDV	Emergency Shut Down Valve
ESP	Electrical Submersible Pump
EU	European Union
Exploration well	Well drilled to determine whether hydrocarbons are present in a particular area
FEED	Front End Engineering Design
Flare	Controlled burning of gas for pressure relief (or during well testing for disposal of excess gas)
Fluorescein	Yellow-green fluorescent dye used for leak detection
Formation	An assemblage of rocks or strata
FPV	Floating Production Vessel
FPS	Floating Production System
FPSO	Floating, Production, Storage and Offloading Facility
Freespan	An unsupported section of pipeline on the seabed, usually resulting from seabed erosion
Front	Boundary region between different water masses; eg between stratified and vertically-mixed waters; often associated with high biological productivity
Fugitive emissions	Very small chronic escape of gas and liquids from equipment and pipework
g	Grams
Gadoid	Fish of the cod family
Geology	Physical structure and substance of the earth
Geomorphology	The study of the underlying form, and weathering processes, of rocks
Giga	Billion (10^9)
Glacigenic	Relating to glacial activity
GOR	Gas Oil Ratio
Greenhouse effect	Rise in the earth's temperature due to infra-red radiation being trapped in the atmosphere by water vapour, carbon dioxide and other gases
Greenhouse Gas	Gas which contributes to the greenhouse effect. Includes gases such as carbon dioxide and methane.
Guar Gum	Natural organic additive used to increase viscosity in drilling fluids
HOCNF	Harmonised Offshore Chemical Notification Format

Term	Definition
Holocene	Geological period since latest glaciation; from about 10,000 years ago to present
HSE	Health and Safety Executive
Hydrocarbon	Compounds containing only the elements carbon and hydrogen, including oil and natural gas
Hydrography	In this context, the study of sea water masses, currents and tides
Hydrotest	Pressure test using water
Hz	Hertz (unit of frequency)
ICES	International Council for the Exploration of the Sea
Immunotoxic	Having a toxic effect on the immune system
IMO	International Maritime Organisation
Imposex	Chemical interference with the sexual development of organisms
Injection well	Well into which gas or water is pumped to maintain reservoir pressure
IPCC	Intergovernmental Panel on Climate Change (See References)
IPPC	Integrated Pollution Prevention and Control
ISO 14001	International standard for environmental management systems
Isobath	Depth contour
JAMP	Joint Assessment Monitoring Programme
JNCC	Joint Nature Conservation Committee
Jumper	Short joining section of pipeline (often flexible) or umbilical
km	Kilometres
Licence block	Area of the sea which has been sub-divided and licensed to a company or group of companies for exploration and production of hydrocarbons
Licensing round	An allocation of licences made to oil companies
Liner	Small diameter casing placed within a well to carry hydrocarbons back to the surface
Lost circulation	Uncontrolled loss of drilling fluid to porous rock formation; may be controlled by addition of a “pill” of a Loss Control Material
LSA (Low Specific Activity)	Low dose, naturally occurring radiation
m	Metres
Macrofauna	Larger benthic organisms, defined as >0.5mm or 1.0mm in size

Term	Definition
Macrozooplankton	Larger free-floating microscopic animals
Manifold	A piping arrangement which allows one stream of liquid or gas to be divided into two or more streams, or which allows several streams to be collected into one
MARPOL	International Marine Pollution Convention
Mattresses	Concrete structures used to protect pipelines or other subsea structures
Meso-pelagic	Relating to the middle section of the water column
mg	Milligrams
Micro-zooplankton	Smaller free-floating microscopic animals
MLWS	Mean Low Water Springs (of tides)
Mud	See Drilling Mud
MW	Megawatt
NATO	North Atlantic Treaty Organisation
Natura 2000	Sites of conservation value designated under the EU Habitats Directive
NEC (No Effect Concentration)	Concentration at which no detrimental effects are expected to occur
NERC	UK Natural Environment Research Council
NGO	Non Governmental Organisation
NSA	National Scenic Area
OCNS	Offshore Chemicals Notification Scheme
Odontocetes	Toothed whales
Oestrogen	Female hormone
Oestrogenic	Acting as an oestrogen
OILMAP	Computer model used to predict oil spill trajectories
OLF	The Norwegian Oil Industry Association
Ontogenetic	Relating to the development of an individual organism
OPRC	International Convention on Oil Pollution Preparedness, Response and Co-operation
Organic compounds	Materials containing carbon combined with hydrogen, often with other elements
Organotins	Organic compounds of tin, used as antifouling and wood preservative; Dibutyl tin (DBT) or Tributyl tin (TBT). Cause imposex in gastropod molluscs
OSD	Offshore Safety Division

Term	**Definition**
OSIS	Oil Spill Information System (Computer model used to predict oil spill trajectories)
OSPAR	Oslo and Paris Commission
OVI	Offshore Vulnerability Index – measure of seabird vulnerability to surface pollution including oil spills
Oxygen Scavenger	Chemical used to remove oxygen
Ozone	A gas formed naturally in the atmosphere containing three atoms of oxygen
PAH	Polycyclic (Polynuclear) Aromatic Hydrocarbons - group of organic chemicals produced naturally and by anthropogenic processes, e.g. combustion. May be carcinogenic and toxic
PCB	Poly Chlorinated Biphenyls – synthetic organic chemicals previously (until 2000) used as specialist lubricants and electrical insulating fluids. Bioaccumulate and cause arrange of effects in animals
PEC (Predicted Environmental Concentration)	Concentration of a chemical predicted to occur in the environment
Pelagic	Organisms living in the water column of the sea
Permeability	Degree to which a solid allows the passage of fluid through it
Petrogenic	Derived from mineral hydrocarbons
Photochemical smog	Aerosol produced by an extremely complex interaction of ultraviolet radiation, nitrogen oxides (NO and NO_2), oxygen, ozone and Volatile Organic Compounds (VOCs); may cause respiratory, eye, nose and throat irritation
Photosynthesis	Process by which plants convert carbon dioxide into organic compounds using the energy of light absorbed by chlorophyll
Phytodetrital deposition	Particulate material derived from dead phytoplankton which settles to the seabed
Phytoplankton	Free floating microscopic plants (algae); including diatoms and dinoflagellates
Pig	Piece of equipment inserted into a pipeline and carried along by the flow of oil and gas; used to clean or monitor the internal condition of the pipeline
Plankton	Free-floating microscopic organisms
PLONOR	Posing Little or No Risk to the Environment
PNEC	Predicted No Effect Concentration
PON	Petroleum Operations Notice
Porosity	Ratio of volume of pore space to total volume (of for example rock)
PPC	Pollution, Prevention and Control
ppm	Parts per million
ppmv	Parts per million by volume

Term	Definition
Produced water	Water removed from the reservoir along with oil and natural gas
Quadrant	Subdivision of sea area for purposes of awarding licences for hydrocarbon exploration and exploitation. A whole quadrant in contains thirty blocks, and is approximately 7,500 sq km.
Quaternary	Geological period from 1.6 million years ago to present; comprising the Pleistocene and the Holocene
Radionuclide	Natural or artificial radioactive isotope
Ramsar Sites	Areas designated by the UK under the Ramsar Convention (Convention on Wetlands of International Importance especially as waterfowl habitat)
Residual current	Time-averaged current, over many tidal cycles (usually expressed as a residual vector)
Rheological	Relating to flow or current
Riser	A pipe which connects a rig or platform to a subsea wellhead or pipeline during drilling or production operations
Riserless	Drilling without the installation of a riser; involves the direct discharge of cuttings to the seabed
RLD	Regional Landscape Designation
ROV	Remotely Operated Vehicle
SAC	Special Area of Conservation - conservation site designated by national government under the EU Habitat & Species Directive
Sacrificial anodes	Metal plates placed on underwater structures to prevent corrosion
SAST	Seabirds at Sea Team (of the JNCC)
Satellite altimetry	Measurement of height (eg wave height) by radar from satellite
Satellite well	Well with subsea wellhead connected via pipelines to the main development
SBM	Synthetic oil-Based Mud
Scale Inhibitor	Chemical formulation used to minimise the formation of metal carbonate scales in pipework and equipment
SCANS	Small Cetaceans Across the North Sea (survey programme)
SEA	Strategic Environmental Assessment or Appraisal
Sediments	Loose material, such as sand and mud, laid down at the bottom of the sea, river or lake
SEERAD	Scottish Executive Environment and Rural Affairs Department

Term	Definition
Seismic	Survey technique used to determine the structure of underlying rocks by passing acoustic shock waves into the strata and detecting and measuring the reflected signals. Depending on the spacing of survey lines, data processing method and temporal elements, the seismic is referred to as either 2-D, 3-D or 4-D.
SFPA	Scottish Fisheries Protection Agency
Shale	Mud or claystone rocks
Shallow gas	Gas accumulation present near the surface of the seabed
Sidescan Sonar	Side-looking sonar system used to map seabed features
Sidetrack	Creation of new section of the wellbore for the purpose of detouring around an obstruction in the main borehole, or of reaching a different target.
SINTEF	The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology
SOAEFD	Scottish Office Agriculture, Environment and Fisheries Department
SOPEP	Shipboard Oil Pollution Emergency Plan
SPA	Special Protection Area - conservation site designated by national government under the EU Wild Birds Directive
Spanning	See freespan.
Special Area of Conservation	Areas designated as European Sites (Natura 2000) under the Habitats and Species Directive
Special Protection Areas	Areas designated as European Sites under the Wild Birds Directive
Spoolpiece or spool	Short section of pipe; e.g. used to join longer lengths of pipeline to riser or manifold
Spud	Installation of conductor; the date of commencement of a drilling operation
SSIV	Subsea Isolation Valve
SSSI	Site of Special Scientific Interest
Strategic Environmental Assessment (or Appraisal)	An appraisal process through which environmental protection and sustainable development is considered in decisions on policy, plans and programmes
Stratification	Development of a stable layered density structure in the water column; may be as a result of temperature gradients (thermal stratification) or salinity gradients. Often seasonal
Stuck Pipe	Drill pipe, collars, casing or tubing that is stuck downhole; may be controlled by mud additives or “spot” fluid
Sweep	Addition of a batch of additive to a drilling fluid; typically of a viscous additive to clear the hole of cuttings
Tank washings	Effluent as a result of cleaning tanks on rigs or vessels

Term	**Definition**
Target location	Position within a reservoir which is the target at the start of drilling the well
Tee	A joint in a pipeline to allow another pipeline to be fed into it
Teratogenic	Causing abnormal foetal development
THC	Total Hydrocarbons
Thermocline	Stable boundary between two layers of water of different temperature
TLP	Tension Leg Platform
Topsides	Section of an offshore facility above the water level
Trenching	Excavation of a trench into the seabed for a pipeline or umbilical
Troposphere	The layer of the atmosphere below the stratosphere extending from ground level to 10-15km above the Earth's surface
UK	United Kingdom
UKCS	United Kingdom Continental Shelf
UKDMAP	United Kingdom Digital Map (software based compilation of environmental information)
UKOOA	United Kingdom Offshore Operators Association
UKOPP	United Kingdom Oil Pollution Prevention
UKTERG	United Kingdom Terrestrial Effects Review Group (See References)
Umbilical	Narrow, reinforced, flexible pipeline containing several different cores, which are used to carry electrical power, chemicals and control fluids to the wellhead or other subsea equipment
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
Venting	Release of gas to atmosphere for operational or emergency reasons
Viscosifier	Component of drilling fluids used to increase viscosity; usually an organic polymer or bentonite
VOC (Volatile organic compounds)	Organic compounds such as ethylene and benzene which evaporate readily and contribute to air pollution directly or indirectly
VSP	Vertical Seismic Profile
Vulnerability	Seabird vulnerability to surface pollution; quantitative index combining several factors
WBM	Water-based mud - drilling fluid using water as the carrier phase (cf. oil-based or synthetic mud)
Well Completion	The process by which a finished well is prepared for use by fitting a wellhead, liner and downhole equipment

Term	Definition
Well Kill	The filling of the well bore with drilling fluid of a suitable density to stop the flow of the well
Wellhead	Control equipment fitted at the top of a well
White Zone	The formerly disputed area of sea between the UK and the Faroes
Workover	Re-entry into a completed well for modification or repair work
Xmas tree	Assembly of valves and fittings located at the head of a well to control the flow of oil and gas
Zooplankton	Free floating animals (often microscopic)

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APPENDIX 2: ENVIRONMENTAL INTERACTIONS

The Steering Group/SEA Team SEA 2 assessment workshop was held on the 16th July 2001 in Aberdeen. Pre-reading materials included an overview of oil and gas activities and sources of effects, potential activity scenarios that might follow from 20th Round licensing of the SEA 2 areas, a preliminary activities/receptors interactions matrix and indicative criteria for use in screening effects (see Table A.1). These materials were used during the workshop to facilitate the generation of a revised interactions matrix and to identify those issues which should be examined in detail in the SEA 2 assessment. Issues were not only identified on scientific evidence of effects and implications for other users but also took account of issues of public concern.

Table A.1 - Guidance Criteria for Screening Potential Regional Importance of Environmental Effects

Effect	Definition
Positive	Activity may contribute to recovery of habitats Positive benefits to local, regional or national economy
None	No detectable effects
Negligible	Effects are unlikely to be noticed or measurable
Minor	Change is within scope of existing variability but potentially detectable
Moderate	Change in ecosystem leading to short term damage with likelihood for recovery within 2 years to an area 2 hectares or less, or to protected or locally important sites Possible but unlikely effect on human health Possible transboundary effects Possible contribution to cumulative effects Issue of limited public concern May cause nuisance Possible short term minor loss to private users or public finance
Major	Change in ecosystem leading to medium term (2+ year) damage with recovery likely within 2 - 10 years to an area 2 hectares or more, or to internationally or nationally protected species, habitats or sites Transboundary effects expected Moderate contribution to cumulative effects Issue of public concern Possible effect on human health Possible medium term loss to private users or public finance
Severe	Change in ecosystem leading to long term (10+ year) damage with poor potential for recovery to an area 2 hectares or more, or to internationally or nationally protected populations, habitats or sites Major transboundary effects expected Major contribution to cumulative effects Issue of acute public concern Likely effect on human health Long term, substantial loss to private users or public finance

The interactions matrix as revised following the Steering Group/SEA Team SEA 2 assessment workshop is given in Table A.2 overleaf. The table is colour coded as the key below to distinguish those interactions which members of the group felt required detailed consideration within the SEA 2 consultation document.

Key to interactions matrix

(white)	No negative effects expected
(cyan)	Minor or negligible issues
(grey)	Issues to be considered further in SEA 2

Table A.2 – Environmental interactions matrix

	Environmental Receptor/Issue																			
Source of Potential Impact	Climate	Air quality	Seawater quality	Seabed	Plankton	Other water column invert's	Benthic fauna	Fish & shellfish	Seabirds	Marine mammals	Conservation sites	Fisheries	Shipping	Recreation	Coastal features & amenity	Onshore/Land Use	Cumulative effects	Transboundary effects	Health/Nuisance	Freshwater Aquifers
UNDERWATER NOISE																				
Seismic																				
Drilling																				
Offshore Construction																				
Production operations																				
Decommissioning																				
PHYSICAL DAMAGE TO BIOTOPES																				
Seismic (dragged array only)																				

	Environmental Receptor/Issue																			
Source of Potential Impact	Climate	Air quality	Seawater quality	Seabed	Plankton	Other water column invert's	Benthic fauna	Fish & shellfish	Seabirds	Marine mammals	Conservation sites	Fisheries	Shipping	Recreation	Coastal features & amenity	Onshore/Land Use	Cumulative effects	Transboundary effects	Health/Nuisance	Freshwater Aquifers
Drilling (rig anchoring)																				
Drilling (rock dumping for jack-ups)																				
Construction (anchoring of lay barge)																				
Construction (pipelay, trenching & rockdumping)																				
PHYSICAL PRESENCE																				
Seismic survey (towed streamers)																				
Drilling (rig & anchors)																				
Production (installations and pipelines																				

Source of Potential Impact	Environmental Receptor/Issue																			
	Climate	Air quality	Seawater quality	Seabed	Plankton	Other water column invert's	Benthic fauna	Fish & shellfish	Seabirds	Marine mammals	Conservation sites	Fisheries	Shipping	Recreation	Coastal features & amenity	Onshore/Land Use	Cumulative effects	Transboundary effects	Health/Nuisance	Freshwater Aquifers
Depletion of reservoir (seabed subsidence)																				
MARINE DISCHARGES																				
Drilling (muds and cuttings)																				
Construction (hydrotest and pipeline drying)																				
Production (produced water)																				
Ballast water (exotics)																				
Low specific activity scale																				

	Environmental Receptor/Issue																			
Source of Potential Impact	**Climate**	**Air quality**	**Seawater quality**	**Seabed**	**Plankton**	**Other water column invert's**	**Benthic fauna**	**Fish & shellfish**	**Seabirds**	**Marine mammals**	**Conservation sites**	**Fisheries**	**Shipping**	**Recreation**	**Coastal features & amenity**	**Onshore/Land Use**	**Cumulative effects**	**Transboundary effects**	**Health/Nuisance**	**Freshwater Aquifers**
SUBSURFACE DISCHARGES																				
Drilling (muds and cuttings injection)																				
Production (produced water injection)																				
ATMOSPHERIC EMISSIONS																				
Drilling (well test/clean-up)																				
Production (power generation)																				
Production (flaring/venting)																				
Production (tanker loading - VOCs)																				

	Environmental Receptor/Issue																			
Source of Potential Impact	**Climate**	**Air quality**	**Seawater quality**	**Seabed**	**Plankton**	**Other water column invert's**	**Benthic fauna**	**Fish & shellfish**	**Seabirds**	**Marine mammals**	**Conservation sites**	**Fisheries**	**Shipping**	**Recreation**	**Coastal features & amenity**	**Onshore/Land Use**	**Cumulative effects**	**Transboundary effects**	**Health/Nuisance**	**Freshwater Aquifers**
Production operations																				
Support vessels																				
WASTES TO SHORE																				
Drilling (muds and cuttings)																				
Low specific activity scale																				
General oil field waste																				
ACCIDENTS																				
Oil spills																				

Source of Potential Impact	***Environmental Receptor/Issue***																			
	Climate	**Air quality**	**Seawater quality**	**Seabed**	**Plankton**	**Other water column invert's**	**Benthic fauna**	**Fish & shellfish**	**Seabirds**	**Marine mammals**	**Conservation sites**	**Fisheries**	**Shipping**	**Recreation**	**Coastal features & amenity**	**Onshore/Land Use**	**Cumulative effects**	**Transboundary effects**	**Health/Nuisance**	**Freshwater Aquifers**
Chemical spills																				
Gas releases																				

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