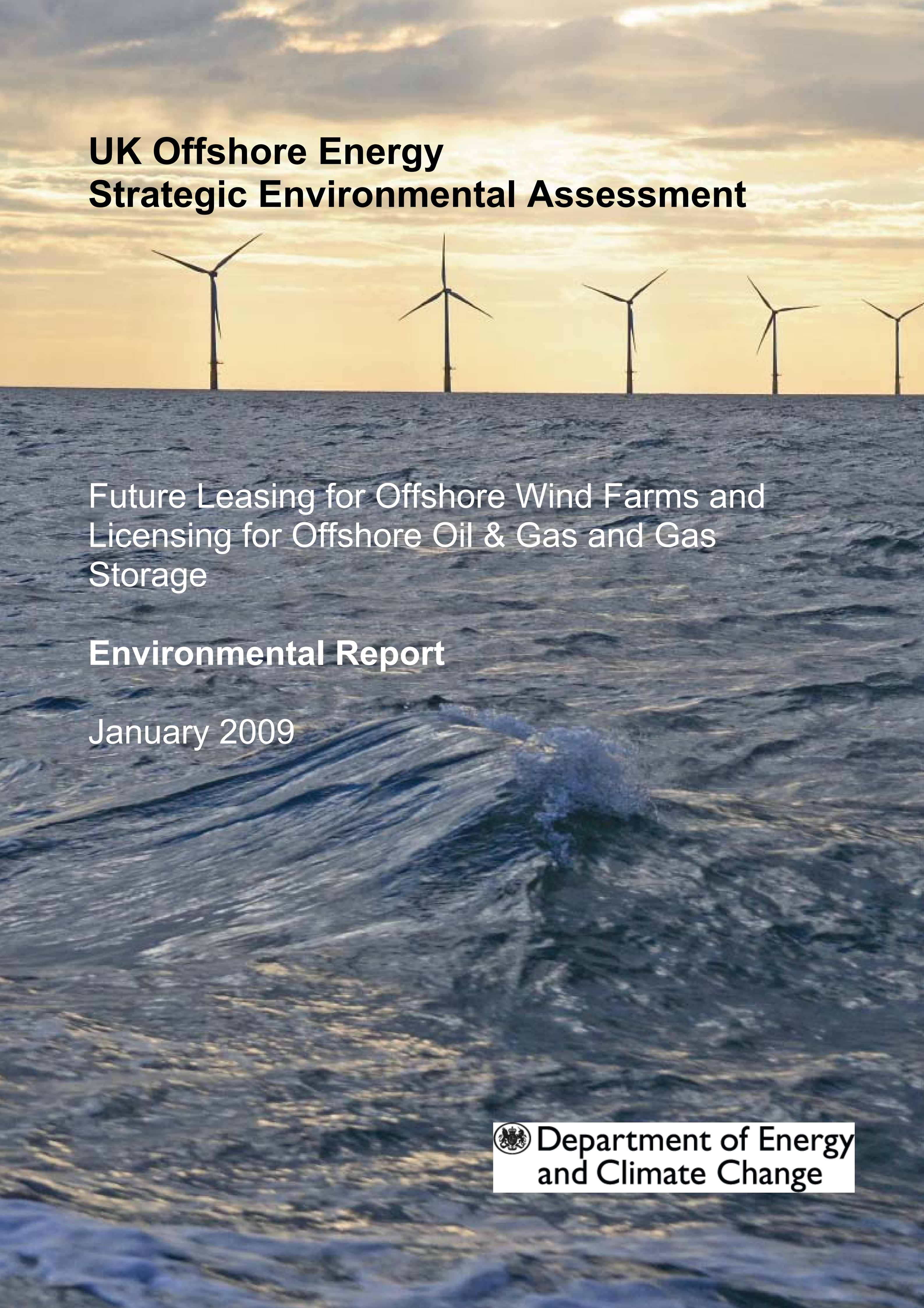


UK Offshore Energy Strategic Environmental Assessment

Future Leasing for Offshore Wind Farms and Licensing for Offshore Oil & Gas and Gas Storage

Environmental Report

January 2009

Department of Energy and Climate Change

CONTENTS

NON-TECHNICAL SUMMARY

Introduction

The Department of Energy and Climate Change (DECC) is conducting a Strategic Environmental Assessment (SEA) of a draft plan/programme to hold further rounds of offshore wind leasing and offshore oil and gas licensing in United Kingdom waters. DECC encompasses the energy functions previously under the remit of the Department for Business, Enterprise and Regulatory Reform (formerly the Department of Trade and Industry), along with various climate change functions previously under the remit of the Department for the Environment, Food and Rural Affairs.

The SEA is being conducted in accordance with the *Environmental Assessment of Plans and Programmes Regulations 2004* (the SEA Regulations), which apply to any relevant plan or programme which relates either solely to the whole or any part of England, or to England and any other part of the United Kingdom (UK).

This SEA is intended to:

- Consider the environmental implications of a draft plan/programme for licensing for offshore oil and gas, including gas storage, and leasing for offshore wind. This includes consideration of the implications of alternatives to the plan/programme and the potential spatial interactions with other users of the sea.
- Inform the UK Government's decisions on the draft plan/programme
- Provide routes for public and stakeholder participation in the process

This non-technical summary provides a synopsis of the SEA Environmental Report, including the conclusions and recommendations.

What is the draft plan/programme?

The 2007 Energy White Paper 'Meeting the Energy Challenge' outlined two serious long-term challenges for the UK:

- Tackling climate change by reducing carbon dioxide emissions both within the UK and abroad; and
- Ensuring secure, clean and affordable energy as we become increasingly dependant on imported fuel.

Ensuring security of energy supply is essential to both climate change and energy policy. Fundamental to securing our energy supplies is to ensure that we are not dependant on any one supplier, country or technology.

The draft plan/programme subject to this SEA needs to be considered in the context of overall UK energy supply policy and greenhouse gas emission reduction efforts. The main objectives of the current draft plan/programme are to enhance the UK economy, contribute to the achievement of carbon emission reductions and security of energy supply, but without compromising biodiversity and ecosystem function, the interests of nature and heritage conservation, human health, or material assets and other users.

The main parts of the draft plan/programme, and context are:

For offshore wind energy - to enable further rounds of offshore wind farm leasing in the UK Renewable Energy Zone and the territorial waters of England and Wales with the objective of achieving some 25GW of additional generation capacity by 2020. This part of the plan/programme does not include the territorial waters of Scotland and Northern Ireland.

The *Energy Act 2004* made provision for the designation of a Renewable Energy Zone outside territorial waters over which the United Kingdom may exercise rights for wind, wave and tidal energy production. The UK Renewable Energy Zone includes an area outside territorial waters where Scottish Ministers have functions in relation to renewable energy installations.

The *Climate Change Act 2008* places a duty on the Secretary of State to ensure that the net UK carbon account for the year 2050 is at least 80% lower than the 1990 baseline.

In December 2008 the European Parliament and Council of Ministers reached political agreement on legislation to require that by 2020, 20% of the EU's energy consumption must come from renewable sources. The UK's contribution to this will require the share of renewables in the UK's energy consumption to increase from around 1.5% in 2006 to 15% by 2020. In 2008 the Government consulted on a UK Renewable Energy Strategy, which is due to be published in Spring 2009.

Renewable energy will also make an important contribution to security of energy supply. By increasing the level of energy generated domestically, there will be less dependance on imports of fuel from abroad. The Government's consultation on a draft Renewable Energy Strategy estimated that increased investment in renewables in the UK, to meet a 15% renewable energy target in 2020, will reduce UK gas imports by some 11-14% in 2020.

The technology for offshore wind farms is continuing to evolve. For example larger turbines, improved gearboxes allowing faster rotation speeds, alternative foundations, vertical axis of rotation turbines are in development, and a range of scenarios were considered in the assessment.

For offshore oil and gas - to hold further seaward rounds of oil and gas licensing in UK waters.

The 2007 Energy White Paper noted that currently around 90% of the UK's energy needs are met by oil, gas and coal. Renewable energy and other low carbon technologies will play an increasing role in the UK's energy mix over the longer term; however, fossil fuels will continue to be the predominant source of energy for decades to come. With production from UK oil and gas fields declining, the UK will become yet more reliant on imports. Making efficient use of the UK's own energy reserves brings obvious benefits both in the contribution it can make to a diverse UK energy mix and to the economy in terms of jobs, investment and national income generated by the sector.

A 2007 HM Treasury discussion paper states that "The UK Government remains committed to promoting a healthy and prosperous UK oil and gas industry and maximising the economic recovery of the UK's oil and gas reserves. The UK's oil and gas reserves are significant, and up to 2006 have produced around 36 billion barrels of oil equivalent (boe). Estimates of the oil and gas remaining to be produced from the UK Continental Shelf (UKCS) range from 15 to 25 billion boe. Although the

UK is already a net importer of oil and gas, indigenous supplies will continue to play a vital role in the UK's energy consumption for many years to come."

For gas storage - to include future licensing for the underground storage of combustible gas in depleted and other offshore oil and/or gas fields in UK waters, as part of the strategy to increase the UK's storage capacity and maintain resilience of gas supply in cold weather periods of high demand or interruptions to imported supplies.

The Government consulted in 2006 on the effectiveness of current security of gas supply arrangements and security of supply is one of the key issues identified by the 2007 Energy White Paper.

By 2020 it is estimated that 80% of the UK's gas supply will be imported. The *Energy Act 2008* makes provision for the designation of Gas Importation and Storage Zones and creates a licensing framework to enable private sector investment in offshore gas storage infrastructure which will help maintain reliable supplies of energy.

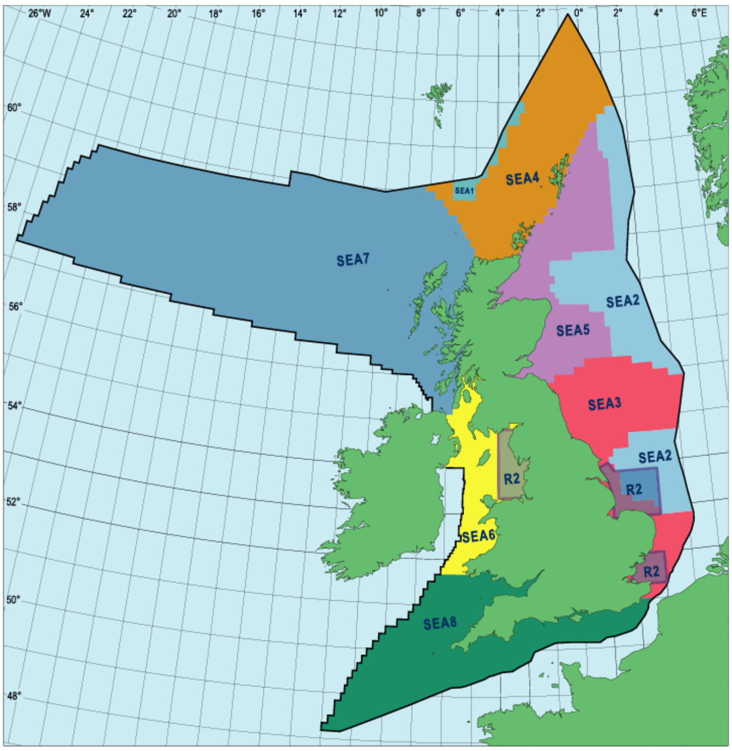
What are the alternatives to the draft plan/programme?

The following alternatives to the draft plan/programme for future offshore wind leasing, oil and gas licensing and gas storage have been assessed in the SEA:

1. Not to offer any areas for leasing/licensing
2. To proceed with a leasing and licensing programme
3. To restrict the areas offered for leasing and licensing temporally or spatially

The DECC SEA process

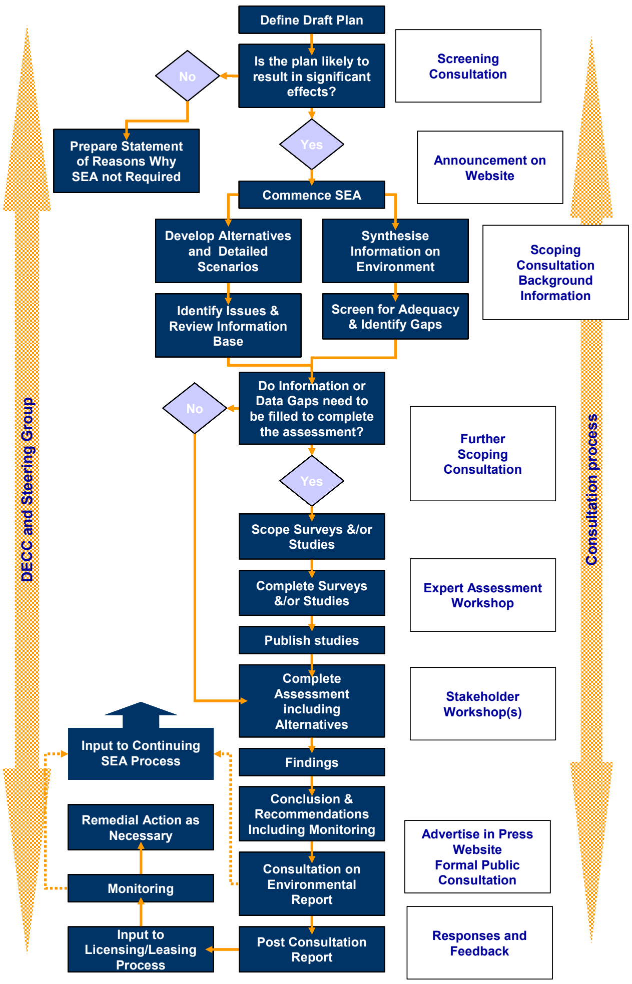
Map 1 - DECC past SEA Sequence



The SEA process aims to help inform licensing and leasing decisions by considering the environmental implications of the proposed plan/programme and the potential exploration, development and energy production activities which could result from its implementation.

Since 1999, the Department has conducted seven SEAs of the implications of further licensing of the UK Continental Shelf (UKCS) for oil and gas exploration and production (SEAs 1-7) and an SEA for a second round of wind leasing (R2) – see list overleaf and Map 1 to the left. Initial work was undertaken for SEA 8, but this area is now included in the Offshore Energy SEA.

	Area	Sector	Licensing/Leasing Round	
SEA 1	The deep water area along the UK and Faroese boundary	Oil & Gas	19^{th} Round	(2001)
SEA 2	The central spine of the North Sea which contains the majority of existing UK oil and gas fields	Oil & Gas	20^{th} Round	(2002)
SEA 2 Extension	Outer Moray Firth	Oil & Gas	20^{th} Round	(2002)
SEA 3	The remaining parts of the southern North Sea	Oil & Gas	21^{st} Round	(2003)
R2	Three strategic regions off the coasts of England and Wales in relation to a second round of offshore wind leasing	Offshore wind	R2	(2003)
SEA 4	The offshore areas to the north and west of Shetland and Orkney	Oil & Gas	22^{nd} Round	(2004)
SEA 5	Parts of the northern and central North Sea to the east of the Scottish mainland, Orkney and Shetland	Oil & Gas	23^{rd} Round	(2005)
SEA 6	Parts of the Irish Sea	Oil & Gas	24^{th} Round	(2006)
SEA 7	The offshore areas to the west of Scotland	Oil & Gas	25^{th} Round	(2008)



The DECC offshore energy SEA process has developed over time, drawing in concepts and approaches from a variety of individuals, organisations and other SEAs as well as addressing the requirements of legislation and guidance. The process followed for this SEA and temporal sequence of events is summarised below, but note that certain activities such as information gathering continue throughout the process.

Initial scoping for the Offshore Energy SEA with the SEA Steering Group, environmental authorities and a range of academic and conservation organisations commenced early in 2006. A formal scoping exercise with the statutory Consultation Bodies/Authorities and other stakeholders was conducted from December 2007; a report of the scoping feedback can be downloaded from www.offshore-sea.org.uk.

In addition, a range of field surveys, technical studies and syntheses of data were commissioned to underpin the offshore energy SEA assessment. These technical and data reports are summarised in the Environmental Report and are available for download at www.offshore-sea.org.uk where documents for previous SEAs are also available.

An Assessment Workshop involving the SEA Steering Group, technical report authors and SEA team was held in early September 2008 and is summarised in Appendix 2. The output of this workshop included the final list of SEA objectives and indicators (see Section 3 of the Environmental Report), the draft plan/programme alternatives and a list of topics to be considered in more detail in the Environmental Report.

Three regional stakeholder meetings were held in Cardiff, Glasgow and London in October 2008 at which stakeholders from a wide variety of organisations, sectors and areas participated. Topic specific fisheries, navigation and developers' workshops were also held in October 2008. The stakeholder input on the information base and other issues of relevance to the SEA is summarised in Appendix 2 of the Environmental Report.

The Environmental Report and draft plan/programme are being issued for consultation in line with the requirements of the SEA Regulations and the Government's Code of Practice on Consultation (latest version July 2008) – see the "Next Steps" section at the end of this no-technical summary. After a 12 week public consultation period, the Department and the Secretary of State will consider comments received from consultation in the decision making regarding the draft plan/programme. A Post Consultation Report will be prepared and placed on the SEA website collating the comments and DECC responses to them.

Environmental Report

The Environmental Report of the Offshore Energy SEA provides relevant information for formal consultation with the statutory Consultation Bodies/Authorities and with the public regarding the implications of the draft plan/programme and its alternatives.

In accordance with the SEA Regulations, the following potentially affected receptors were included within the scope of the assessment.

- Biodiversity, habitats, flora and fauna
- Geology and sediments
- Landscape/seascape
- Water environment
- Air quality
- Climatic factors
- Population and human health
- Other users, material assets (infrastructure, other natural resources)
- Cultural heritage, including architectural and archaeological heritage
- Interrelationships of the above

Information on the environmental baseline and its likely future evolution has been grouped into these subject areas and the assessment has used the same headings in the interests of clarity.

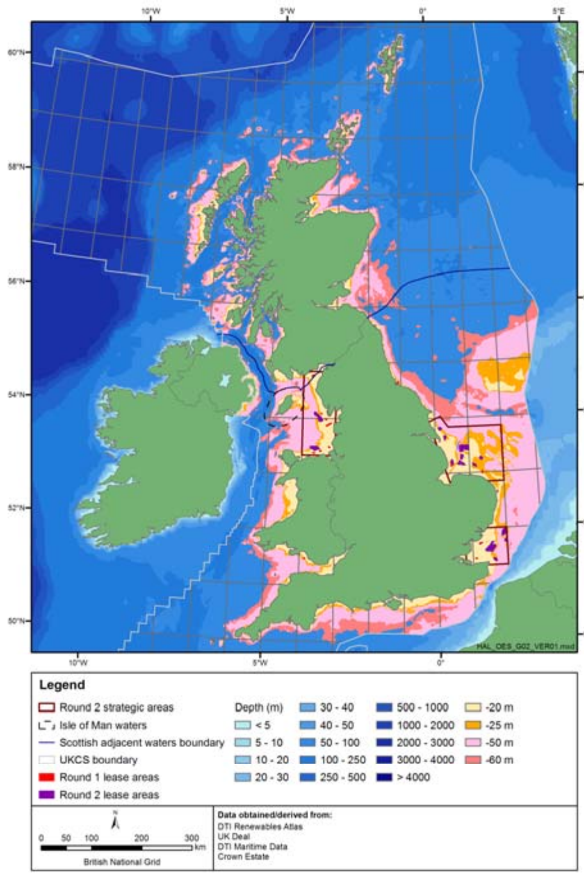
The key points and conclusions of the assessment are summarised below.

What areas are included in this SEA?

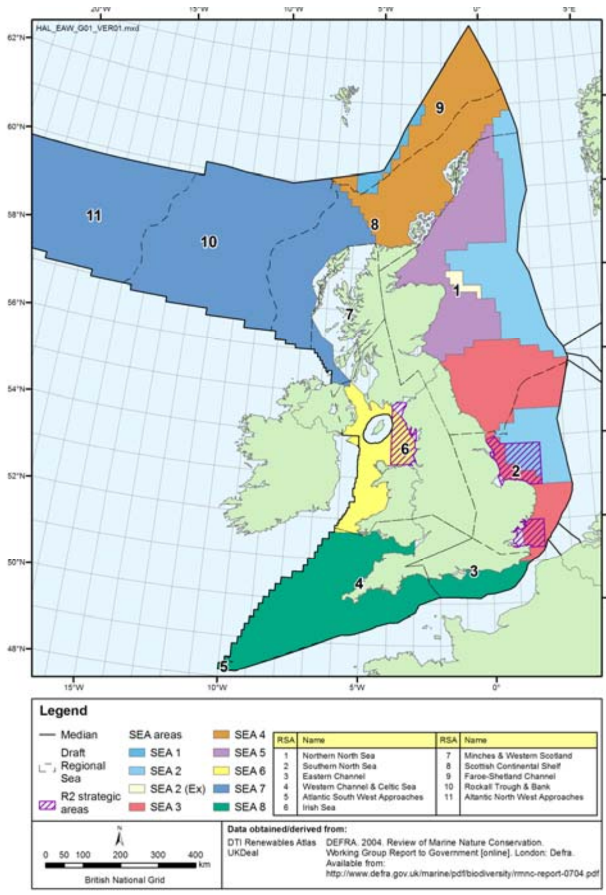
For offshore wind leasing, this SEA covers those parts of the UK Renewable Energy Zone and the territorial waters of England and Wales where the water depth is around 60m or less - see Map 2.

For offshore (seaward) oil and gas licensing and for offshore gas storage licensing this SEA covers all UK waters (SEA 1 to 8 areas) – see Map 3.

Map 2 – Location of shallow waters (<60m)



Map 3 – Past SEA areas (coloured) and Regional Seas (numbered)



Overview of the natural environment

Following discussion with the SEA Steering Group in February 2008 it was agreed to use the draft Regional Seas divisions as a basis for considering UK waters for this SEA – see numbered areas on Map 3.

The UK has a rich marine biodiversity reflecting both the range of habitats present in water depths from the shore to >2400m, and its position where several biogeographical provinces overlap. Some species and habitats are naturally rare, whilst others are endangered by human activities, and actions to protect and promote biodiversity are being taken at many levels including national, European and global. The natural environment of UK waters is summarised in Appendix 3 to the Environmental Report and selected highlights are given below.

The bird fauna of the UK is western Palaearctic, that is the great majority of species are found widely over western Europe and extend to western Asia and northern Africa. There are three regular patterns of species occurrence: resident, summer visitors (to breed) and winter visitors. Some of the summer visitors undertake long migrations to overwinter in southern Africa or South America. A few species are found only or predominantly in the UK. By way of example, the three Pembrokeshire islands of Skomer, Skokholm and Middleholm are estimated to hold some 50%, and the Isle of Rum off western Scotland between a quarter and a third of the world's breeding population of Manx shearwaters.

Many of the species of whales and dolphins found in UK waters have a worldwide distribution, although a number have restricted ranges, typically temperate to sub-Arctic or Arctic waters of the North Atlantic. British whales and dolphins include resident species as well as migrants (regularly moving through the area to and from feeding and breeding grounds) and vagrants (accidental visitors from the tropics or polar seas). Two species of seal breed in the UK; the grey seal has a North Atlantic distribution with the UK holding over 40% of the world population; and the harbour seal is found along temperate, sub-Arctic and Arctic coasts of the northern hemisphere, with the UK population representing over 5% of the global total.

A wide range of biogeographic distribution patterns are shown by the fish in UK waters. The majority of continental shelf species have a north-east Atlantic/northern Atlantic distribution, although a proportion are found globally in the tropics/subtropics and others have a circum-polar pattern of occurrence. Widely distributed species often include local stocks with distinct breeding times and locations (e.g. herring). Deep water fish show different distribution patterns with major differences occurring north and south of the Wyville Thomson Ridge (*ca*. 60°N), and a distinct species group found in the cold waters of the Faroe-Shetland Channel and Norwegian Sea. Virtually all commercially fished species are heavily exploited.

In broad biogeographical terms, the planktonic flora and fauna of UK waters is part of the North-East Atlantic Shelves Province which extends from Brittany to mid-Norway. In addition, the deeper Faroe-Shetland Channel and areas to the north are within the Atlantic sub-Arctic Province. Each province can be subdivided according to hydrography and plankton composition.

The composition of the seabed fauna of the UK reflects the intersection of four biogeographical zones:

- Boreal Province including the North and Irish Seas
- Lusitanian-Boreal Province comprising the Celtic Sea and west coasts of Ireland and Scotland
- 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

Within each Province it is possible to distinguish a series of faunal communities inhabiting specific sediment types. Often these communities extend over wide areas (e.g. the fine sands of the central North Sea and the sandy muds of the Fladen Ground in the northern North Sea). In addition, there are a number of highly localised habitats and communities, including reefs of long lived horse mussels and cold water corals, some of which are the subject of biodiversity action either at an OSPAR, EU or UK level. A large proportion of the seabed of the UK continental shelf and upper slope is physically disturbed by fishing activities.

Other context to the draft plan/programme

The Marine Bill White Paper (2007) notes that activities in the marine area contribute substantially to the UK economy and quality of life, with an annual economic contribution in the order of £67 billion.

The SEA Regulations require that consideration is given to the degree to which the "plan or programme influences other plans and programmes including those in a hierarchy".

The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) is an important mechanism through which Governments of the western coasts and catchments of Europe, together with the European Community, cooperate to protect the marine environment of the North-East Atlantic. The OSPAR Commission is in the process of establishing a network of Marine Protected Areas (MPAs), the designation of which will be informed by the OSPAR Initial List of Threatened and/or Declining Species and Habitats. It is aimed to complete a joint network of well managed MPAs by 2010 that, together with the Natura 2000 network, is ecologically coherent.

OSPAR periodically publishes assessments in the form of Quality Status Reports (QSRs) of the North-East Atlantic and its sub-regions with the last QSR being published in 2000. OSPAR is currently preparing a new assessment, QSR 2010, a consultation draft of which will be published in November 2009. QSR 2010 will inform the 2010 OSPAR Ministerial Meeting in Bergen on the environmental status and future actions for the protection and conservation of the North-East Atlantic.

The EU Marine Strategy Framework Directive entered into force in July 2008. The key objectives of the Directive are to achieve good environmental status of the EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend.

The Directive establishes European Marine Regions on the basis of geographical and environmental criteria. UK waters lie within the Greater North Sea and Celtic Sea sub-regions of the North-East Atlantic Ocean Region. Each Member State is required to develop strategies for their marine waters in cooperation with other Member States and non-EU countries within a Marine Region.

The Marine Strategies must contain a detailed assessment of the state of the environment, a definition of "good environmental status" at regional level, and the establishment of clear environmental targets and monitoring programmes. The Directive requires that programmes of measures be established to achieve good environmental status, and that these include spatial protection measures contributing to coherent and representative networks of marine protected areas, adequately covering the diversity of the constituent ecosystems. Such protected areas are to be coordinated with the Natura 2000 site network established under the Birds and Habitats Directives, for which designations in some UK marine areas are not yet completed.

The *Marine and Coastal Access Bill* was introduced to the House of Lords on 4th December 2008. The Bill will:

- Introduce a new marine planning system, with long-term objectives for the marine area around the UK and, subsequently, the creation of more detailed local marine plans

- Establish a Marine Management Organisation for the waters around England and the UK offshore area
- Streamline the law on licensing marine development so that, as far as possible, only one licence is needed for each development
- Provide powers to designate Marine Conservation Zones and to protect those zones from damaging activities
- Secure a long-distance route around the coast of England, including beaches, cliffs, rocks and dunes, with public access for coastal walking and other recreational activities
- Strengthen and modernise the licensing and management of marine, migratory, freshwater and shellfish fisheries, including the creation of new Inshore Fisheries and Conservation Authorities, and introduce a scheme to manage live fish movement
- Streamline and modernise enforcement powers for fisheries and nature conservation, providing a civil sanctions scheme for licensing and nature conservation offences, and an administrative penalty scheme for domestic fisheries offences

A full list of other initiatives which have been analysed in terms of their implications for the draft plan/programme and vice versa is given in Appendix 4.

Prospectivity

For commercial **hydrocarbon resources** to occur, a number of factors and features have to coincide, including:

- The presence of source rocks, with an appreciable organic matter content
- Adequate depth of burial to allow the conversion of the organic matter to oil or gas through the action of temperature and pressure
- The presence of rocks with sufficient porosity to allow the accumulation of oil or gas
- Cap or seal rocks to prevent the oil or gas from escaping from the reservoir rocks
- Migration pathways to permit oil and gas formed in the source rocks to move to reservoir formations

Such conditions typically occur in sedimentary basins, and not areas of igneous rock unless these overlay sedimentary rocks as in parts of the Faroe-Shetland Channel.

Offshore areas of the UK have been offered for oil and gas licensing in a series of rounds since 1964, with the 25th Round held in 2008. Areas with hydrocarbon prospectivity have been extensively explored over this period and many fields brought into production, mainly in the North and Irish Seas, resulting in an extensive infrastructure which can be utilised by new developments. There is a consensus view that the great majority of large fields in shelf depth waters (<200m) have been found, and deeper water areas are either not prospective or increasingly well explored and understood. Gas storage in depleted and other hydrocarbon reservoirs is part of the current draft plan/programme, and can be expected to take place in the same areas as existing oil and gas production.

The UK has extensive **marine renewable energy** resources including wind, wave and tidal, all of which are variable over space and time. There are several demonstration and commercial offshore wind farms in operation or under construction in UK waters following two rounds of offshore wind leasing in 2000 and 2003, with the generation capacity of all consented developments currently totalling some 5.5GW. Away from the shelter of the coast, the total wind resource over a year is relatively uniform across very large areas, although clearly the occurrence and strength of wind is dependant on a number of meteorological factors. At any point in time while some areas of the UK may be calm, the wind is likely to be blowing elsewhere. Water depth, distance from areas of high electricity demand, and the availability of connection points to the onshore transmission grid are significant factors in the preferred location of offshore wind developments.

Exploitation of wave and tidal stream energy is not yet fully commercial in UK waters, although several test and demonstrator projects have been deployed or are in development. Wave and tidal energy is not part of the draft plan/programme considered in this SEA.

Overview of main sources of effect and controls in place

The main stages of offshore wind farm development are:

1. Site prospecting/selection including collection of site specific wind data, and seabed information by geophysical and geotechnical survey
2. Development, including construction of foundations and any scour protection, turbine installation, cable laying including shoreline crossings and armouring, installation of gathering stations/substations and connection to the onshore national electricity transmission system
3. Generation operations
4. Maintenance
5. Decommissioning, including removal of facilities

The main stages of oil and gas activity (including natural gas storage) are:

1. Exploration, including seismic survey and exploration drilling
2. Development, including production facility installation, generally with construction of an export pipeline, and the drilling of producer and injector wells
3. Production/operation, with routine supply, return of wastes to shore, power generation, chemical use, produced water reinjection management and reservoir monitoring
4. Maintenance
5. Decommissioning, including cleaning and removal of facilities

These activities can interact with the natural and broader environment in a number of ways. The main potential sources of environmental effects from activities which could follow adoption of the draft plan/programme are:

- Noise (impulsive) from seismic survey and piling during installation
- Noise (semi-continuous or continuous) from turbines, drilling rigs, production facilities or vessels
- Physical damage (acute) to seabed features, biota and features of archaeological interest from anchoring, pipeline construction and cable laying
- Physical damage (non-acute) from particulate smothering
- Physical presence of structures, colonisation of structures by organisms, avoidance of wind farm areas e.g. by birds, animal collisions with structures and turbine blades
- Physical presence of structures, interference with other users of the sea
- Physical presence of structures, visual intrusion
- Chemical contamination (routine) from drilling and other discharges, antifouling coatings etc
- Chemical contamination (accidental) from spills
- Atmospheric emissions from fuel combustion, venting
- Electromagnetic Fields, possible effects on electrically or magnetically sensitive species from subsea power cables

All the major stages of offshore oil and gas and offshore wind farm operation are covered by environmental regulations including the requirement for Environmental Impact Assessment at the development stage (see Appendix 5).

For oil and gas, consents (with applications supported by assessments of effects) are required for seismic survey, exploration drilling, field development, pipeline installation, development drilling, field operation (including atmospheric emissions, production of hydrocarbons, use of chemicals, produced water treatment), offshore facility modification, field decommissioning etc. The major consents also include a public consultation stage which allows stakeholders to draw issues to the attention of DECC and the developers.

The *Energy Act 2004,* the *Energy Act 2008,* the *Planning Act 2008* and the *Marine and Coastal Access Bill 2008* together with "Marine Bills" proposed by the devolved administrations provide a revised framework for the consenting of offshore wind farms.

Assessment summary

Biodiversity, habitats, flora and fauna

In general, marine mammals show the highest sensitivity to **acoustic disturbance by noise** generated by offshore wind farms and by hydrocarbon exploration and production activities. The severity of potential effect has therefore been related principally to marine mammal species composition and abundance in the area under consideration, although effects on fish (including spawning aggregations) have also been considered. For both marine mammals and fish, various effects will generally increase in severity with increasing exposure to noise; a general distinction may be drawn between effects associated with physical injury or physiological effects, and effects associated with behavioural disturbance.

Seismic surveys generate among the highest noise source levels of any non-military marine activity. The potential for significant effect in relation to oil & gas activities is therefore largely related to the anticipated type, extent and duration of seismic survey. In offshore wind farm construction, pile-driving of turbine foundations may also generate high source levels and has been widely recognised as a potential concern, in particular for large developments where many piles may be installed sequentially, or where more than one piling rig might be used simultaneously thus affecting a larger area.

There is now a reasonable body of evidence to quantify noise levels associated with both seismic survey and wind turbine foundation pile-driving, and to understand the likely propagation of such noise within the marine environment. There is less clarity about the potential effects on marine mammals (and other receptors including fish), particularly in relation to distinguishing a significant behavioural response from an insignificant, momentary alteration in behaviour. Consequently, recent expert assessments have recommended that onset of significant behavioural disturbance resulting from a single pulse is taken to occur at the lowest level of noise exposure that has a measurable transient effect on hearing. In the light of limited behavioural data the SEA also concurs with the scientific consensus judgement that seismic and pile-driving operations have the potential to cause some level of disruption of normal behaviour in marine mammals and possibly some species of fish at ranges of many kilometres. However, both planning and operational controls cover noise from relevant marine activities, including geophysical surveying and pile-driving. In addition, it is an offence to deliberately disturb wild animals of a European Protected Species (EPS), particularly during the period of breeding, rearing, hibernation and migration or to cause the deterioration or destruction of their breeding sites or resting places. EPS are those species listed in Annex IV of the Habitats Directive, which includes all cetacean species.

The SEA has considered the protections afforded to EPS under the habitats Directive and the latest JNCC guidance on interpretation of the main elements of the disturbance offence. Using maximum abundance data from the Survey of Small Cetaceans Abundance of the North Sea and Adjacent Waters (SCANS) II survey, the SEA has estimated the noise level experienced at the edge of the area in which high densities of animals would be expected to occur (this would be a large area for species with large a population size but occurring at low density, but a small area for small groups/high densities). This analysis indicates that single seismic or pile-driving sources are unlikely to have a significant disturbance effect, with the possible exception of coastal populations of bottlenose dolphins (where impacts would be assessed/further mitigated through the Appropriate Assessment process under the Habitats Regulations). The SEA therefore concludes that neither regional nor local prohibitions on the activities under consideration are justified by acoustic disturbance considerations. Given the lack of definition of the actual survey and development programmes which the draft plan/programme may entail (in terms of duration, nature of acoustic sources and the potential for temporal or spatial mitigation), it is also not possible to make specific recommendations concerning mitigation. However, it is noted that such project-specific assessments will be required for all areas under the existing regulatory regime, including requirements for consideration of deliberate disturbance of cetaceans.

Having considered marine mammal sensitivities of individual Regional Seas, together with potential cumulative effects resulting from the probable combination of oil and gas licensing and offshore wind leasing, the SEA recommends that within certain key areas of marine mammal sensitivity, operational criteria are established to limit the cumulative pulse noise "dose" (resulting from seismic survey and pile-driving) to which these areas are subjected. It will be necessary to consult with both industries to define the terms of such criteria; however, a simple approach could be implemented within the existing regulatory framework for activity consenting, particularly if initially developed and adopted voluntarily in collaboration within the industries (as was the case, initially, with the existing JNCC mitigation guidelines). The approach would also require a mechanism to facilitate the exchange of information, for example through a web-based forum hosted by DECC, JNCC or the future MMO.

Activities associated with offshore wind farm development, exploration and production of oil and gas, and gas storage can lead to **physical disturbance of seabed habitats**, with consequent effects on seabed features and biotopes and potentially on archaeological artefacts. In particular, scour – a localised erosion and lowering of the seabed around a fixed structure – was recognised at an early stage as a potential issue in relation to wind turbine foundations, and has been subject to considerable research and monitoring. These studies have concluded that scour effects are small in scale and local in extent.

The SEA has considered the spatial extent of predicted disturbance effects, and the sensitivity of seabed habitats (in particular habitats which potentially qualify under the Habitat and Species Directive Annex I) and placed these in the context of natural disturbance events and current assessment (using newly available data) of the major sources of direct, physical pressure from human activities on seabed environments. The SEA concludes that physical disturbance associated with activities resulting from proposed oil and gas licensing and wind farm leasing will be negligible in scale relative to natural disturbance and the effects of demersal fishing. The potential for significant effects, in terms of regional distribution of features and habitats, or population viability and conservation status of benthic species, is considered to be remote.

The broadscale distribution of seabed biotopes is relatively well mapped, so the likely occurrence and general sensitivity of habitats in proximity of proposed activities can be assessed. Similarly, specific projects can be assessed in terms of likelihood of the presence of significant archaeological features. In both cases, however, detailed site surveys (which are routinely undertaken prior to development operations) should be evaluated with regard to environmental and archaeological sensitivities.

The **physical presence of offshore infrastructure and support activities** may potentially cause behavioural responses in fish, birds and marine mammals, through a range of different mechanisms. Previous SEAs have considered the majority of such interactions with offshore oil and gas infrastructure (whether positive or negative) to be insignificant, because the total number of surface facilities is relatively small (low hundreds) and the majority are far offshore, in relatively deep water. This assessment is considered to remain valid for the potential consequences of future rounds of oil and gas licensing (including for gas storage). However, the large number of individual structures in offshore wind farm developments, the presence of rotating turbines, and their potential location (e.g. in relation to coastal breeding or wintering locations for waterbirds), indicate a higher potential for physical presence effects. In relation to birds, these include displacement and barrier effects associated with exclusion from ecologically important (e.g. feeding, breeding) areas, disturbance of regular movements (e.g. foraging, migration), collision risk, and the disturbance effects of light. Bat collisions with offshore structures are not considered to be a significant issue for the draft plan/programme assessed. Other potential effects considered by the SEA include fouling growth (colonisation of a structure by plants and animals), the introduction of rock in sedimentary areas, effects on natural habitats (such as localised warming around seabed cables) which could facilitate colonisation by non-indigenous species, and electromagnetic fields (EMF) as a potential source of effect resulting from marine electricity transmission, particularly on electrosensitive fish (e.g. sharks and rays) behaviour.

Overall, the assessment of these effects concludes that based on available evidence, displacement, barrier effects and collisions are all unlikely to be significant to bird populations at a strategic level. However, there are some important uncertainties in relation to bird distribution, variability in migration routes and timings, the statistical power of monitoring methods, and the sensitivity of this conclusion to modelling assumptions (notably avoidance frequency in modelling of collision risk and several important factors in modelling of population dynamics). Therefore, recognising that a large proportion of the bird sensitivities identified are concentrated in coastal waters, a coastal buffer zone of 12 nautical miles (some 22km) is recommended, within which major wind farm development would not normally occur.

Although there has recently been significant survey effort in coastal waters, the lack of modern data on waterbirds in offshore areas is noted. Developers need to be aware that access to adequate data on waterbird distribution and abundance is a prerequisite to effective environmental management of activities, for example in site selection, timing of operations and oil spill contingency planning.

There are some information gaps relating to EMF effects, and although not considered significant at a strategic level, it is recommended that research results are monitored to inform site specific considerations.

Geology and sediments

All UK areas include a wide range of geomorphological features resulting from the underlying solid geology, past glaciations and recent processes, with sediments ranging from muds to boulders. Various wind farm and oil industry activities would result in sediment disturbance or potentially, without mitigation, destruction of small scale features. The seabed mapping undertaken in advance of operations allows the identification and hence avoidance of valued features. Contamination of sediments may occur from discharges of drilling wastes and spills, or in the case of the oil industry from production wastes such as produced water. The composition of planned discharges from wind farm and oil industry operations is regulated, with increasingly stringent controls applied in recent years. Monitoring results indicate that sediment contamination is not a significant issue in wind farms or recent hydrocarbon developments. The geological information derived from seabed mapping, seismic survey, geotechnical surveys and the drilling of wells is regarded as a positive contribution to the understanding of the UKCS.

Landscape/seascape

The major development of offshore wind farms envisaged by the draft plan/programme could result in significant effects on landscape/seascape. In contrast, most potential hydrocarbon developments are likely to be sub-sea facilities, well offshore and beyond sight of land. The assessment has considered the theoretical maximum visibility of offshore wind turbines (of a range of sizes and heights) during day and night based on curvature of the Earth, the relative effectiveness of the 8 and 13km seascape buffers adopted in the Round 2 SEA, based on evidence from Round 1 and 2 developments, the relative sensitivity of the coast and hinterland based on protected/valued landscape designations, and international practice in wind farm siting. Significant adverse effects are likely without mitigation; however, for a variety of impact reduction reasons a general guideline of a 12 nautical mile buffer zone is recommended for large (>100MW) wind farm developments. This is not to exclude wind farms from being built closer to shore but to reduce conflicts with a range of ecological and other receptors (including landscape/seascape) and avoid potential public opposition and extended consenting timescales.

Water environment

Contamination of water may occur from discharges of drilling wastes, production wastes such as produced water (i.e. water produced along with oil and gas during the production phase), dissolution of antifouling coatings and corrosion protection anodes, accidental spills, grouting, or disturbance of previously contaminated sediments.

Drilling discharges from the renewable energy and hydrocarbon industries are comprehensively regulated, with the discharge of oil-based drilling fluids effectively banned, and strict controls implemented over chemical additives used in water-based fluids. In view of the offshore locations, water depths and current regimes prevalent in areas of likely wind farm development, prospecting for hydrocarbons and gas storage, significant contamination or ecological effects of drilling discharges are not expected. It is not expected that significant discharges of produced water will be made from new hydrocarbon developments, since there is a strong presumption against marine discharge and regulatory preference for reinjection to a suitable subsurface formation. Other operational discharges are subject to regulatory controls, and are not considered to have significant environmental risk.

UK regional and national monitoring programme results indicate that water column contamination and associated biological effects are not significant issues.

Air quality

Atmospheric emissions from the potential activities likely to follow implementation of the draft plan/programme could affect local air quality. Gaseous emissions contribute to regional acid gas loads and may result in local low level ozone and smog formation. The principal routine operational emissions during offshore wind and oil industry exploration, construction and production operations are of combustion products (CO_2, CO, NO_X, SO_2, CH_4, and volatile organic compounds (VOCs)) from power generation and engines on rigs, production facilities, vessels and helicopters. Fugitive emissions such as those from cement tanks, diesel storage and cooling/refrigeration systems can result in emissions of dust/particulates, VOCs, hydrofluorocarbon refrigerants etc depending on the source.

In some parts of UK waters there are appreciable atmospheric emissions from maritime activities. However, the likely geographic spread and timing of projected activities which may follow leasing/licensing, and the limited scale of other such sources offshore indicate that significant effects on local and regional air quality will not occur. The implications of atmospheric emissions from all wind farm developments, and hydrocarbon exploration, production and storage activities would be assessed through the statutory EIA process, which would serve to identify if mitigation was required.

Climatic factors

Atmospheric emissions from the potential activities following implementation of the draft plan/programme will contribute to local, regional and global concentrations of CO_2 and other greenhouse gases, although in the case of offshore wind farm developments these will be offset by the production of renewable energy. There are growing concerns about the effects of fossil fuel combustion in terms of climate change and ocean acidification. However, the contribution of atmospheric emissions from hydrocarbon related activities that may result from implementation of draft plan/programme alternative 2 or 3, or the end use of any hydrocarbons produced, would represent a small fraction of existing UK, European and global emissions. In response to climate change concerns, the UK government and European Union continue to introduce a variety of policy initiatives intended to stabilise and reduce greenhouse gas emissions. All recognise the long term nature of the venture and that there is no one solution, with a series of contributory steps being required. These steps include reduction in energy demand through increased energy efficiency, promotion of renewable fuels and electricity generation, fuel switching to lower carbon alternatives, carbon capture and sequestration etc. In the short term, UK energy demand not met from indigenous sources (whether fossil or renewable) will be supplied by imported fossil fuels – with little distinction in terms of resultant atmospheric emissions. Thus domestic hydrocarbon production would be neutral in the attainment of UK climate change response policy objectives, and potentially positive in respect of oil, since associated gas is put to beneficial use rather than mostly flared as in some other sources of potential supply. In addition, domestic hydrocarbon production has a positive contribution to the UK economy and security of supply.

Population and human health

No adverse effects on population or human health are expected, based on the nature of the activities that could follow leasing and licensing, the offshore locations, the low risk (based on historic frequency and severity) of major accidental events, the regulations in place to manage occupational health risks to the workforce and others, and the controls on chemical use and discharge and on other marine discharges. Potential difficulties in effecting search and rescue operations by helicopter in offshore wind farms are noted; these can be mitigated in part by the lay out of turbines within a wind farm.

The adoption of the draft plan/programme is likely to contribute to maintaining investment and activity in the UK offshore oil and gas industry, and to increase investment and activity in the offshore wind energy industry and offshore gas storage. This will bring positive benefits in terms of an increased proportion of low carbon energy in the UK energy mix, greater security of energy supply and increased employment and tax revenues.

Other users, material assets (infrastructure, other natural resources)

A casual look out to sea may suggest an open space with few other uses. The reality is very different, with multiple uses particularly of coastal areas. Partly in response to the scale of the area needed for major expansion of offshore renewable energy generation (100s to 1000s of square kilometres), proposals for formal marine spatial planning are included in the *Marine and Coastal Access Bill 2008*. The range and importance of existing and some potential uses of the sea are described in Appendix 3 of the Environmental Report, with key aspects summarised below. In advance of formal marine spatial planning, the approach taken in this SEA has been to obtain accurate and recent information on other current and likely uses of the sea in the foreseeable future, to facilitate identification of sensitive areas and measures to reduce the scope and scale of significant adverse effects.

The UK is heavily reliant on shipping for the import and export of goods, and will remain so for the foreseeable future. Over 95% of the goods entering or leaving the UK are transported by ship, with substantial numbers of vessels also transiting UK waters en route to other European and more distant ports. In recognition of the vessel traffic densities and topographic constraints on various routes, the International Maritime Organisation (IMO) has established a number of traffic separation schemes and other vessel routeing measures to reduce risks of ship collision and groundings. In addition, IMO regulations required that from the beginning of 2005, an Automatic Identification System (AIS) transponder be fitted aboard all ships of >300 gross tonnage engaged on international voyages, all cargo ships of >500 gross tonnage and all passenger ships irrespective of size. AIS allows precise tracking of individual vessels, and for this SEA, AIS data covering 4 weeks spanning 2007 were obtained and analysed to provide accurate information on important areas for larger vessel navigation. In addition to collision and grounding risk considerations, most vessels typically take direct routes from place to place and new obstructions causing large route deviations would increase transit times and fuel usage. It was concluded that wind farm siting should be outside areas important for navigation (these are mapped in the Environmental Report) and that this would not preclude the attainment of the draft plan/programme objectives.

Fishing in the UK has a long history and is of major economic and cultural importance. In 2007, there were nearly 13,000 working fishermen in the UK (of which 79% were full time), operating over 6,700 vessels, many of which were smaller inshore boats. These vessels landed 610,000 tonnes of fin- and shellfish in 2007, with a total value of £645 million. On top of this, fish processing provides over 22,000 jobs in the UK. The livelihoods of individual fishermen depend on their ability to exploit traditional fishing grounds and to adapt to changing circumstances to maximise profit. Consequently, they are vulnerable to competition within the UK industry and with foreign vessels, and to being displaced from primary grounds. To better understand the fishing activities of UK vessels, information from the UK Sea Fisheries Statistics (logbook submissions) was used to derive maps of fishing effort density, gear type and season. These show that the greatest density of fishing effort takes place in coastal waters, for both static (such as pots, traps or gillnets) and mobile gears (such as trawls and dredges). In addition, larger fishing vessels (>24m) in the EU have carried a Vessel Monitoring System (VMS) since 2000. From 2003, this requirement was extended to vessels >18m, and from 2005 to vessels >15m. To inform the SEA, VMS data for UK vessels over three years (2005-2007) was obtained and analysed to provide information on important fishing areas for larger vessels and offshore areas. It is recommended that waters near the coast and certain especially important fishing areas offshore are avoided for future wind farm siting.

Military use of the coasts and seas of the UK is extensive, with all three Services having defined Practice and Exercise Areas, some of which are danger areas where live firing and testing may occur. Such areas are well documented and have been taken account of in the

SEA. In addition, in terms of national security the potential for offshore wind farms to interfere with the reception and discrimination of military radars (air traffic control and those part of an early warning system) is a key consideration for the siting of such developments. There are a number of other defence sensitive areas which are not necessarily mapped, but need to be taken account of at the planning stages of an individual project. These aspects require internal Government discussion and are, of necessity, outside the scope of this SEA.

Offshore wind farms have the potential to affect civilian aerodromes and radar systems. The UK air traffic control service for aircraft flying in UK airspace has made available mapped data indicating the likelihood of interference from offshore wind turbines on its radar reception. Similarly, the Civil Aviation Authority (CAA) produces an Aerodrome Safeguarding Map and Local Planning Authorities are required to consult on relevant Planning Applications which fall within a 15km radius. Any proposals for a wind turbine within a 30km radius of an airport also require consultation with the Airport Company. In addition, the CAA has indicated the need to maintain a 6 nautical mile obstacle-free zone around offshore oil and gas facilities to allow for the safe operation of helicopters undertaking instrument (as opposed to visual) approaches. This requirement may restrict the location of offshore wind farm developments although, with adequate risk assessment and consultation with the field operator, variations to the 6nm zone can be agreed.

Tourism and recreational use of UK coasts and coastal waters is of major importance in many areas. Annually, the British public take some 28 million days on seaside holidays in the UK spending £5.1 billion, split between England (£4 billion), Wales (£0.52 billion), Scotland (£0.44 billion) and Northern Ireland. Major recreational uses of the sea beyond beaches and coastal paths include yachting (for which the Royal Yachting Association has published charts of cruising and racing routes) and sea angling, which in England and Wales generates some £82m for charter boats and £278m for own boat activities. Many visitors to the coast cite unspoilt and beautiful natural scenery as the important factors influencing their selection of location to visit. The importance of such attributes is widely recognised and protected through designations such as National Parks, Areas of Outstanding Natural Beauty, and National Scenic Areas. The wind farm siting recommendation made above for landscape/seascape is also considered to significantly reduce the potential for adverse effects on tourism and recreation.

Various areas of sea are used or licensed/leased for marine aggregate extraction, telecommunications and other cables, disposal of capital and other dredging wastes, Round 1 and Round 2 offshore wind farms, surface and subsea oil and gas production and export infrastructure. These have a combined turnover of some £34 billion, employing nearly 320,000 people and have all been mapped and considered in this SEA. Potential future uses of the sea include gas storage (both natural gas and carbon dioxide) in geological formations, aquifers or constructed salt caverns. Where available, information on potentially suitable locations for this has been considered in the assessment.

The implementation of the draft plan/programme will result in some associated development activities onshore for example the installation of substations and National Electricity Transmission System connections for offshore wind farms and the installation of additional equipment at existing gas terminals for gas storage. The construction phase of offshore wind farms at the scale envisaged in the draft plan/programme is likely to require the expansion of certain port facilities.

Cultural Heritage

The collective inventory and knowledge of maritime sites in particular is quite poor and may be subject to recording biases. Archaeology associated with human and/or proto-human activities either on the current seafloor of the southern North Sea, in the coastal zone of the British Isles and further inland, has the potential to date back at least as far as 500,000 years BP. Relatively recent finds of flint artefacts from the Cromer Forest-bed Formation in Suffolk date to as early as 700,000 years BP. The current understanding of marine prehistoric archaeology is based on knowledge of the palaeolandscapes of the continental shelf between the UK and Europe during glacial phases and limited finds of archaeological materials, augmented with knowledge of analogous cultural and archaeological contexts from modern day terrestrial locations. The record for wreck sites is biased towards those from the post-Medieval and later periods, presumably a function of greater traffic and increased reporting associated with the introduction of marine insurance and the Lloyds of London list of shipping casualties in 1741. The strategic military importance of the sea, the importance of the North Sea as a fishing area, the importance of maritime trade routes and the treacherous nature of many nearshore waters, has lead to a large number of ship and aircraft wrecks in UK waters.

A number of coastal sites have been designated as World Heritage Sites, for example St Kilda, the Dorset and East Devon Coast and the Heart of Neolithic Orkney.

No strategic level controls were identified during the SEA assessment, and it is through site specific surveys that cultural heritage features would be identified and mitigation measures to be developed, in line with existing guidelines for seabed developers.

Interrelationships - Cumulative effects

The effects of activities which could result from adoption of the draft plan/programme have the potential to act incrementally with those from other wind farm and oil & gas existing facilities or new activities, or to act cumulatively with those of other human activities (e.g. fishing and shipping). Secondary effects are indirect effects which do not occur as a direct result of the proposed activities, while synergistic effects are considered to be potential effects of oil or wind farm industry activities where the joint result of two or more effects is greater than the sum of individual effects.

Cumulative effects in the sense of overlapping "footprints" of detectable contamination or biological effect were considered to be either unlikely (accidental events), or very limited (for physical damage, emissions, discharges), since monitoring data indicates that the more stringent emissions, discharge and activity controls introduced over recent years have been effective and there is no evidence for significant cumulative effects from current activities.

The SEA recognises that there is uncertainty regarding potential cumulative effects of noise disturbance, and recommendations to address this are outlined above. There is also the potential for significant adverse effects on other users of the sea (including radar coverage) and on landscape/seascape from major development of offshore wind farms. However, this can be mitigated to acceptable levels by appropriate site selection, in particular avoidance of areas of prime importance to other industries/users and preferential selection of sites away from the coast where offshore structures are less visually intrusive (such areas usually benefit from an improved quality of wind resource available). Area-wide mitigation solutions for potential radar interference may be possible but require pilot studies and trials.

Atmospheric emissions resulting from fossil fuel use during wind farm facility manufacture, construction and maintenance, are more than balanced by the overall net reductions in carbon dioxide emissions as a result of electricity generation from renewable energy. Atmospheric emissions from oil industry activities that may result from implementation of draft plan/programme alternative 2 or 3, and the end use of any hydrocarbons produced, will contribute to overall global emissions of greenhouse gases. However, the scale of such emissions is relatively small, and they will be included in overall UK emissions inventories and also in the longer term initiatives to shift the balance of energy demand and supply towards a low carbon economy.

Besides a minor contribution to climate change and ocean acidification, no secondary or synergistic effects were identified that were considered to be potentially significant, although the effects of multiple noise sources is an area requiring better understanding.

Interrelationships - Wider policy objectives

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. The contribution of atmospheric emissions from oil and gas and gas storage activities that may result from implementation of draft plan/programme alternative 2 or 3, or the end use of any hydrocarbons produced, would represent a minor fraction of existing UK, European and global emissions. These emissions where they relate to combustion end use would be neutral in the attainment of UK climate change response policy objectives, and potentially positive in respect of oil since associated gas is husbanded, rather than mostly flared as in some other potential sources of supply.

A number of offshore European Conservation (Natura 2000) sites are in the process of being designated under the Habitats Directive, and the boundaries of some coastal and marine sites are being extended. In addition, the Marine Strategy Directive through the *Marine and Coastal Access Bill* will introduce further requirements for identification and designation of Marine Conservation Zones (or Marine Protected Areas). These will require careful consideration in the selection of offshore wind farm sites and oil and gas/gas storage infrastructure to avoid adverse effects on the integrity of the sites or compromising good environmental status.

With suitable mitigation and appropriate controls on activities which could follow adoption of the draft plan/programme, major negative effects on other policies or programmes can be avoided; this includes non-environmental topics such as navigation and air traffic control. In a number of policy areas the draft plan/programme will contribute positively to the achievement of goals.

Transboundary effects

The area covered by the draft plan/programme and considered in the Offshore Energy SEA abuts the waters of all the UK's immediate neighbours. The activities which could result from adoption of the draft plan/programme may occur adjacent to the median lines and thus have the potential to result in transboundary effects including:

- Underwater noise
- Marine discharges
- Atmospheric emissions
- Displacement of fishing activity
- Disruption to migratory species (birds and, possibly, fish and mammals)
- Disruption of radar sensitivity and discrimination
- Accidental events – vessel collisions
- Accidental events – oil spills

All of the effects listed above may be able to be detected physically or chemically in the waters of neighbouring states.

The scale and consequences of environmental effects in adjacent state territories due to activities resulting from the proposed leasing/licensing will be less than those in UK waters, and with the mitigation measures proposed, are considered not to be significant.

Conclusions

The SEA considered the alternatives to the draft plan/programme and the potential environmental implications of the resultant activities in the context of the objectives of the draft plan/programme, the SEA objectives, the existing regulatory and other control mechanisms, the wider policy and environmental protection objectives, the current state of the environment and its likely evolution over time, and existing environmental problems. The conclusion of the SEA is that alternative 3 to the draft plan/programme is the preferred option, with the area offered restricted spatially through the exclusion of certain areas. It is concluded that there are no overriding environmental considerations to prevent the achievement of the offshore oil and gas, gas storage and wind elements of the plan/programme, albeit with a number of mitigation measures to prevent, reduce and offset significant adverse impacts on the environment and other users of the sea.

To attain the 25GW objective of the draft plan/programme, several thousand wind turbines would be needed which, depending on turbine spacing and wind farm separation, may occupy up to 10,000km^2. Development on this scale is judged to have the potential to result in significant environmental effects on areas or landscapes of recognised national, European Community or international protection status, as well as on other uses of the sea. Coastal areas typically have higher environmental sensitivity, both in ecological terms (for example waterbirds and seabed habitats), and in existing human uses (for example shipping, fishing and yachting). Tourism and recreation are key activities and industries in coastal areas, many of which are also protected landscapes such as National Parks. Reflecting the relative sensitivity of multiple receptors in coastal waters, this report concludes that the bulk of this new generation capacity should be sited well away from the coast, generally outside 12 nautical miles (some 22km). The proposed coastal buffer zone is not intended as an exclusion zone, since there may be scope for further offshore wind development within this area, but as mitigation for the potential environmental effects of development which may result from this draft plan/programme. The environmental sensitivity of coastal areas is not uniform, and in certain cases new offshore wind farm projects may be acceptable closer to the coast. Conversely, a coastal buffer in excess of 12nm may be justified for some areas/developments. Detailed site-specific information gathering and stakeholder consultation is required before the acceptability of specific major Round 3 or subsequent wind farm projects close to the coast can be assessed. Marine spatial planning proposals are under consideration in Parliament, which would give coastal regulators and communities further opportunities to have a say in the way the marine environment is managed, in addition to the existing routes for consultation as part of the development consent process.

A series of proposals are made regarding precautions, areas to be withheld, operational controls and certain data gaps.

Next steps

The Offshore Energy SEA Environmental Report and supporting documents are available for review and public comment for a period of 12 weeks from the date of publication in January 2009. The documents are being made available from the SEA website (www.offshore-sea.org.uk) or on CD or printed copy. Comments[1] and feedback should be marked "Offshore Energy SEA Consultation" and may be made via the website or by letter or e-mail addressed to:

Offshore Energy SEA Consultation
The Department of Energy and Climate Change
4th Floor Atholl House
86-88 Guild Street
Aberdeen AB11 6AR
Fax: 01224 254019
E-mail: sea.2009@berr.gsi.gov.uk

The Department will consider comments received from the public consultation in their decision making regarding the draft plan/programme.

A Post Consultation Report will be prepared and placed on the website collating the comments, DECC responses to them and indicating how they and the Environmental Report have been taken account of in the implementation of the plan/programme.

[1] Confidentiality: Your comments may be made public by DECC in relation to this consultation exercise. If you do not want your name or all or part of your response made public, please state this clearly in the response. Any confidentiality disclaimer that may be generated by your organisation's IT system or included as a general statement in your fax cover sheet will be taken to apply only to information in your response for which confidentiality has been requested. However, please also note that DECC may disclose information it holds pursuant to a statutory, legal or parliamentary obligation, including without limitation, requirements for disclosure under the Freedom of Information Act 2000 and/or the Environmental Information Regulations 2004. In considering any request for disclosure of such information under the Freedom of Information Act 2000 or the Environmental Information Regulations 2004, DECC will consider and make use of relevant exemptions or exceptions where they properly apply and, where relevant, will consider whether the public interest in withholding the information outweighs the public interest in disclosing the information. It is DECC's normal practice to consult and consider the views of third parties where necessary although decisions on disclosure are ultimately taken by DECC. However, any decision by DECC against the release of information can be appealed to the Information Commissioner and ultimately the Information Tribunal. We will handle any personal data you provide appropriately in accordance with the Data Protection Act 1998 and the Freedom of Information Act 2000.

1 INTRODUCTION

1.1 This Strategic Environmental Assessment

The Department of Energy and Climate Change (DECC) is conducting a Strategic Environmental Assessment (SEA) of a draft plan/programme to hold further rounds of offshore wind leasing and offshore oil and gas licensing in United Kingdom waters. DECC encompasses the energy functions previously under the remit of the Department for Business, Enterprise and Regulatory Reform (formerly the Department of Trade and Industry), along with various climate change functions previously under the remit of the Department for the Environment, Food and Rural Affairs.

The SEA is being conducted in accordance with the *Environmental Assessment of Plans and Programmes Regulations 2004* (the SEA Regulations), which apply to any relevant plan or programme which relates either solely to the whole or any part of England, or to England and any other part of the United Kingdom (UK).

This SEA is intended to:

- Consider the environmental implications of a draft plan/programme for licensing for offshore oil and gas, including the underground storage of combustible gas in partially depleted oil/gas reservoirs, and leasing for offshore wind. This includes consideration of the implications of alternatives to the plan/programme and the potential spatial interactions with other users of the sea.
- Inform the UK Government's decisions on the draft plan/programme
- Provide routes for public and stakeholder participation in the process

1.2 The requirement for SEA

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 (commonly called the SEA Directive) was adopted to provide a strategic complement to the Council Directives (85/337/EEC and 97/11/EC) which require Environmental Impact Assessments of specific developments and activities.

The Directive's stated objective 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."*

A series of regulations have been established across the United Kingdom to implement the requirements of the Directive.

The Environmental Assessment of Plans and Programmes Regulations 2004 apply to any plan or programme which relates either solely to the whole or any part of England[2] or to

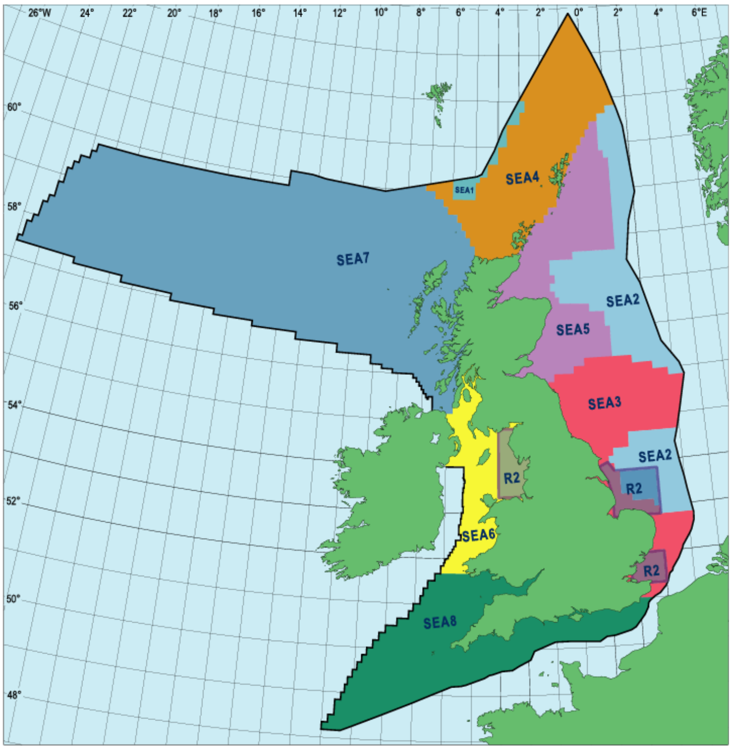
[2] Including the territorial waters of the United Kingdom that are not part of Northern Ireland, Scotland or Wales, and waters in any area for the time being designated under Section 1(7) of the *Continental Shelf Act 1964*.

England and any other part of the UK. The Regulations apply to plans/programmes whose first formal preparatory act was on or after 21 July 2004, and also, with retroactive effect, to those which have not been either adopted or submitted to a legislative procedure leading to adoption by 21 July 2006.

A required part of SEA is consultation with the consultation bodies and public, together with such neighbouring states as may be potentially affected.

1.3 Previous DECC SEAs

Figure 1.1 - DECC past SEA Sequence



The SEA process aims to help inform licensing and leasing decisions by considering the environmental implications of the proposed plan/programme and the potential exploration, development and energy production activities which could result from its implementation.

Since 1999, the Department has conducted seven SEAs of the implications of further licensing of the UK Continental Shelf (UKCS) for oil and gas exploration and production (SEAs 1-7) and an SEA for a second round of wind leasing (R2) – see list overleaf and Figure 1.1 to the left. Initial work was undertaken for SEA 8, but this area is now included in the Offshore Energy SEA.

	Area	Sector	Licensing/Leasing Round	
SEA 1	The deep water area along the UK and Faroese boundary	Oil & Gas	19th Round	(2001)
SEA 2	The central spine of the North Sea which contains the majority of existing UK oil and gas fields	Oil & Gas	20th Round	(2002)
SEA 2 Extension	Outer Moray Firth	Oil & Gas	20th Round	(2002)
SEA 3	The remaining parts of the southern North Sea	Oil & Gas	21st Round	(2003)
R2	Three strategic regions off the coasts of England and Wales in relation to a second round of offshore wind leasing	Offshore wind	R2	(2003)
SEA 4	The offshore areas to the north and west of Shetland and Orkney	Oil & Gas	22nd Round	(2004)
SEA 5	Parts of the northern and central North Sea to the east of the Scottish mainland, Orkney and Shetland	Oil & Gas	23rd Round	(2005)

	Area	Sector	Licensing/Leasing Round	
SEA 6	Parts of the Irish Sea	Oil & Gas	24th Round	(2006)
SEA 7	The offshore areas to the west of Scotland	Oil & Gas	25th Round	(2008)

1.4 The Environmental Report and its purpose

The purpose of this Environmental Report is to identify, describe and evaluate the likely significant effects on the environment of implementing the draft plan/programme and reasonable alternatives, taking into account the objectives and the geographical scope of the draft plan/programme. The report provides a basis of information for formal consultation with the statutory consultation bodies and authorities, and with the public, regarding the environmental implications of the draft plan/programme and its alternatives. The Environmental Report and the feedback from consultation will be taken into account during the finalisation of the plan/programme prior to its adoption.

1.4.1 Consultation bodies

Since the 2004 Regulations were made, a number of the nominated consultation bodies/authorities have been subject to organisational/name change. The following are the current consultation bodies/authorities for this SEA:

- English Heritage
- Natural England (previously English Nature and the Countryside Agency)
- Environment Agency
- Historic Scotland
- Scottish Natural Heritage
- Scottish Environment Protection Agency
- Cadw (Welsh Assembly Government's historic environment division)
- Countryside Council for Wales
- Environment Agency (Wales)
- Department of Environment (NI) (Northern Ireland Environment Agency)

In addition, the Joint Nature Conservation Committee will also be included as a consultation body for this SEA.

1.4.2 The relevant areas

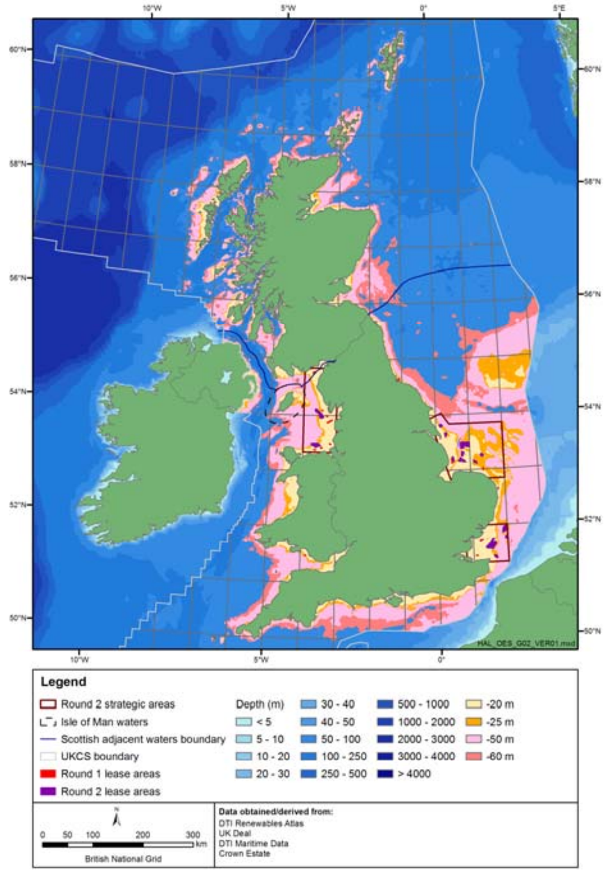
For offshore wind leasing, this SEA[3] covers those parts of the UK Renewable Energy Zone and the territorial waters of England and Wales where the water depth is around 60m or less - see Figure 1.2A.

For offshore (seaward) oil and gas licensing and for offshore gas storage licensing this SEA covers all UK waters (SEA 1 to 8 areas) – see Figure 1.2B[4].

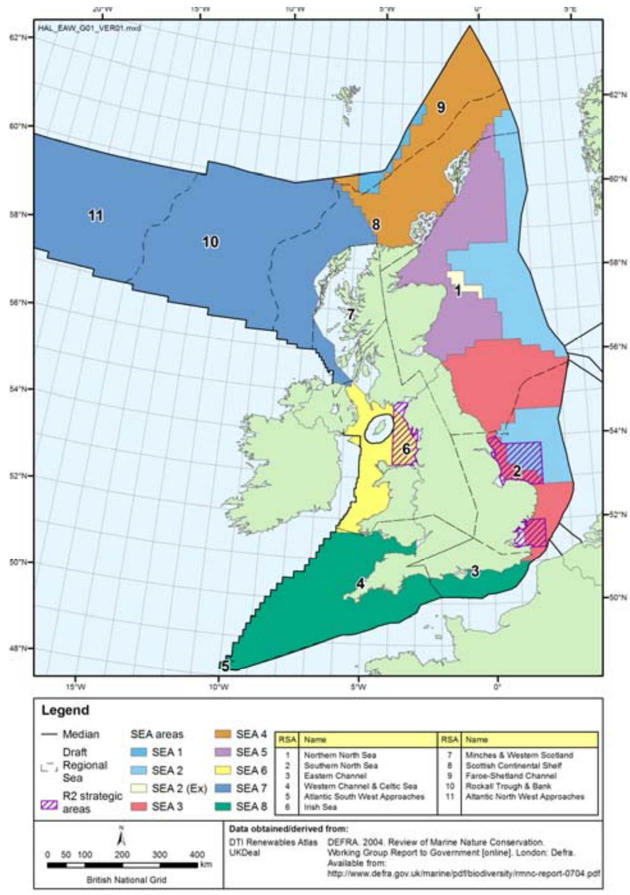
[3] In cooperation with the devolved administrations
[4] Areas that lie within bay closure lines (shown in pale blue adjacent to the UK coast on Figure 1.2B) e.g. the Minches are subject to a different oils and gas licensing regime and do not form part of this draft plan/programme. However, to allow full consideration the SEA addresses the potential of the draft plan/programme for effects on these blocks.

Figure 1.2 – Relevant areas

A – Location of shallow waters (<60m)



B – Past SEA areas (coloured) and Regional Seas (numbered)



1.4.3 Contents of the Environmental Report

Schedule 2 of the Regulations sets out the information to be included in an Environmental Report of a Strategic Environmental Assessment - see Table 1.1. Regulation 12(3) specifies that….

"the report shall include such of the information referred to in Schedule 2 …. as may reasonably be required, taking account of:- (a) current knowledge and methods of assessment; (b) the contents and level of detail in the plan or programme; (c) the stage of the plan or programme in the decision-making process; and (d) the extent to which certain matters are more appropriately assessed at different levels in that process in order to avoid duplication of the assessment."

Table 1.1 – Information to be included in Environmental Reports as required by Schedule 2 of the *Environmental Assessment of Plans and Programmes Regulations 2004*

1. An outline of the contents and main objectives of the plan/programme, and of its relationship with other relevant plans/programmes.
2. The relevant aspects of the current state of the environment and the likely evolution thereof without implementation of the plan/programme.

3.	The environmental characteristics of areas likely to be significantly affected.
4.	Any existing environmental problems which are relevant to the plan/programme including, in particular, those relating to any areas of a particular environmental importance, such as areas designated pursuant to Council Directive 79/409/EEC on the conservation of wild birds and the Habitats Directive.
5.	The environmental protection objectives, established at international, Community or Member State level, which are relevant to the plan/programme and the way those objectives and any environmental considerations have been taken into account during its preparation.
6.	The likely significant effects on the environment, including short, medium and long-term effects, permanent and temporary effects, positive and negative effects, and secondary, cumulative and synergistic effects, on issues such as - (a) biodiversity; (b) population; (c) human health; (d) fauna; (e) flora; (f) soil; (g) water; (h) air; (i) climatic factors; (j) material assets; (k) cultural heritage, including architectural and archaeological heritage; (l) landscape; and (m) the inter-relationship between the issues referred to in sub-paragraphs (a) to (l).
7.	The measures envisaged to prevent, reduce and as fully as possible offset any significant adverse effects on the environment of implementing the plan/programme.
8.	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.
9.	A description of the measures envisaged concerning monitoring in accordance with regulation 17.
10.	A non-technical summary of the information provided under paragraphs 1 to 9.

The criteria for determining the likely significance of effects are set out in Schedule 1 of the Regulations and are listed in Table 1.2.

Table 1.2 – Criteria for determining the likely significance of effects on the environment as specified in Schedule 1 of the *Environmental Assessment of Plans and Programmes Regulations 2004*

1.	The characteristics of plans/programmes, having regard, in particular, to:- (a.) the degree to which the plan/programme sets a framework for projects and other activities, either with regard to the location, nature, size and operating conditions or by allocating resources; (b.) the degree to which the plan/programme influences other plans/programmes including those in a hierarchy; (c.) the relevance of the plan/programme for the integration of environmental considerations in particular with a view to promoting sustainable development; (d.) environmental problems relevant to the plan/programme; and (e.) the relevance of the plan/programme for the implementation of Community legislation on the environment (for example, plans/programmes linked to waste management or water protection).
2.	Characteristics of the effects and of the area likely to be affected, having regard, in particular, to:- (a.) the probability, duration, frequency and reversibility of the effects; (b.) the cumulative nature of the effects; (c.) the transboundary nature of the effects; (d.) the risks to human health or the environment (for example, due to accidents); (e.) the magnitude and spatial extent of the effects (geographical area and size of the population likely to be affected);

(f.) the value and vulnerability of the area likely to be affected due to –
   (i.) special natural characteristics or cultural heritage;
   (ii.) exceeded environmental quality standards or limit values; or
   (iii.) intensive land-use; and
(g.) the effects on areas or landscapes which have a recognised national, Community or international protection status.

1.4.4 Organisation of the Environmental Report

A large amount of information has been collated, reviewed and assessed as part of this SEA. To facilitate reader access and understanding, the following 'road-map' identifies where relevant information can be found. The body of the Environmental Report comprises 7 main sections plus a bibliography, glossary, appendices and a non-technical summary. Figures and tables are interspersed throughout the document.

Table – 1.3 – Structure of the Environmental Report

ER Section	Summary
Non-technical summary	A stand alone summary in non technical language of the SEA, its findings and conclusions.
Section 1 Introduction	Describes the background to the draft plan/programme and the regulatory context and purpose of the SEA and the ER.
Section 2 Overview of the draft plan/programme	Provides details of the background to the proposed plan/programme, the plan/programme itself, its objectives and relationships to other initiatives. Alternatives to the plan/programme are also described.
Section 3 SEA approach	Describes the scope and methodology of the SEA.
Section 4 Environmental Information	Describes the environmental characteristics of the relevant areas, identifies relevant existing environmental problems, the likely evolution of the environmental baseline and SEA objectives.
Section 5 Consideration of the potential effects of the draft plan/programme	Provides details of the assessment method, a consideration of the results of the assessment and identifies mitigation and enhancement measures to prevent, reduce or offset any significant adverse effects identified during the assessment process.
Section 6 Recommendations and monitoring	Provides an overall conclusion regarding the likely implications of the proposed licensing/leasing and alternatives, together with recommendations for mitigation and monitoring and gaps in understanding relevant to the process.
Section 7 Next steps	Describes the consultation phase for the Environmental Report and proposed plan/programme, the process underpinning the adoption of the plan/programme and the final SEA statement.
	Bibliography
	Glossary and abbreviations
Appendix 1 Key issues	Contains a matrix of key thematic issues identified to be addressed in the Environmental Report during scoping consultation, assessment and stakeholder workshops.
Appendix 2 SEA Workshops	Contains summaries of the range workshops (assessment, regional stakeholder and sector) which contributed to the SEA process and information base
Appendix 3 Environmental baseline	Underpins Section 4 and contains a series of sub-appendices (A3a to A3j) describing the key characteristics in relation to biodiversity, habitats, flora and fauna; geology, substrates and coastal morphology; landscape/seascape; water environment; air quality; climate and meteorology; population and human health; other users, material assets (infrastructure, other natural resources); cultural heritage and conservation of sites and species in relation to UK waters as a whole and for each of the draft regional seas.

ER Section	Summary
Appendix 4 Other initiatives	Includes a matrix describing other initiatives, plans and programmes of relevance to the proposed plan/programme, the implications of these for the proposed plan/programme and the implications of the proposed plan/programme on these other plans and programmes.
Appendix 5 Regulatory and other controls	Summarises the key environmental legislation and controls in relation to the offshore wind farm and oil and gas (including gas storage) industries

1.4.5 The study team

This report was prepared by independent consultants, Hartley Anderson Limited supported by CMACS Ltd, in conjunction with DECC. Contributions to the assessment and the public consultation document have been received from the SEA Steering Group, together with authors of the underpinning studies commissioned for the DECC SEA process and the participants in the SEA workshops.

1.5 Public consultation

The Environmental Report and draft plan/programme will be issued for formal consultation as required by the SEA Regulations.

In July 2008 the Government published a third version of the Code of Practice on Consultations which provides seven criteria for consultations – see extract below.

CODE OF PRACTICE ON CONSULTATION
THE SEVEN CONSULTATION CRITERIA

Criterion 1 When to consult
Formal consultation should take place at a stage when there is scope to influence the policy outcome.

Criterion 2 Duration of consultation exercises
Consultations should normally last for at least 12 weeks with consideration given to longer timescales where feasible and sensible.

Criterion 3 Clarity of scope and impact
Consultation documents should be clear about the consultation process, what is being proposed, the scope to influence and the expected costs and benefits of the proposals.

Criterion 4 Accessibility of consultation exercises
Consultation exercises should be designed to be accessible to, and clearly targeted at, those people the exercise is intended to reach.

Criterion 5 The burden of consultation
Keeping the burden of consultation to a minimum is essential if consultations are to be effective and if consultees' buy-in to the process is to be obtained.

Criterion 6 Responsiveness of consultation exercises
Consultation responses should be analysed carefully and clear feedback should be provided to participants following the consultation.

Criterion 7 Capacity to consult
Officials running consultations should seek guidance in how to run an effective consultation exercise and share what they have learned from the experience.

Extract from Code of Practice on Consultation issued July 2008

2 OVERVIEW OF THE DRAFT PLAN/PROGRAMME & RELATIONSHIP TO OTHER INITIATIVES

The SEA Regulations require that the Environmental Report includes:

> "*an outline of the contents and main objectives of the plan or programme, and of its relationship with other relevant plans and programmes*" and that consideration is given to the degree to which the "*plan or programme influences other plans and programmes including those in a hierarchy"*
>
> "*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*".

A list of the international European and UK initiatives, including plans/programmes, together with their objectives which have been analysed in terms of their implications for the draft plan/programme and vice versa is given in Appendix 4.

2.1 The draft plan/programme

The 2007 Energy White Paper 'Meeting the Energy Challenge' outlined two serious long-term challenges for the UK:

- Tackling climate change by reducing carbon dioxide emissions both within the UK and abroad; and
- Ensuring secure, clean and affordable energy as we become increasingly dependant on imported fuel.

Ensuring security of energy supply is essential to both climate change and energy policy. Fundamental to securing our energy supplies is to ensure that we are not dependant on any one supplier, country or technology.

The draft plan/programme subject to this SEA needs to be considered in the context of overall UK energy supply policy and greenhouse gas emission reduction efforts. The main objectives of the current draft plan/programme are to enhance the UK economy, contribute to the achievement of carbon emission reductions and security of energy supply, but without compromising biodiversity and ecosystem function, the interests of nature and heritage conservation, human health, or material assets and other users.

The main parts of the draft plan/programme and its context are:

> **For offshore wind energy** - to enable further rounds of offshore wind farm leasing in the UK Renewable Energy Zone and the territorial waters of England and Wales with the objective of achieving some 25GW of additional generation capacity by 2020. This part of the plan/programme does not include the territorial waters of Scotland and Northern Ireland.
>
> The *Energy Act 2004* made provision for the designation of a Renewable Energy Zone outside territorial waters over which the United Kingdom may exercise rights for wind, wave and tidal energy production. The UK Renewable Energy Zone includes

an area outside territorial waters where Scottish Ministers have functions in relation to renewable energy installations.

The *Climate Change Act 2008* places a duty on the Secretary of State to ensure that the net UK carbon account for the year 2050 is at least 80% lower than the 1990 baseline.

In December 2008 the European Parliament and Council of Ministers reached political agreement on legislation to require that by 2020, 20% of the EU's energy consumption must come from renewable sources. The UK's contribution to this will require the share of renewables in the UK's energy consumption to increase from around 1.5% in 2006 to 15% by 2020. In 2008 the Government consulted on a UK Renewable Energy Strategy, which is due to be published in Spring 2009.

Renewable energy will also make an important contribution to security of energy supply. By increasing the level of energy generated domestically, there will be less dependence on imports of fuel from abroad. The Government's consultation on a draft Renewable Energy Strategy estimated that increased investment in renewables in the UK, to meet a 15% renewable energy target in 2020, will reduce UK gas imports by some 11-14% in 2020.

The technology for offshore wind farms is continuing to evolve. For example larger turbines, improved gearboxes allowing faster rotation speeds, alternative foundations, vertical axis of rotation turbines are in development, and a range of scenarios were considered in the assessment.

For offshore oil and gas - to hold further seaward rounds of oil and gas licensing in UK waters.

The 2007 Energy White Paper noted that currently around 90% of the UK's energy needs are met by oil, gas and coal. Renewable energy and other low carbon technologies will play an increasing role in the UK's energy mix over the longer term; however, fossil fuels will continue to be the predominant source of energy for decades to come. With production from UK oil and gas fields declining, the UK will become yet more reliant on imports. Making efficient use of the UK's own energy reserves brings obvious benefits both in the contribution it can make to a diverse UK energy mix and to the economy in terms of jobs, investment and national income generated by the sector.

A 2007 HM Treasury discussion paper states that "*The UK Government remains committed to promoting a healthy and prosperous UK oil and gas industry and maximising the economic recovery of the UK's oil and gas reserves. The UK's oil and gas reserves are significant, and up to 2006 have produced around 36 billion barrels of oil equivalent (boe). Estimates of the oil and gas remaining to be produced from the UK Continental Shelf (UKCS) range from 15 to 25 billion boe. Although the UK is already a net importer of oil and gas, indigenous supplies will continue to play a vital role in the UK's energy consumption for many years to come.*"

For gas storage - to include future licensing for the underground storage of combustible gas in depleted and other offshore oil and/or gas fields in UK waters, as part of the strategy to increase the UK's storage capacity and maintain resilience of gas supply in cold weather periods of high demand or interruptions to imported supplies.

The Government consulted in 2006 on the effectiveness of current security of gas supply arrangements and security of supply is one of the key issues identified by the 2007 Energy White Paper.

By 2020 it is estimated that 80% of the UK's gas supply will be imported. The *Energy Act 2008* makes provision for the designation of Gas Importation and Storage Zones and creates a licensing framework to enable private sector investment in offshore gas storage infrastructure which will help maintain reliable supplies of energy.

2.2 Further spatial considerations

The Marine Bill White Paper (2007) notes that activities in the marine area contribute substantially to the UK economy and quality of life, with an annual economic contribution in the order of £67 billion.

The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) is an important mechanism through which Governments of the western coasts and catchments of Europe, together with the European Community, cooperate to protect the marine environment of the North-East Atlantic. The OSPAR Commission is in the process of establishing a network of Marine Protected Areas (MPAs), the designation of which will be informed by the OSPAR Initial List of Threatened and/or Declining Species and Habitats. It is aimed to complete a joint network of well managed MPAs by 2010 that, together with the Natura 2000 network, is ecologically coherent.

OSPAR periodically publishes assessments in the form of Quality Status Reports (QSRs) of the North-East Atlantic and its sub-regions with the last QSR being published in 2000. OSPAR is currently preparing a new assessment, QSR 2010, a consultation draft of which will be published in November 2009. QSR 2010 will inform the 2010 OSPAR Ministerial Meeting in Bergen on the environmental status and future actions for the protection and conservation of the North-East Atlantic.

The EU Marine Strategy Framework Directive entered into force in July 2008. The key objectives of the Directive are to achieve good environmental status of the EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend.

The Directive establishes European Marine Regions on the basis of geographical and environmental criteria. UK waters lie within the Greater North Sea and Celtic Sea sub-regions of the North-East Atlantic Ocean Region. Each Member State is required to develop strategies for their marine waters in cooperation with other Member States and non-EU countries within a Marine Region.

The Marine Strategies must contain a detailed assessment of the state of the environment, a definition of "good environmental status" at regional level, and the establishment of clear environmental targets and monitoring programmes. The Directive requires that programmes of measures be established to achieve good environmental status, and that these include spatial protection measures contributing to coherent and representative networks of marine protected areas, adequately covering the diversity of the constituent ecosystems. Such protected areas are to be coordinated with the Natura 2000 site network established under the Birds and Habitats Directives, for which designations in some UK marine areas are not yet completed.

The *Marine and Coastal Access Bill* was introduced to the House of Lords on 4th December 2008. The Bill will:

- Introduce a new marine planning system, with long-term objectives for the marine area around the UK and, subsequently, the creation of more detailed local marine plans
- Establish a Marine Management Organisation for the waters around England and the UK offshore area
- Streamline the law on licensing marine development so that, as far as possible, only one licence is needed for each development
- Provide powers to designate Marine Conservation Zones and to protect those zones from damaging activities
- Secure a long-distance route around the coast of England, including beaches, cliffs, rocks and dunes, with public access for coastal walking and other recreational activities
- Strengthen and modernise the licensing and management of marine, migratory, freshwater and shellfish fisheries, including the creation of new Inshore Fisheries and Conservation Authorities, and introduce a scheme to manage live fish movement
- Streamline and modernise enforcement powers for fisheries and nature conservation, providing a civil sanctions scheme for licensing and nature conservation offences, and an administrative penalty scheme for domestic fisheries offences

2.3 Alternatives to the draft plan/programme

The following alternatives to the draft plan/programme for future offshore wind leasing, oil and gas licensing and gas storage have been assessed in the SEA:

1. Not to offer any areas for leasing/licensing
2. To proceed with a leasing and licensing programme
3. To restrict the areas offered for leasing and licensing temporally or spatially

The alternatives were considered using the hierarchy of options below (modified from ODPM 2005).

need or demand: is it necessary?
Can the need or demand be met without implementing the plan or programme at all?

↓

mode or process: how should it be done?
Are there technologies or methods that can meet the need with less environmental damage than 'obvious' or traditional methods?

↓

location: where should it go?

↓

timing and detailed implementation:
When, in what form and in what sequence should the plan be carried out?
What are the important issues? Do existing controls and measures address them? What other controls and measures are required?

The results are summarised in Table 2.2.

Table 2.2 – Consideration of hierarchy of alternatives

Is there a need or demand	Security of supply is one of the key issues identified in a series of Energy White Papers and Reviews. As production from UK oil and gas fields declines, the UK will become more reliant on imports. By 2010, imports could be meeting up to 40% of the UK's total gas demand, rising to 80–90% by 2020. The UK is also expected to become a net importer of oil by 2010. In the absence of the plan the UK would import additional fuel to make up the shortfall in domestic production. In December 2008 the European Parliament and Council of Ministers reached political agreement on legislation to require that by 2020, 20% of the EU's energy consumption must come from renewable sources. The UK's contribution to this will require the share of renewables in the UK's energy consumption to increase from around 1.5% in 2006 to 15% by 2020. In 2008 the Government consulted on a UK Renewable Energy Strategy, which is due to be published in Spring 2009. The Energy Reviews recognised that, in spite of developments in low carbon technologies and improvements in energy efficiency, fossil fuels, and particularly oil and gas, will constitute the majority of the UK energy mix for the foreseeable future. Exploiting the UK's energy reserves contributes to a diverse and secure UK energy mix as well as to the economy in terms of jobs, investment and national income generated by the sector.
Mode or process	Offshore wind farm technologies and oil and gas exploration, drilling and production technologies are not static and improvements are introduced to increase efficiency and reduce environmental footprint and impacts. New techniques and technologies, once proven, can be expected to rapidly become accepted practice.
Location	The presence of exploitable wind resource and commercial hydrocarbon resources/gas storage capacity is variously a function of location, geological history and existing sensitivities and uses which dictate the areas of potential interest.
Timing and detailed implementation	The plan is needed before further areas can be leased for offshore wind farms or for hydrocarbon exploration/production/storage can occur in currently unlicensed blocks/unleased areas. In relation to the offer of blocks covered by previous SEAs, the early implementation of the plan would allow potential synergies in terms of use of existing infrastructure (e.g. pipelines) to be taken advantage of. The extent of such synergies will decline if the plan is delayed as infrastructure is decommissioned and removed.

2.4 Context to licensing and leasing

2.4.1 Oil and gas licensing

The exclusive rights to search and bore for and get petroleum in Great Britain, the territorial sea adjacent to the United Kingdom and on the UK Continental Shelf (UKCS) are vested in the Crown and the *Petroleum Act 1998* (as amended) gives the Secretary of State the power to grant licences to explore for and exploit these resources. The main type of offshore Licence is the Seaward Production Licence. Offshore licensing for oil and gas exploration and production commenced in 1964 and has progressed through a series of Seaward Licensing Rounds. A Seaward Production Licence may cover the whole or part of a specified Block or a group of Blocks. A Licence grants exclusive rights to the holders "to search and bore for, and get, petroleum" in the area covered by the Licence. A Licence does not confer any exemption from other legal/regulatory/fiscal requirements.

There are three types of Seaward Production Licences:

- Traditional Production Licences are the standard type of Seaward Production Licences and run for three successive periods or Terms. Each Licence expires automatically at the end of each Term, unless the Licensee has made enough progress to earn the chance to move into the next Term. The Initial Term lasts for four years and the Licence will only continue into a Second Term of four years if the agreed Work Programme has been completed and if 50% of the acreage has been relinquished. The Licence will only continue into a Third Term of 18 years if a development plan has been approved, and all the acreage outside that development has been relinquished.

- Frontier Production Licences are a variation of the Traditional Production Licence with four Terms rather than three. A Frontier Production Licence has a longer exploration phase (six years as opposed to four) with the objective of allowing companies to screen larger areas, during a three year Initial Term so they can look for a wider range of prospects. At the end of the Initial Term, the Licensee must relinquish 75% of the licensed acreage. The Second Term lasts three years at the end of which (i.e. when the Licence is six years old), the exploration Work Programme must have been completed and the Licensee must relinquish, 50% of what is left (i.e. leaving one eighth of the original licensed area). In this sense, the end of a Frontier Licence's Second Term corresponds to the end of a Traditional Licence's Initial Term.

- In the 21st Round (2002) the Department introduced Promote Licences. The general concept of the Promote Licence is that the Licensee is given two years after award to attract the technical, environmental and financial capacity to complete an agreed Work Programme. In effect, DECC will defer (not waive) its financial, technical and environmental checks until the preset Check Point. Promote Licensees are not allowed to carry out field operations until they have met the full competence criteria. The way this is implemented is that each Promote Licence carries a "Drill-or-Drop" Initial Term Work Programme. The Licence will therefore expire after two years if the Licensee has not made a firm commitment to DECC to complete the Work Programme (e.g. to drill a well). By the same point, it must also have satisfied DECC of its technical, environmental and financial capacity to do so.

The model clauses and terms and conditions which are attached to Licences are contained in Regulations.

It is noted that the environmental management capacity and track record of applicants is considered by DECC, through written submissions and interviews, before licences are awarded.

2.4.2 Gas storage

The *Energy Act 2008* makes provision for the designation of Gas Importation and Storage Zones and creates a licensing framework for the underground storage of combustible gas offshore. The Act makes it an offence to carry any of the activities below except in accordance with a licence and with prior consent:

- use of a controlled place for the unloading of gas to an installation or pipeline
- use of a controlled place for the storage of gas
- conversion of any natural feature in a controlled place for the purpose of storing gas
- recovery of gas stored in a controlled place
- exploration of a controlled place with a view to gas storage
- establishment or maintenance in a controlled place of an installation for the purposes of activities within this subsection

The Competent Authority for the issuance and regulation of licences is DECC, and the Act makes provision for the future making of more detailed regulations in respect of this.

This Act also makes provision with respect to the interaction between activities regulated under the Petroleum Act and gas storage activities.

Developers will also need to apply for a Crown lease covering the relevant area in addition to the licence described above.

2.4.3 Offshore wind farm leasing

Under *The Crown Estate Act 1961*, The Crown Estate is landowner of the UK seabed and areas of foreshore (www.thecrownestate.co.uk). The Crown Estate's permission, in the form of a site option Agreement and Lease is required for the placement of structures or cables on the seabed, this includes offshore wind farms and their ancillary cables and other marine facilities. Potential offshore wind farm developers also require statutory consents from a number of Government departments before development can take place; (see Appendix 5). During Rounds 1 and 2 of UK offshore wind farm development, successful applicants were awarded an option for a Lease by The Crown Estate. When all necessary statutory consents are obtained by the developer, The Crown Estate can grant a site lease for a development.

The *Energy Act 200*4, provided for the designation of Renewable Energy Zones from 12nm (nautical miles) out to 200nm in which rights under Part V of the UN Convention on the Law of the Sea may be exercised to exploit water or wind energy.

The Crown Estate has announced the competitive process and commercial terms for a Round 3 of offshore wind farm lease options. For reference, Round 1 full term leases are for twenty-two years (plus 1 year for removal and decommissioning). For the largest Round 2 projects, the full term lease is for fifty years, including decommissioning. For Round 3, The Crown Estate proposes that development will be undertaken within exclusive Zones. The Crown Estate also proposes to fund up to 50% of Round 3 development costs through co-investment. The Round 3 Zones are indicative and may be refined as a result of the SEA Environmental Report and consultation feedback on it.

In English and Welsh waters, DECC is responsible for consenting under the *Electricity Act 1989*, through its Offshore Renewables Consents Energy Development Unit, which acts as a central point for all offshore wind farm consent applications. DECC works closely with the Marine and Fisheries Agency, which licenses a number of activities in the marine environment on behalf of the Secretary of State for Environment, Food and Rural Affairs, and in certain areas for Wales for the Welsh Assembly Government. In the Scottish Renewable Energy Zone, Scottish Ministers are responsible for *Electricity Act 1989* consent decisions.

The *Energy Act 2004,* the *Energy Act 2008,* the *Planning Act 2008* and the *Marine and Coastal Access Bill 2008* together with "Marine Bills" proposed by the devolved administrations provide a revised framework for the consenting of offshore wind farms.

2.5 Prospectivity

For commercial **hydrocarbon resources** to occur, a number of factors and features have to coincide, including:

- The presence of source rocks, with an appreciable organic matter content
- Adequate depth of burial to allow the conversion of the organic matter to oil or gas through the action of temperature and pressure
- The presence of rocks with sufficient porosity to allow the accumulation of oil or gas
- Cap or seal rocks to prevent the oil or gas from escaping from the reservoir rocks
- Migration pathways to permit oil and gas formed in the source rocks to move to reservoir formations

Such conditions typically occur in sedimentary basins, and not areas of igneous rock unless these overlay sedimentary rocks as in parts of the Faroe-Shetland Channel.

Offshore areas of the UK have been offered for oil and gas licensing in a series of rounds since 1964, with the 25th Round held in 2008. Areas with hydrocarbon prospectivity have been extensively explored over this period and many fields brought into production, mainly in the North and Irish Seas, resulting in an extensive infrastructure which can be utilised by new developments. There is a consensus view that the great majority of large fields in shelf depth waters (<200m) have been found, and deeper water areas are either not prospective or increasingly well explored and understood. Gas storage in depleted and other hydrocarbon reservoirs is part of the current draft plan/programme, and can be expected to take place in the same areas as existing oil and gas production.

The UK has extensive **marine renewable energy** resources including wind, wave and tidal, all of which are variable over space and time. There are several demonstration and commercial offshore wind farms in operation or under construction in UK waters following two rounds of offshore wind leasing in 2000 and 2003, with the generation capacity of all consented developments currently totalling some 5.5GW. Away from the shelter of the coast, the total wind resource over a year is relatively uniform across very large areas, although clearly the occurrence and strength of wind is dependant on a number of meteorological factors. At any point in time while some areas of the UK may be calm, the wind is likely to be blowing elsewhere. Water depth, distance from areas of high electricity demand, and the availability of connection points to the onshore transmission grid are significant factors in the preferred location of offshore wind developments.

Exploitation of wave and tidal stream energy is not yet fully commercial in UK waters, although several test and demonstrator projects have been deployed or are in development. Wave and tidal energy is not part of the draft plan/programme considered in this SEA.

2.6 Potential activities following licensing

2.6.1 Oil and gas scenarios

Offshore areas of the UK have been offered for oil and gas licensing in a series of rounds since 1964, with the 25th Round held in 2008. All licensing rounds since the 19th in 2000 have been preceded by an SEA, with all UK waters besides the Channel and Southwest

Approaches covered by previous SEAs. Areas with hydrocarbon prospectivity have been extensively explored over this period and many fields brought into production, mainly in the North and Irish Seas, resulting in an extensive infrastructure (see Figures 2.1 and 2.2) which can be utilised by new developments. Large field discoveries in shelf depth waters (<200m) have reduced in number as much of the area has been subject to exploration but further large finds cannot be ruled out. Deeper water areas are less well explored; some may not be prospective but there may be potential which has either not been drilled or cannot currently be imaged effectively.

The new area of UK marine waters included in the current SEA is of comparatively low prospectivity for hydrocarbons, and the scale of exploration activity in that area is anticipated to be very low. The Channel and Southwest Approaches area can be divided into 3 areas with distinctly different hydrocarbon prospectivity as outlined below with the anticipated levels of activity that could follow adoption of the draft plan/programme. For hydrocarbon licensing purposes UK waters are divided into quadrants of 1° of latitude by 1° of longitude (except where the coastline, “bay closing line” or a median line intervenes). Each quadrant is further partitioned into 30 blocks each of 10 x 12 minutes. The average block size is about 250km^2 (see Figures 2.1 and 2.2 overleaf).

1. The English Channel (Quadrants 58, 85-89 and 95 south-100) (Regional Sea 3)
Where future activity has been estimated by DECC to include:
A maximum of 5 blocks are likely to be applied for under a Traditional licence in a 26th Round, with up to 500km^2 3D seismic data, and a maximum of 5 Promote blocks may be applied for if that type of Licence is offered in the area. If licensed, a well must be drilled within 4 years of award on either Traditional or Promote licences.

2. The Severn Estuary and Bristol Channel (Quadrants 91-95 north and 103-106) (approximately Regional Sea 4)
Where future activity has been estimated by DECC to include:
A maximum of 10 blocks are likely to be applied for under a Frontier licence in a 26th Round, with work programmes of up to 500 km^2 3D seismic data. If acreage is licensed, a well must be drilled within 6 years of award on a Frontier licence (4 on a Traditional one). This may be very difficult due to the Bristol Channel shipping traffic.

3. The Western Approaches (Quadrants 72-75 and 83-84) (approximately Regional Sea 5)
Where future activity has been estimated by DECC to include:
A maximum of 10 blocks are likely to be applied for probably under Frontier Terms, in the 26th Round, with up to 500km^2 3D seismic data. If licensed, a well must be drilled within 6 years of award on a Frontier licence.

As a context for the consideration of the likely scale of overall drilling activity which could follow future offshore licensing Figures 2.3 and 2.4 show the number of exploration and appraisal wells drilled on the offshore UKCS over the last thirteen years. The number of exploration wells shows a general decline over time although with a slight increase since 2002.

Figure 2.1 – Location of existing oil and gas infrastructure (north)

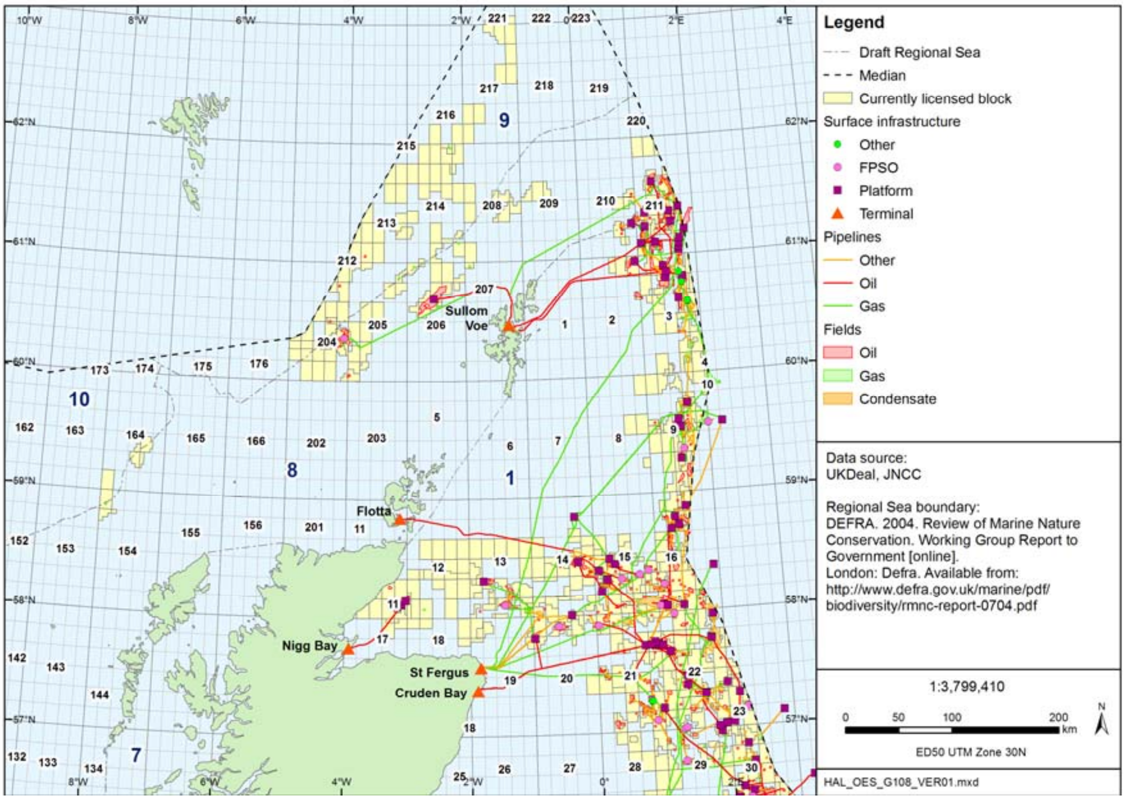


Figure 2.2 - Location of existing oil and gas infrastructure (south)

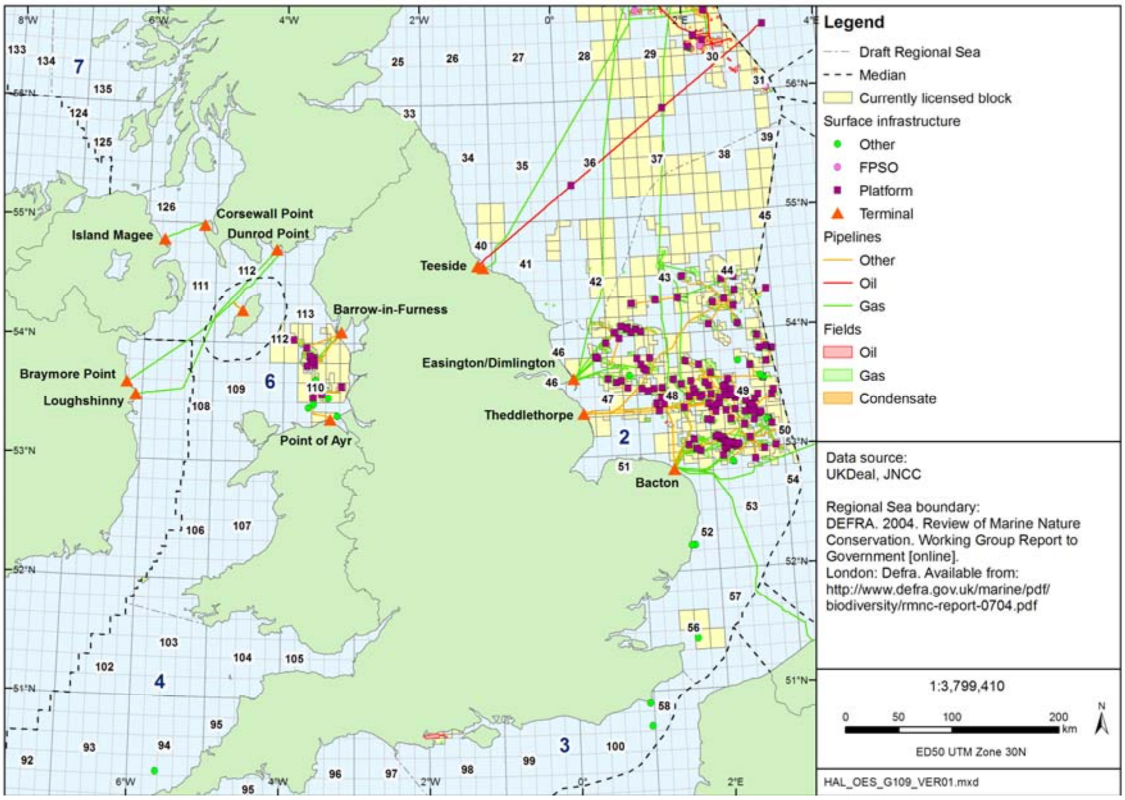


Figure 2.3 – Trends in exploration drilling on the UKCS

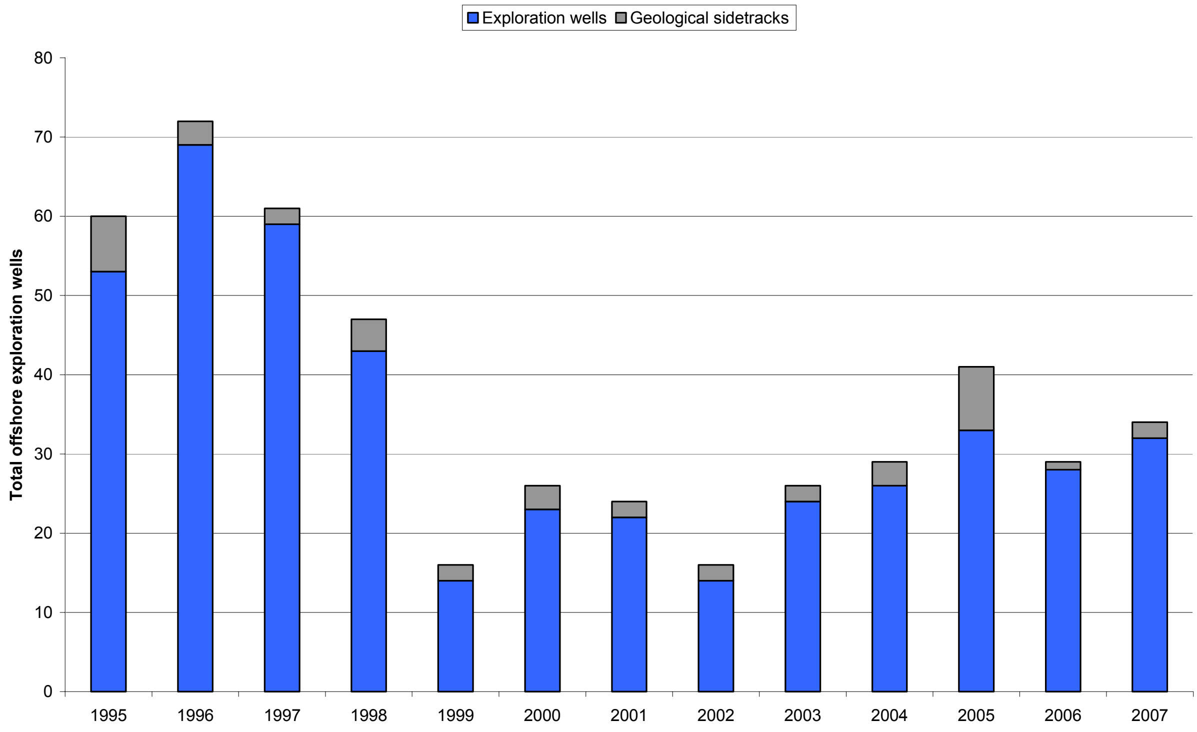
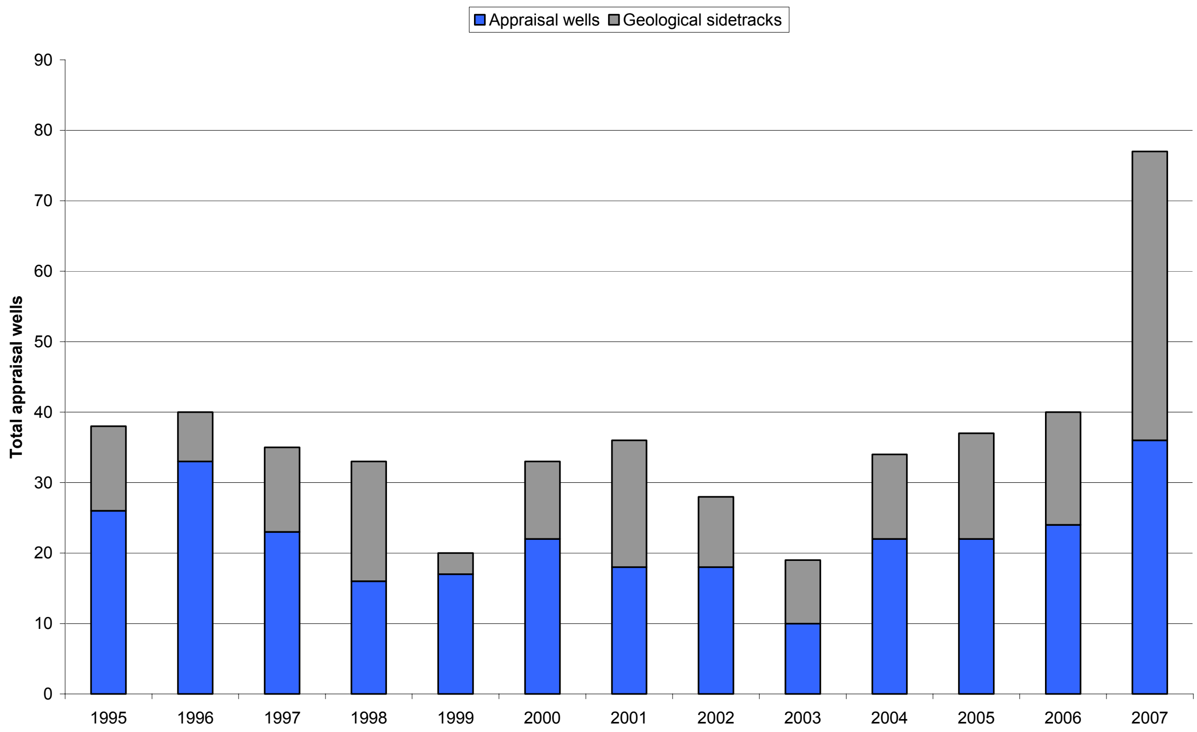


Figure 2.4 – Trends in appraisal drilling on the UKCS



2.6.2 Gas storage

In the context of the changing nature of the UK gas market as the UK becomes increasingly dependent on imported energy as domestic production of natural gas declines, BERR initiated a consultation exercise “Gas Security of Supply” in October 2006 to gauge stakeholder feedback on the effectiveness of current gas security of supply arrangements. Responses were published in May 2007 and reflected in the 2007 Energy White Paper (see http://www.berr.gov.uk/consultations/page34643.html). Although there was the view that the current market and regulatory framework provided the correct signals and incentives for the market to achieve an appropriate level of security of supply, measures were identified to encourage energy efficiency and energy savings in order to reduce the use of fossil fuels and encourage energy market flexibility.

The inclusion in the current draft plan/programme of gas storage in depleted and other hydrocarbon reservoirs is part of the strategy to increase the UK’s storage capacity and maintain resilience of gas supply in cold weather periods of high demand or interruptions to imported supplies. Gas storage activities resulting from the draft plan/programme can be expected to take place in the same areas as existing oil and gas production, with the numbers, timing and location largely dependent on a range of economic factors.

2.7 Potential activities following leasing

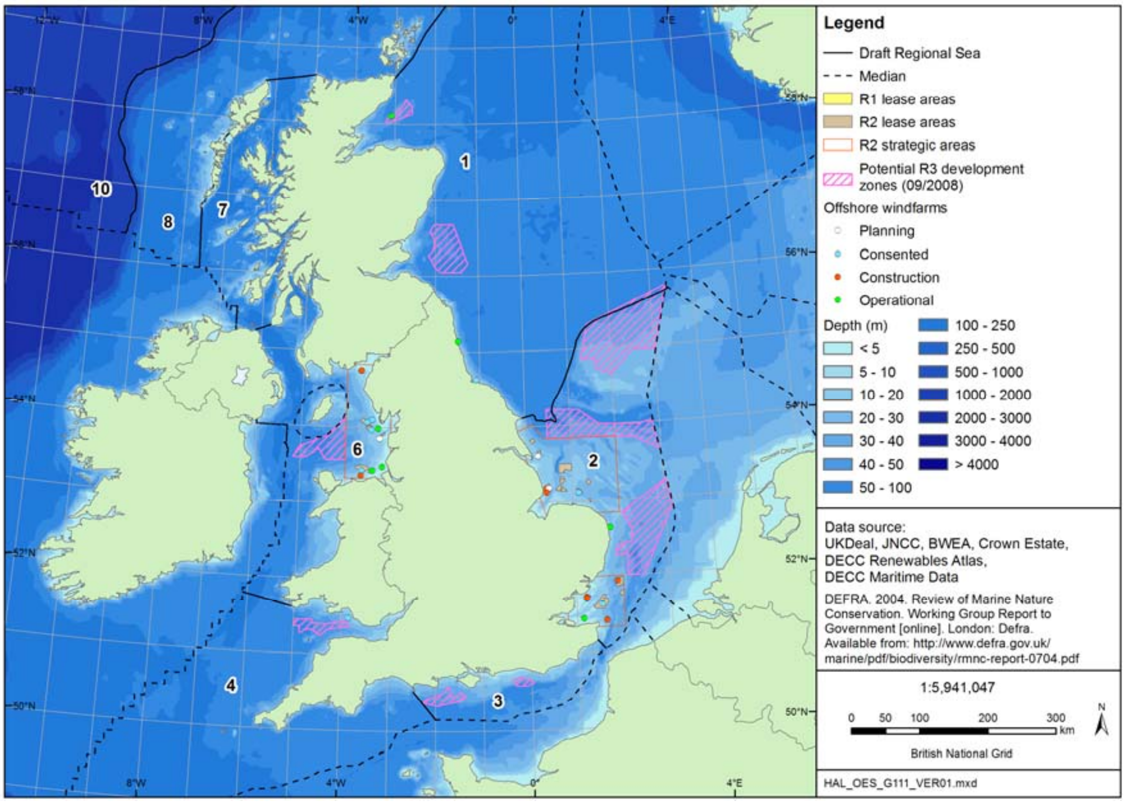
For offshore wind leasing, this SEA covers those parts of the UK Renewable Energy Zone and the territorial waters of England and Wales where the water depth is around 60m or less. For reference, the current indicative Crown Estate Round 3 Development Zones are shown in Figure 2.5 along with existing Round 1 and 2 lease areas.

The nature and scale of the 25GW of additional generation capacity offshore wind farm development envisaged by the draft plan/programme will vary depending on a number of factors, primarily the size of turbines used and the spacing between individual turbines in a wind farm.

At present most offshore wind farms are using 3.6MW or 5MW turbines but larger turbines (up to 10MW) are in development and may be deployed in the lifetime of this draft plan/programme. Similarly, experience and understanding of the effects of the wakes from other turbines is improving, and may lead to greater separation between individual turbines in a wind farm and between wind farms.

Based on advice from BWEA and various developers, the following example is given to allow visualisation of the potential scale of Round 3 developments. A 1GW wind farm may occupy a total area of 391.62 km2 based on the assumptions that it comprises two groups of 98 x 5MW turbines arranged in a rectangular array of 7 rows of 14 turbines facing the prevailing wind direction with 850m between turbines within the rows and 1200m between rows giving an average array spacing of approximately 8 rotor diameters. Each wind farm is separated from its neighbours by 5km in all directions to reduce adverse wake effects. Based on this example, 25GW of generation capacity could occupy some 9800 km2 of the shallow (<60m water depth) seabed around the UK.

Figure 2.5 – Wind energy activity and leasing areas



3 SEA APPROACH

3.1 Scoping

A key purpose of scoping is to identify key issues of concern at an early stage so that they can be considered in appropriate detail in the SEA. Scoping also aids in the identification of information sources and data gaps that may require to be filled by studies or surveys to underpin the assessment.

For the Offshore Energy SEA process the principal purposes of scoping were to:

- Promote stakeholder awareness of the SEA initiative
- Ensure access to all relevant environmental information
- Identify opportunities for potential collaboration and the avoidance of duplication of effort
- Identify information gaps so these could be evaluated and filled if necessary
- Identify stakeholder issues and concerns which should be considered in the SEA

Initial informal scoping for the Offshore Energy SEA with the SEA Steering Group, environmental authorities and a range of academic and conservation organisations commenced early in 2006.

A formal scoping exercise with the statutory Consultation Bodies/Authorities for Wales, Scotland, England and Northern Ireland and other stakeholders was conducted from December 2007 to February 2008. The scoping consultation was undertaken by direct mailing to the statutorily defined Consultation Bodies and Authorities, and OSPAR representatives of neighbouring states. The scoping document was also placed on the DECC Offshore SEA website (www.offshore-sea.org.uk) with an alert sent to registered users. The aim of the scoping exercise was both to inform the Consultation Bodies/Authorities and other stakeholders of the draft plan/programme and associated SEA process and to request feedback.

The following consultation questions were asked:

1. Consultees are invited to highlight additional initiatives which they consider relevant to the consideration of the draft plan/programme.
2. Consultees are invited to draw attention to and provide (where possible) additional information and data sets which they consider of potential relevance to this SEA.
3. Are there any objectives that you feel should be included, modified or removed?
4. Are the indicators for each objective suitable? If not please suggest alternatives?
5. Do you have any comments on the proposed approach to assessment and consultation?

Responses were received from 35 organisations listed below, with joint responses being received from DEFRA and the MFA, and from the CCW and JNCC:

- Airtricity
- The British Wind Energy Association (BWEA)
- Centre for Environment, Fisheries and Aquaculture Science (CEFAS)
- Centrica
- Chamber of Shipping
- Countryside Council for Wales (CCW)

- Department for Environment, Food and Rural Affairs, Marine and Fisheries Agency (DEFRA)
- Department for Transport (DfT)
- DONG Energy Power
- Environment Agency (EA)
- English Heritage (EH)
- E.ON UK
- Fisheries Research Services (FRS)
- Historic Scotland (HS)
- Joint Nature Conservation Committee (JNCC)
- Marine Conservation Society (MCS)
- Marine and Fisheries Agency (MFA)
- National Federation of Fishermen's Organisations (NFFO)
- Natural England (NE)
- Northumberland Sea Fisheries Committee (NSFC)
- North Western and North Wales Sea Fisheries Committee (NWNWSFC)
- nPower
- Royal Society for the Protection of Birds (RSPB)
- Royal Yachting Association (RYA)
- Cardigan Bay Save Our Seas Group (SOS)
- Scottish Environment Protection Agency (SEPA)
- Scottish Natural Heritage (SNH)
- SLP Energy
- TCI Renewables
- Vestas Wind Systems
- Whale and Dolphin Conservation Society (WDCS)
- The Crown Estate (CE)
- The Wildlife Trusts (WT)
- Trinity House (TH)
- World Wide Fund for Nature (WWF-UK)

A compilation and summary of stakeholder responses together with full copies of the responses are available on the DECC Offshore SEA website (www.offshore-sea.org.uk). In addition to responses to the specific consultation questions asked, a number of additional comments were received and these were also compiled and summarised.

Responses to scoping were used to help frame the level of detail and issues addressed in the Environmental Report. Key issues are listed in Appendix 1.

3.2 The DECC SEA process

The DECC offshore energy SEA process has developed over time, drawing in concepts and approaches from a variety of individuals, organisations and other SEAs as well as addressing the requirements of legislation and guidance.

Since SEA 1, the DECC Offshore Energy SEA process has evolved and the following process improvements have been implemented:

- Establishment of a SEA Steering Group with wide representation from a range of stakeholders (established in early 2001)
- A formal scoping step with relevant consultation bodies and authorities
- Integrated management of survey, consultation and assessment processes
- Facilitation of public consultation through a dedicated website
- Widespread dissemination of data and information
- Development of modular documents applicable to more than one SEA
- Syntheses of data to facilitate access
- Commissioning of expert underpinning studies
- Publication of technical reports on website, CD as well as hard copy where requested
- Involvement of authors of expert underpinning studies and other users in an assessment workshop
- Regional stakeholder workshops
- Sector workshops
- Environmental report available via website or as CD or hard copy
- Continuing development of the methods for the consideration of cumulative and synergistic effects

The process followed for this SEA and temporal sequence of events is summarised below, but note that certain activities such as information gathering continue throughout the process, only ending at the post-consultation report stage immediately prior to the Secretary of State's decision on the draft plan/programme.

In addition, a range of field surveys, technical studies and syntheses of data were commissioned to underpin the offshore energy SEA assessment. These technical and data reports are summarised in the Environmental Report and are available for download at www.offshore-sea.org.uk where documents for previous SEAs are also available.

Preparatory to SEA, the Department conducted a screening exercise for potential future rounds of offshore wind leasing, to understand major constraints and issues, and whether there are any data gaps for strategic planning. Such an exercise has not been undertaken for offshore oil and gas licensing since UK areas with suitable geology for hydrocarbon occurrence are well defined

There has been active engagement with Scottish and Welsh initiatives and the Severn tidal power feasibility study.

An Assessment Workshop involving the SEA Steering Group, technical report authors and SEA team was held in early September 2008 and is summarised in Appendix 2. The output of this workshop included the final list of SEA objectives and indicators (see Section 3 of the Environmental Report), the draft plan/programme alternatives and a list of topics to be considered in more detail in the Environmental Report.

Three regional stakeholder meetings were held in Cardiff, Glasgow and London in October 2008 at which stakeholders from a wide variety of organisations, sectors and areas participated. Topic specific fisheries, navigation and developer workshops were also held in October 2008. The stakeholder input on the information base and other issues of relevance to the SEA is summarised in Appendix 2 of the Environmental Report with key issues included in Appendix 1.

The Environmental Report and draft plan/programme are being issued for consultation in line with the requirements of the SEA Regulations and the Government's Code of Practice on Consultation (latest version July 2008) – see the "Next Steps" section at the end of the non-technical summary and the Environmental Report. After a 12 week public consultation period, the Department and the Secretary of State will consider comments received from consultation in the decision making regarding the plan/programme. A Post Consultation Report will be prepared and placed on the SEA website collating the comments and DECC responses to them.

3.3 SEA process and stages completed to date

The DECC offshore energy SEA process is underpinned by the requirements of the SEA Directive and UK implementing legislation – see Section 1.

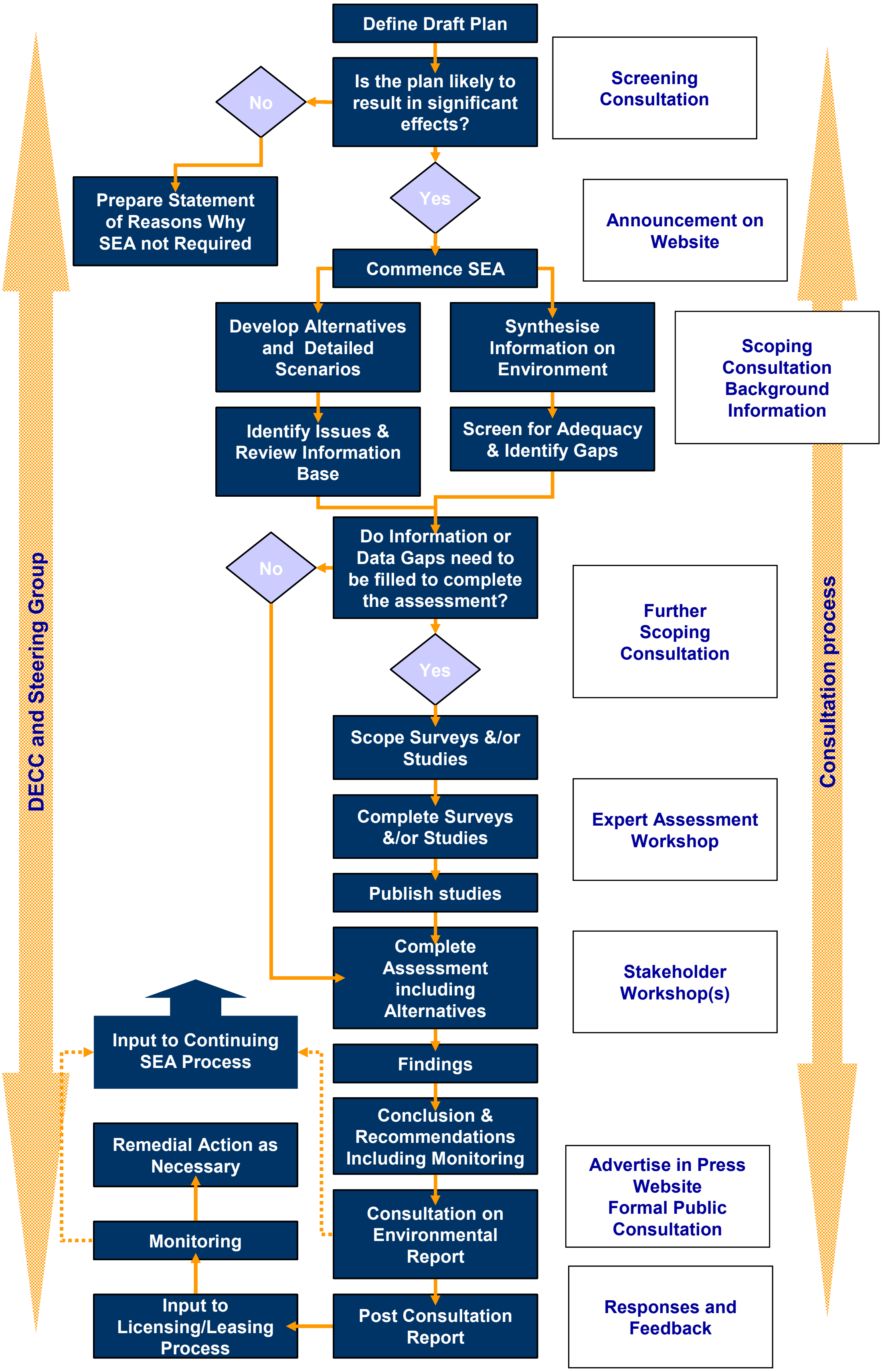
A summary of the SEA process used for this SEA is given below and in Figure 3.1. The SEA process aims to help inform licensing and leasing decisions through consideration of the environmental implications of the proposed draft plan/programme.

The key stages in the conduct of this SEA are:

1. Instigation of draft plan/programme and identification of alternatives and draft objectives
2. Scoping for field work
3. Consultation with the Consultation Bodies and Authorities and other Stakeholders on the scope and level of detail of the Environmental Report
4. Information gathering and collation on:
    a. Environmental baseline
    b. Offshore survey
    c. Existing environmental problems
    d. Potential effects of proposed plan
    e. Other relevant plans and programmes and their objectives
5. Assessment workshop
6. Assessment of effects including consideration of alternatives
7. Regional stakeholder workshops
8. Sector workshops
9. Production of Environmental Report
10. Public Consultation
11. Post consultation evaluation of feedback and input to decision on the plan
12. Monitoring plan implementation

The first nine stages of the SEA are now complete and preparatory work has been undertaken for subsequent stages.

Figure 3.1 – Overview of the SEA Process



Responsibility for the publication of the Environmental Report rests with DECC. Members of the Steering Group, as individuals and through their organisations, may comment on the proposed draft plan and the consultation materials (including this document) during the public consultation phase, and encourage others to comment.

3.4 Surveys and studies

3.4.1 Previous and recent survey work field data gathering

A large body of seabed survey and other field work has been commissioned since 1999 by the DECC SEA programme. These surveys have made a valuable contribution to the overall understanding of the marine environment in UK waters and to the identification of important conservation sites.

Data and other outputs from this work are archived on the UK DEAL website. Biological material collected during seabed surveys (and supporting data documentation) has been archived and the majority is deposited in the collection of the National Museums of Scotland, Edinburgh to promote its long term availability for scientific study.

Data from the survey programme is used as appropriate in the Environmental Baseline (Appendix 3) and the SEA assessment (Section 5). Examples of the output from this work are shown in Figures 3.2 – 3.12 below.

Figure 3.2 – Distribution of Darwin Mounds East as interpreted from side scan sonar and photographs taken during 1999 SEA survey

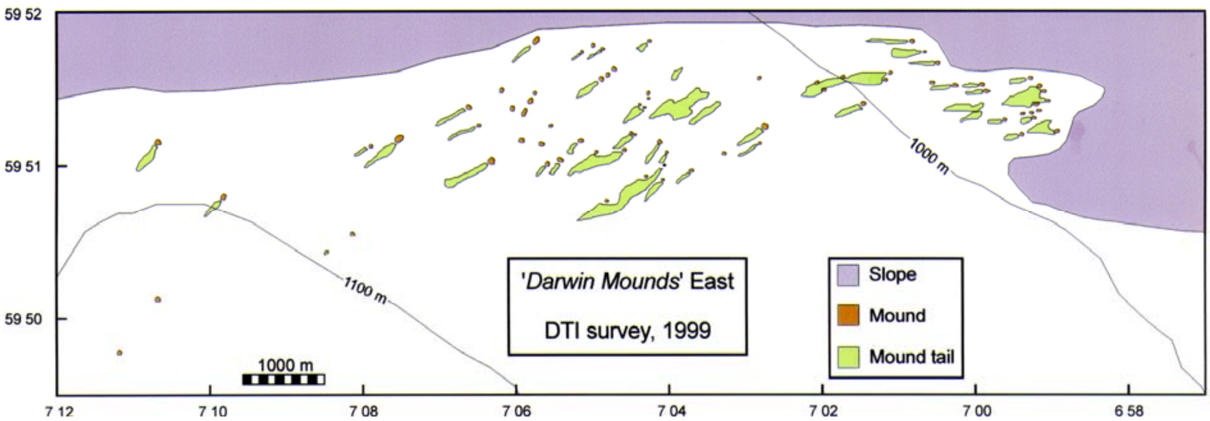
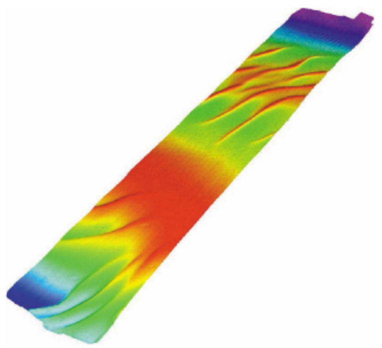


Figure 3.3 - Linear sandbank features on the Dogger Bank surveyed during the 2001 SEA survey

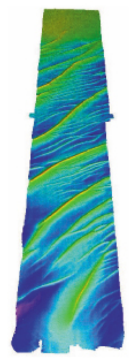
① Viking bank area



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 (Belderson 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).

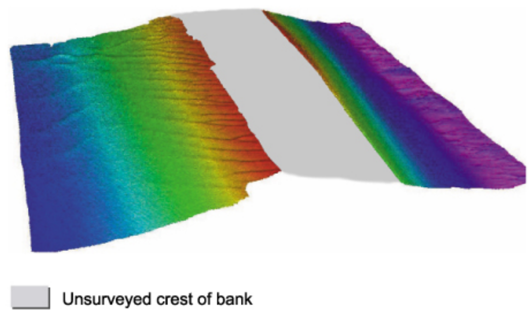
② Galleon sandwave field



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.

③ Smith's Knoll



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).

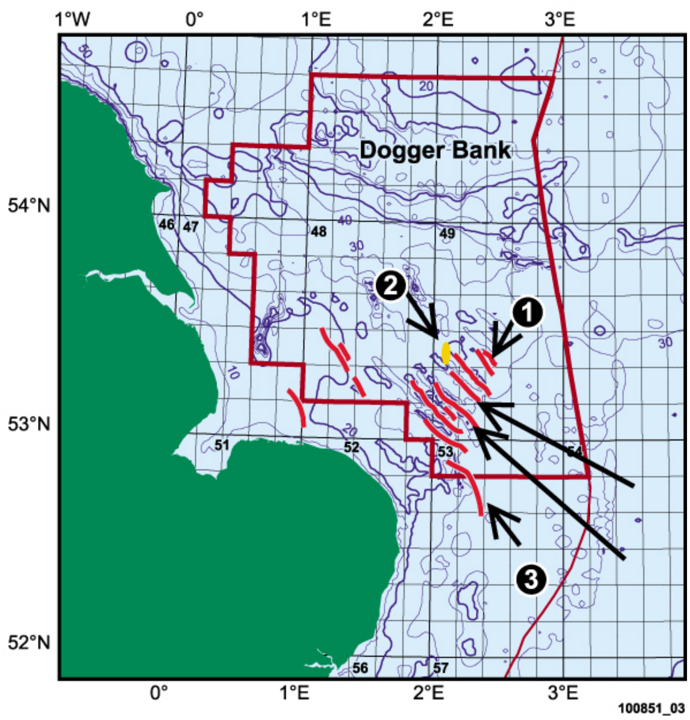


Figure 3.4 - Pockmark features in the Central North Sea surveyed during the 2001 SEA survey

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 km^2 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.

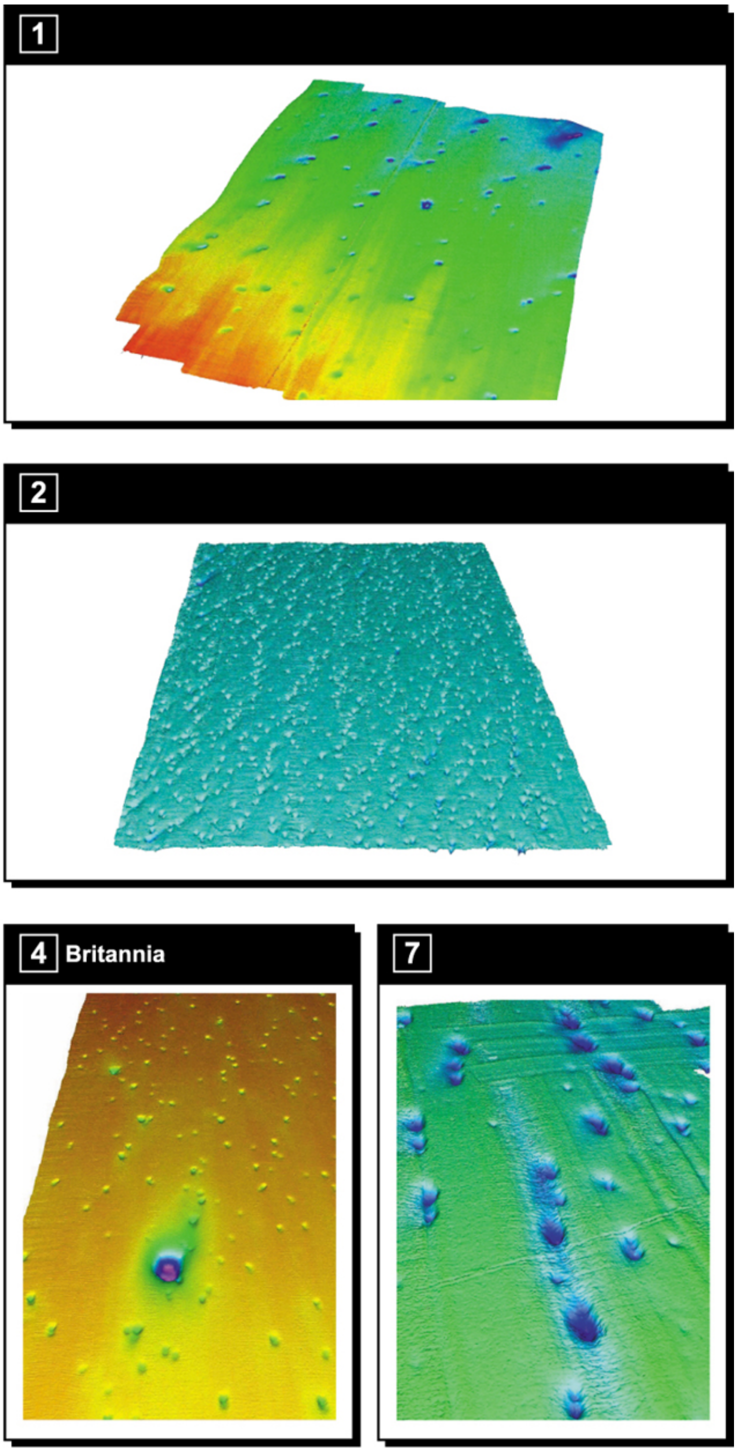


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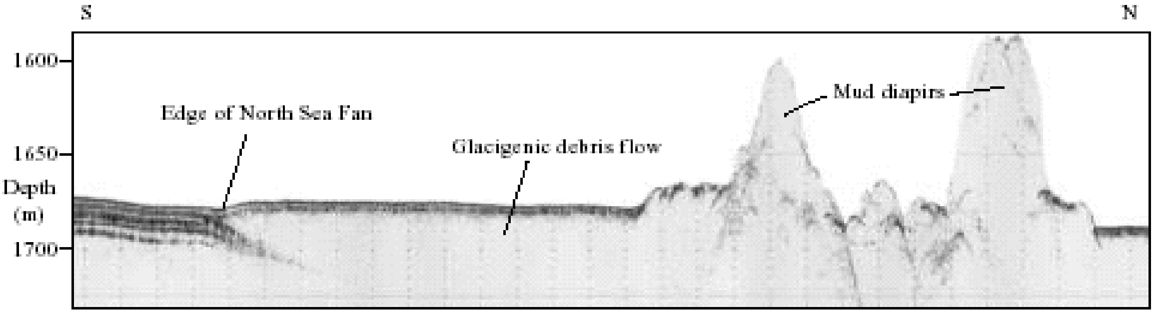
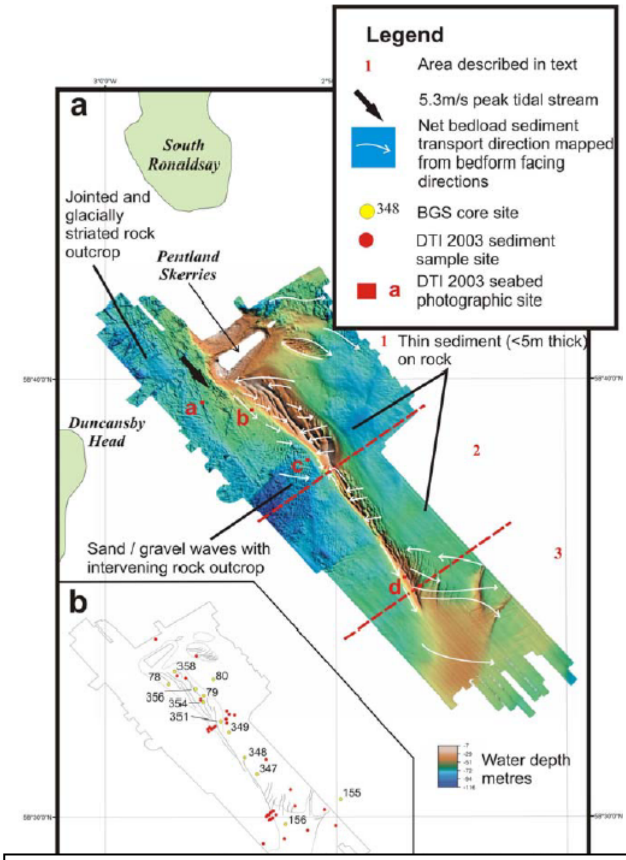
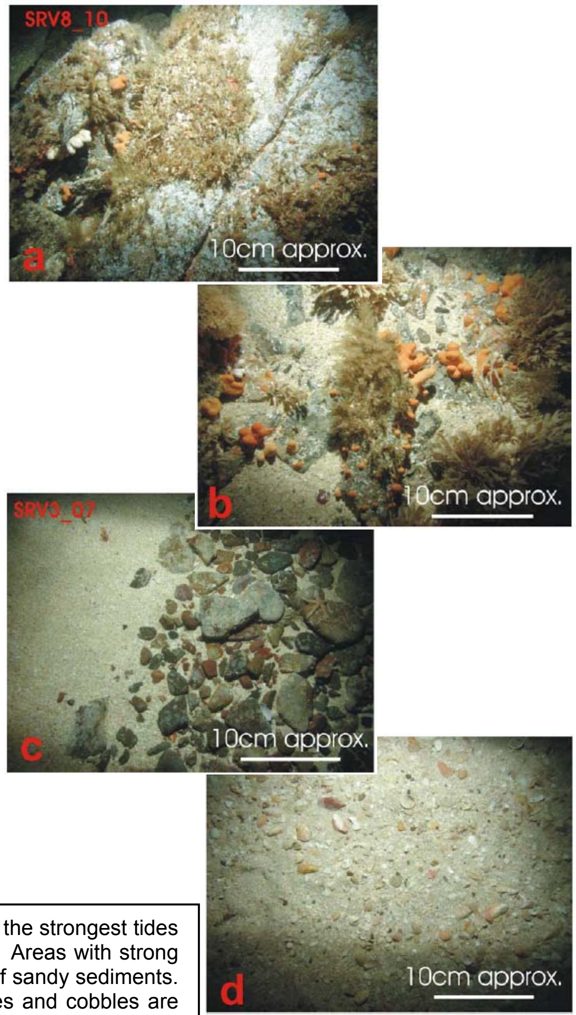
Figure 3.5 - A 3.5kHz profile from the Norwegian Basin floor showing mud diapirs (*Masson et al. 2003*).



(Pilot Whale Diapirs surveyed in 2002)

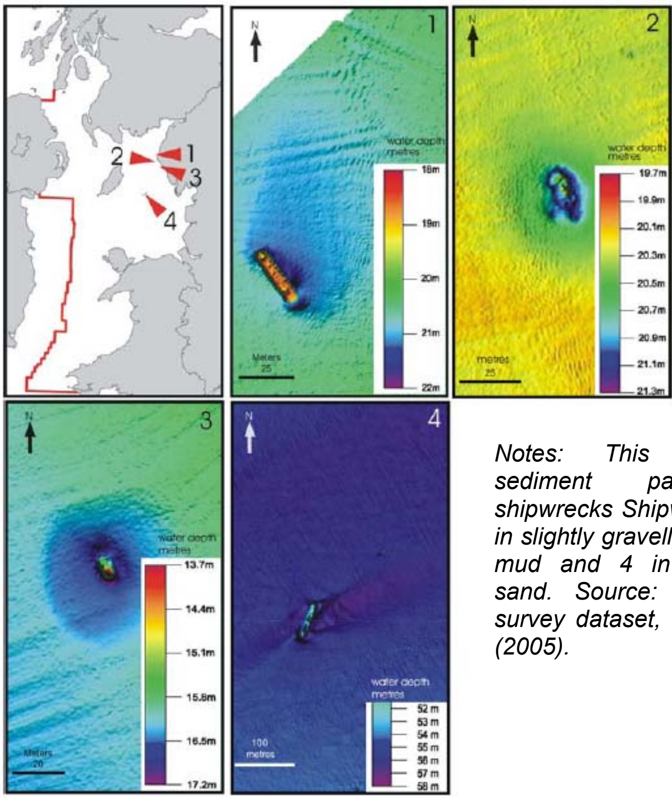
Figure 3.6 - Mapping of The Sandy Riddle during 2003 SEA survey





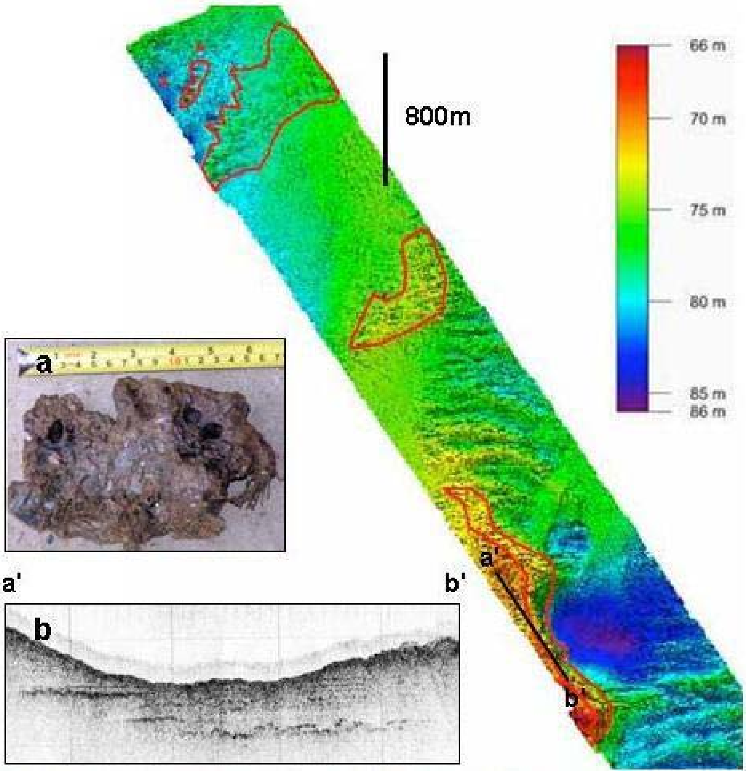
Notes; To the north and west of the Sandy Riddle, the areas with the strongest tides are swept clean of sediments exposing bedrock (photograph a). Areas with strong currents and cobbles and boulders are also largely swept clean of sandy sediments. In this sediment-starved environment the surfaces of the pebbles and cobbles are characterised by abundant attached biota (photograph b). In areas of weaker currents the seabed is characterised by mobile sands which are thick enough to migrate as sediment waves over the seabed and periodically bury an underlying pavement of cobbles and pebbles. This process appears to prevent the establishment of abundant permanently attached biota on the pebbles and cobbles (photograph c). Carbonate sand and gravel accumulate in areas of weak or convergent currents (photograph d).

Figure 3.7 – Sediment patterns around shipwrecks from 2004 SEA surveys



Notes: This image shows sediment patterns around shipwrecks Shipwreck 1 and 3 set in slightly gravelly mud, 2 in sandy mud and 4 in slightly gravelly sand. Source: DTI 2004 SEA 6 survey dataset, Holmes & Tappin (2005).

Figure 3.8 – Survey of Texel 11 from 2004 SEA surveys



Notes: Main picture – anticipated extent of methane derived authigenic carbonate (MDAC) in Texel 11 (in red), a) an MDAC samples collected by grab and b) seismic profile showing enhanced reflectors (shallow gas near the seabed at the edge of the southern seabed hollow (see main picture for seismic transect). Source: Judd (2005).

Figure 3.9 – Areas included in the 2005 and 2006 SEA surveys

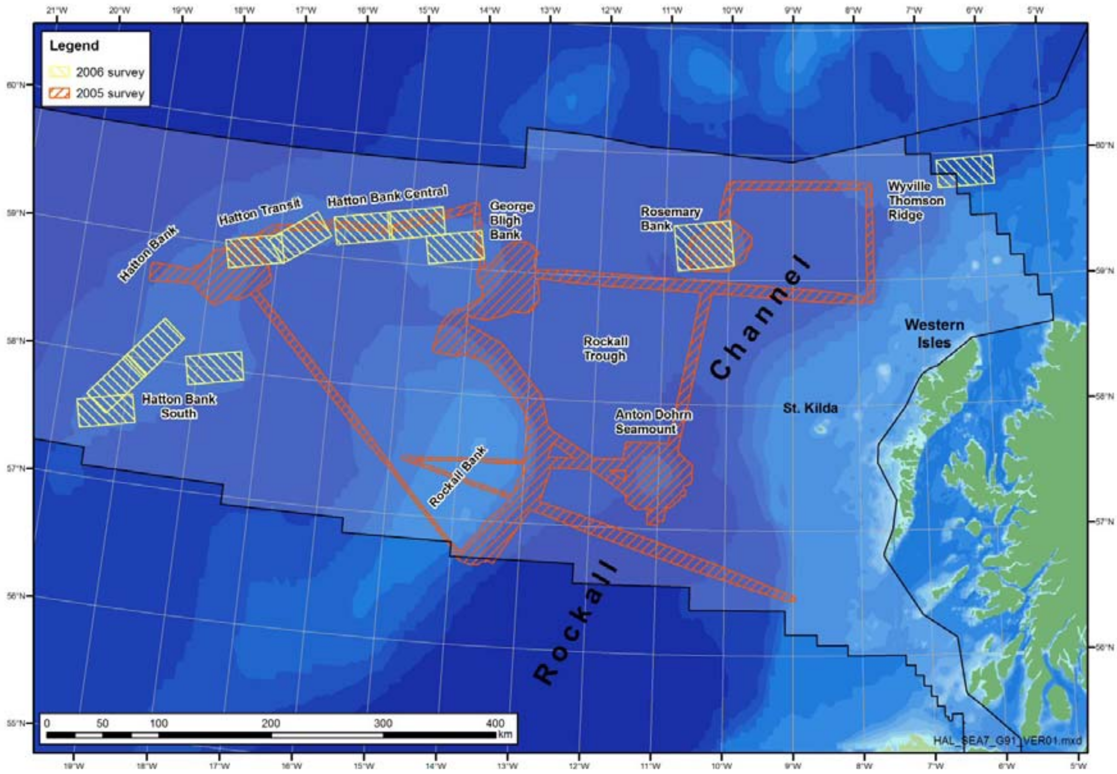


Figure 3.10 – Example seabed images from the 2005 and 2006 SEA surveys

Cold water coral on Hatton Bank

Rabbit fish at George Bligh Bank

Figure 3.11- Grey Seal satellite tag tracks from SEA funded SMRU seal tagging programme

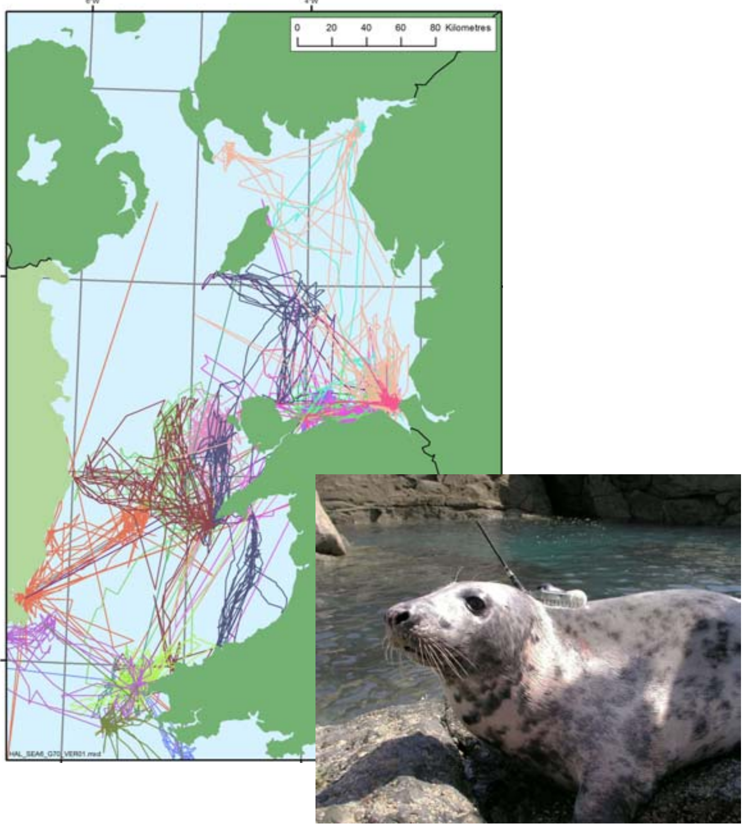
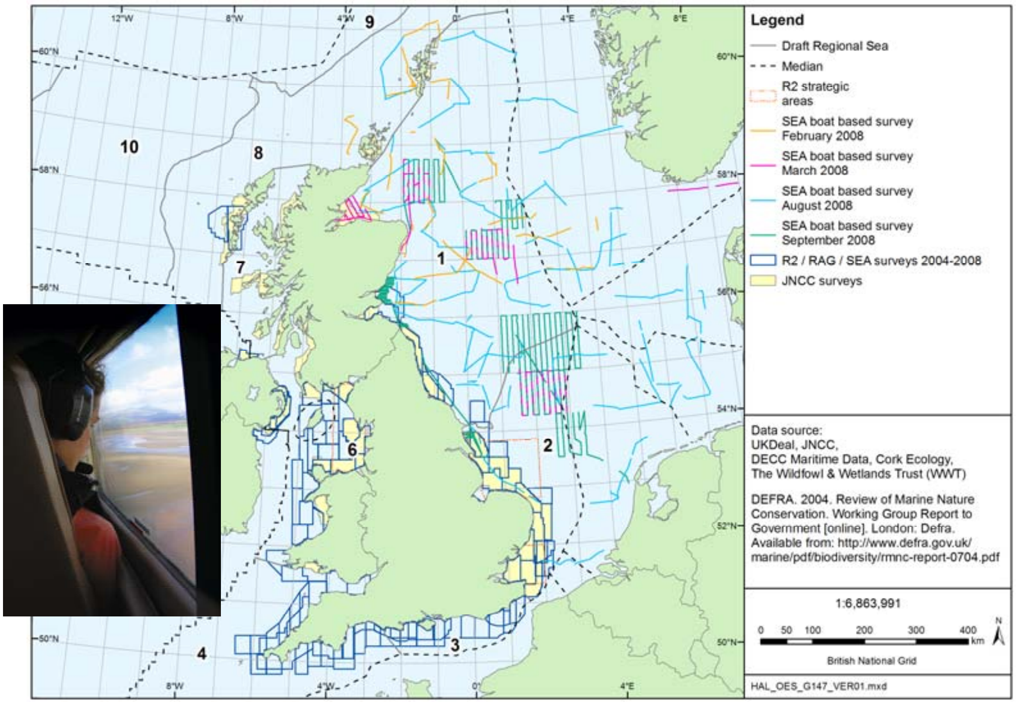


Figure 3.12 - Aerial and boat based seabird and waterbird surveys



A number of studies were commissioned either to provide expert reviews or data syntheses in areas for which synoptic overviews were not published or readily available. These reports underpin the assessment documented in this report and are available from the DECC SEA website (www.offshore-sea.org.uk).

Technical Reports covering the SEA 8 Area

- Archaeology
- Marine Mammals
- Plankton
- Benthos
- Mapping Portland
- Mapping Bristol Channel
- Hydrography
- Geology
- Non-commercial fish
- Recreational yachting
- Conservation
- Contaminants
- Other users
- Seabirds

Additional studies for the Offshore Energy SEA & general SEA process

- Aerial bird surveys
- Aerial surveys - shearwaters
- SEA 8 sample analysis
- Bivalve identification
- Marine renewables atlas (2)
- Boat based bird surveys
- Large cetaceans - SOSUS
- Marine mammals – UK
- Seal tagging
- Archaeology - UK
- Grid study Phase 1 & 2
- Seascape

3.5 SEA objectives

The development of SEA objectives is a recognised way in which environmental considerations can be described, analysed and compared. Draft objectives and indicators for the Offshore Energy SEA were included in the Scoping Document. Feedback from scoping was discussed at a Steering Group meeting in February 2008 and a revised draft of the objectives and indicators was discussed at an Assessment Workshop, held in Bristol in September 2008, in which members of the SEA steering group, SEA team and technical authors participated. The SEA Objectives are presented in Table 3.1 below.

Table 3.1 - SEA Topics, objectives and Indicators

SEA Objective	Indicators
SEA Topic: Biodiversity, habitats, flora and fauna	
Contributes to conservation of the wildlife and wildlife habitats of the United Kingdom.	For selected 'valued ecosystem components' no loss of diversity or decline in population (measures as % of relevant biogeographic population) attributable to offshore oil and gas and wind farm activities and promotion of recovery wherever possible.
Avoids significant impact to conservation sites, including draft, possible, candidate and designated Natura 2000 sites, along with consideration of future Marine Conservation Zones.	Activities subsequent to licensing/leasing which are on, or potentially affecting, a Natura site are compliant with the requirements of the Conservation (Natural Habitats, &c.) Regulations 1994 (as amended), the Conservation (Natural Habitats, etc.) (Northern Ireland) Regulations 1995 (as amended), the Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007 (as amended), and the Offshore Petroleum Activities (Conservation of Habitats) Regulations

SEA Objective	Indicators
	2001 (as amended).
Avoids significant impact to, or disturbance of, protected species.	Every activity with the potential to impact upon or disturb a protected species is compliant with the requirements of the Conservation (Natural Habitats, &c.) Regulations 1994 (as amended), the Conservation (Natural Habitats, etc.) (Northern Ireland) Regulations 1995 (as amended), the Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007 (as amended), and the Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001 (as amended).
SEA Topic: Geology and soils	
Protects the quality of the seabed and sediments and avoids significant effects on seabed morphology and sediment transport.	No adverse change in quality of seabed sediments at a series of regional monitoring stations.
Avoids significant damage to geological conservation sites and protects important geological features.	No physical damage to designated geological conservation sites.
SEA Topic: Landscape/seascape	
To accord with, and deliver, the Aims and Articles of The European Landscape Convention and minimises significant adverse impact on seascape/landscape including designated and non-designated areas.	No significant impact on nationally-designated areas (inclusive of related shore developments). Extent of the visual resource potentially effected by the particular developments. Number of areas of landscape sensitivity affected by proposed developments (e.g. offshore wind developments). Area of seascape/landscape restoration and enhancement associated with the proposed developments.
SEA Topic: Water resources	
To protects surface water and aquifer resources.	No adverse change in quality of surface water and aquifers. UKCS Exploration and Production (E&P) meets OSPAR discharge reduction targets. Number of spills and quantity of spilled oil.
SEA Topic: Air quality	
Avoids degradation of regional air quality from oil and gas activities.	Existing monitoring of local air quality shows no adverse impact.
SEA Topic: Climatic factors	
Minimises greenhouse gas emissions.	UKCS E&P greenhouse gas emissions.

SEA Objective	Indicators
	2003 Energy white paper "Reducing Carbon Emissions Indicator" (Greenhouse gas and carbon dioxide emissions).
SEA Topic: Population and human health	
Has no adverse impact on human health.	Progress in achieving OSPAR targets for continued reduction in harmfulness of offshore discharges.
Avoids disruption, disturbance and nuisance to communities.	Seascape and nuisance indicators.
SEA Topic: Other users of the sea, material assets (infrastructure, and natural resources)	
Balances other United Kingdom resources and activities of economic, safety, security and amenity value including defence, shipping, fishing, aviation, aggregate extraction, dredging, tourism and recreation against the need to develop offshore energy resources.	Spatial planning capable of addressing changes in technology, policy and prioritisation of site selection. Economic and social impact.
Safety of Navigation.	Increased collision risks and restrictions on pollution-prevention methods or Search & Rescue options in the event of an emergency.
Reduces waste.	Progress in reducing volumes of waste to landfill.
SEA Topic: Cultural heritage	
Protects the historic environment and cultural heritage of the United Kingdom.	No adverse impact upon the condition of. designated sites and features (including impact on their setting).

3.6 SEA scope

The area of study for the Offshore Energy SEA is shown in Figures 1.1.

The main stages of offshore wind farm development are:

6. Site prospecting/selection including collection of site specific wind data, and seabed information by geophysical and geotechnical survey
7. Development, including construction of foundations and any scour protection, turbine installation, cable laying including shoreline crossings and armouring, installation of gathering stations/substations and connection to the onshore national electricity transmission system
8. Generation operations
9. Maintenance
10. Decommissioning, including removal of facilities

The main stages of oil and gas activity (including natural gas storage) are:

6. Exploration, including seismic survey and exploration drilling
7. Development, including production facility installation, generally with construction of an export pipeline, and the drilling of producer and injector wells

8. Production/operation, with routine supply, return of wastes to shore, power generation, chemical use, produced water reinjection management and reservoir monitoring
9. Maintenance
10. Decommissioning, including cleaning and removal of facilities

These activities can interact with the natural and broader environment in a number of ways. The main potential sources of environmental effects from activities which could follow adoption of the draft plan/programme are:

- Noise (impulsive) from seismic survey and piling during installation
- Noise (semi-continuous or continuous) from turbines, drilling rigs, production facilities or vessels
- Physical damage (acute) to seabed features, biota and features of archaeological interest from anchoring, pipeline construction and cable laying
- Physical damage (non-acute) from particulate smothering
- Physical presence of structures, colonisation of structures by organisms, avoidance of wind farm areas e.g. by birds, animal collisions with structures and turbine blades
- Physical presence of structures, interference with other users of the sea
- Physical presence of structures, visual intrusion
- Chemical contamination (routine) from drilling and other discharges, antifouling coatings etc
- Chemical contamination (accidental) from spills
- Atmospheric emissions from fuel combustion, venting
- Electromagnetic Fields, possible effects on electrically or magnetically sensitive species from subsea power cables

All the major stages of offshore oil and gas and offshore wind farm operation are covered by environmental regulations including the requirement for Environmental Impact Assessment at the development stage (see Appendix 5).

The SEA assessment considered the likely significant effects of the implementation of the plan including short, medium and long-term effects, permanent and temporary effects, positive and negative effects, and secondary, cumulative and synergistic effects on:

- Biodiversity, habitats, flora and fauna
- Geology, substrates and coastal morphology
- Landscape/seascape
- Water environment
- Air quality
- Climate and meteorology
- Population and human health
- Other users, material assets (infrastructure, other natural resources)
- Cultural heritage
- Conservation of sites and species

and the interrelationship between the above.

3.7 Assessment methodology

The assessment is presented as evidence based discussion (Section 5) citing peer reviewed and other literature as appropriate together with spatial GIS output maps and graphics. The assessment considers the implications of the draft plan for relevant existing environmental problems including, especially, those relating to any areas of particular environmental importance, such as areas designated under the Habitats & Species and Birds Directives. The assessment draws on stakeholder perspectives on key issues relating to offshore oil and gas exploration and production obtained through consultation with regulators, local authorities, operators and others. The results of the assessment are summarised for each alternative in a receptor based matrix format (Section 5).

4 ENVIRONMENTAL INFORMATION

4.1 Introduction

The following section and associated appendices provide environmental information as required under Schedule 2 of *The Environmental Assessment of Plans and Programmes Regulations 2004* (Regulation 12(3)).

The environmental baseline for the Offshore Energy SEA is provided in full as Appendix 3. The baseline is described under a series of headings which relate to issues identified by the SEA Regulations on which to judge the *"…likely significant effects on the environment, including short, medium and long-term effects, permanent and temporary effects, positive and negative effects, and secondary, cumulative and synergistic effects…"* These include:

- Biodiversity, habitats, flora and fauna
- Geology, substrates and coastal morphology
- Landscape/seascape
- Water environment
- Air quality
- Climate and meteorology
- Population and human health
- Other users, material assets (infrastructure, other natural resources)
- Cultural heritage
- Conservation of sites and species

and the interrelationships of the above.

The environmental baseline considers all the above headings in a UK context, before providing more detailed information on key features specific to UK Regional Seas, as defined by JNCC (2004).

Within Section 4.2, summary details are provided for each heading and Regional Sea, with further information and figures available in a series of sub-appendices to Appendix 3.

Section 4.3, relevant existing environmental problems, identifies for each Regional Sea *"Any existing problems which are relevant to the plan or programme including, in particular those relating to any areas of particular environmental importance, such as areas designated pursuant to Council Directive 79/409/EEC on the conservation of wild birds and the Habitats Directive."*

Finally, Section 4.4, Likely evolution of the baseline highlights *"…relevant aspects of the current state of the environment and the likely evolution thereof without implementation of the plan or programme."*

Throughout Sections 4.2-4.4, signposts are provided to the locations of further information within the relevant sub-appendices of the full environmental baseline.

4.2 Overview of environmental baseline

4.2.1 UK context

Biodiversity, habitats, flora and fauna

The UK has a rich marine biodiversity reflecting both the range of habitats present in water depths from the shore to >2400m, and its position where several biogeographical provinces overlap (see for example Murray (1886), Longhurst (1998) and Spalding *et al*. (2007)). Some species and habitats are naturally rare, whilst others are endangered by human activities, and actions to protect and promote biodiversity are being taken at many levels.

In broad biogeographical terms, the planktonic flora and fauna of UK waters is part of the North-East Atlantic Shelves Province which extends from Brittany to mid-Norway. In addition, the deeper Faroe-Shetland Channel and areas to the north are within the Atlantic sub-Arctic Province. Each province can be subdivided according to hydrography and plankton composition. In general, the phytoplankton community is dominated by diatoms and dinoflagellates. Plankton blooms typically take place in spring, with a smaller bloom in late summer. The timing, composition and size of these blooms are dependent on a range of environmental factors. Some phytoplankton blooms may be toxic to marine life. The zooplankton community is dominated by copepods, including *Calanus finmarchicus* and *C. helgolandicus*. Jellyfish, krill and salps are also abundant, as are the larvae of fish, and many benthic animals (meroplankton). Further information is provided in Appendix 3a.1.

The composition of the seabed fauna of the UK reflects the intersection of four biogeographical zones:

- Boreal Province including the North and Irish Seas
- Lusitanian-Boreal Province comprising the Celtic Sea and west coasts of Ireland and Scotland
- 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

Within each Province it is possible to distinguish a series of faunal communities inhabiting specific sediment types. Often these communities extend over wide areas (e.g. the fine sands of the central North Sea and the sandy muds of the Fladen Ground in the northern North Sea). In addition, there are a number of highly localised habitats and communities, including reefs of long lived horse mussels and cold water corals, some of which are the subject of biodiversity action either at an OSPAR, EU or UK level. A large proportion of the seabed of the UK continental shelf and upper slope is physically disturbed by fishing activities. Greater information is provided in Appendix 3a.2.

Most cephalopods in UK waters are long-finned squids, short-finned squids, bobtail squids, octopuses or cuttlefish. The long-finned squids (including *Loligo forbesii*) tend to have a more coastal distribution and a northerly distribution. Short-finned squids are oceanic species and are recorded particularly to the west of the UK. Bobtail squids are abundant in shallow, coastal regions, while octopuses and cuttlefish are more common in southern areas. A number of deep-sea cephalopods are present in the deep waters of the Faroe-Shetland Channel and Rockall Trough. Further information is provided in Appendix 3a.3.

A wide range of biogeographic distribution patterns are shown by the fish in UK waters. The majority of continental shelf species have a north-east Atlantic/northern Atlantic distribution, although a proportion are found globally in the tropics/subtropics and others have a circum-polar pattern of occurrence. Widely distributed species often include local stocks with distinct breeding times and locations (e.g. herring). Widespread pelagic species include herring and mackerel, particularly around the western and northern parts of the UK. Demersal species include gadoids (e.g. cod, whiting) and flatfish (e.g. plaice, dab). Demersal communities tend to be more diverse in southern areas of the UK. Diadromous fish in UK waters include sea trout and Atlantic salmon. A number of sharks and rays are present in UK waters, including the basking shark. Deep water fish show different distribution patterns with major differences occurring north and south of the Wyville Thomson Ridge (*ca*. 60°N), and a distinct species group found in the cold waters of the Faroe-Shetland Channel and Norwegian Sea. Widespread commercial shellfish species include crustaceans (e.g. *Nephrops*, brown crab), bivalve molluscs (e.g. scallops, cockles) and gastropod molluscs (e.g. whelks). Many of these species, such as *Nephrops* and scallops, are closely tied to particular seabed sediments and so occupy distinct grounds. Virtually all commercially fished species are heavily exploited. Further information is provided in Appendix 3a.4.

Of the five species recorded in UK waters, the vast majority of records are of the leatherback turtle (*Dermochelys coriacea*) which is the only species considered a regular member of the UK marine fauna. While turtles have been observed along the majority of UK and Irish coasts, records are concentrated on the west and south coasts of Ireland, southwest England, south and northwest Wales, the west coast of Scotland, Orkney and Shetland. Further information is provided in Appendix 3a.5.

The bird fauna of the UK is western Palaearctic, that is the great majority of species are found widely over western Europe and extend to western Asia and northern Africa. There are 3 regular patterns of species occurrence: resident, summer visitors (to breed) and winter visitors. Some of the summer visitors undertake long migrations to overwinter in southern Africa or South America. A few species are found only or predominantly in the UK. For example, the three Pembrokeshire islands of Skomer, Skokholm and Middleholm are estimated to hold some 50%, and the Isle of Rum off western Scotland between a quarter and a third of the world's breeding population of Manx shearwaters. Further information is provided in Appendix 3a.6.

Many of the species of cetaceans found in UK waters have a worldwide distribution, although a number have restricted ranges, typically temperate to sub-Arctic or Arctic waters of the North Atlantic. British whales and dolphins include resident species as well as migrants (regularly moving through the area to and from feeding and breeding grounds) and vagrants (accidental visitors from the tropics or polar seas). Two species of seal breed in the UK; the grey seal has a North Atlantic distribution with the UK holding over 40% of the world population; and the harbour seal, found along temperate, sub-Arctic and Arctic coasts of the northern hemisphere, with the UK population representing over 5% of the global total. Otters inhabit a variety of aquatic habitats, with some populations feeding in shallow, inshore marine areas. The most important otter populations utilising coastal habitats occur in western Scotland, Shetland, west Wales and the Wash and north Norfolk coast. Small numbers of the Nathusius' pipistrelle bat occur seasonally over UK waters on migrations between the UK and mainland Europe. Extensive information on the distribution, abundance and ecology of marine and other mammals in UK waters is provided in Appendix 3a.7.

Geology substrates and coastal morphology

The distribution of geological strata in the UKCS is determined by past geological and geomorphological processes. The distribution of sediments and certain topographic features is a function of the underlying geology, and millennia of aeolian, fluvial and glacial activity both in the marine and terrestrial environment. The distribution of sediments and deep geological structure of the UKCS, and the North Sea in particular, is quite well known, particularly in areas of mature oil and gas production which have been extensively explored since the 1960s. Oil and gas reserves are dependent on viable source rocks and a suitable impermeable cap-rock, and these reservoirs are responsible for the distribution of much offshore activity. Certain topographic features are notable, primarily for the quality of habitat they provide, and these are bound by geology (e.g. Haig Fras) or sediment type (e.g. north Norfolk sandbanks). Further information is provided in Appendix 3b.

Existing levels of contamination in the UK marine environment vary considerably on both regional and local scales, and in general have declined appreciably in recent decades. The majority of marine pollution comes from land-based activities; most pollutants enter the UK marine environment through direct discharges of effluents, land run-off (mainly via rivers) or indirectly via the atmosphere. The highest concentrations of contaminants, and hence the greatest effects, are therefore often in inshore areas. Water samples with the highest levels of chemical contamination are found at inshore estuary and coastal sites subject to high industrial usage. In offshore waters, contaminant levels (chiefly hydrocarbons) in water and sediments are generally expected to be at or near background concentrations. Levels are expected to be higher close proximity to oil and gas infrastructure, with concentrations decreasing with increasing distance from the source. Detailed information on a variety of contaminants is provided in Appendix 3b.

Landscape/seascape

Seascape is defined in DTI (2005) as ‘a discrete area within which there is shared inter-visibility between land and sea’, which can be separated into areas of sea, land and intervening coastline. The study of seascape is not only concerned with the physical changes in a given view but the interaction of that view with individuals and how it affects overall visual amenity. Seascapes and coastal environments (including the sea itself) are extensively used for recreation which generates significant tourist income from which many coastal communities are dependent, and this can strongly conflict with commercial and industrial activity (Hill *et al.* 2001). The ‘value’ of many of the UK’s seascapes is reflected in the range of designations which relate in whole or in part to the scenic character of a particular area (e.g. Area of Outstanding Natural Beauty, Heritage Coast, National Scenic Area). Further information is provided in Appendix 3c.

Water environment

The UK marine water environment is highly varied, ranging from entirely oceanic conditions to the north and west of the UK to complex estuarine systems widely distributed around the coast. It is also a dynamic environment, with a complex system of currents and varied oceanographic conditions including areas of considerable frontal activity and high-energy wave and tidal environments. Section 4.2.2 describes the general physical characteristics of the UK draft Regional Seas, while detailed information on the water masses and circulation, stratification and frontal zones, coastal tidal flows, temperature, salinity and wave climate is provided in Appendix 3d.

Air quality

Whilst air quality is not monitored routinely offshore, regular air quality monitoring is carried out by local authorities in coastal areas adjacent to each Regional Sea and by the OSPAR Comprehensive Atmospheric Monitoring Programme (CAMP) network. The air quality of all local authorities is generally within national standards set by the UK government’s air quality strategy though several Air Quality Management Areas (AQMAs) have been declared to deal with problem areas. Industrialisation of the coast and certain inshore areas has led to increased levels of pollutants in these areas which decrease further offshore, though oil and gas platforms provide numerous fixed point sources of atmospheric emissions. Further information is provided in Appendix 3e.

Climate and meteorology

The UK lies within temperate latitudes and the climate is generally mild. Numerous easterly moving depressions meet the UK in the west leading to a gradient of relatively high wind speeds and precipitation in the exposed west and relatively low wind speeds and precipitation in the sheltered south and east. The upland nature of much of the west coast also contributes to this west-east gradient, with topography-induced enhanced precipitation, particularly in the north-west. The UK has a strong maritime influence, which has the effect of reducing the diurnal and annual temperature ranges; such effects are most notable at the coast and on islands (e.g. Orkney, Shetland). The North Atlantic Oscillation (NAO) has also been linked with variations in UK sea surface temperatures, wind strength, direction and rainfall. It is very likely that climatic change is influenced and/or generated by the anthropogenic production of greenhouse gases, which are likely to generate a temperature increase of 0.2°C for the next few decades as well as an increase in sea-level. More changeable and extreme weather is also a possible outcome. Further information is provided in Appendix 3f.

Population and human health

Population density is highest in England at 390 persons per km^2, comparably lower in Wales and Northern Ireland at 143 and 128 persons per km^2 respectively, and the lowest by a considerable margin in Scotland at 66 persons per km^2. In coastal areas, there are lower densities around much of the southwest of England, west and north Wales, the far north of England, and much of Scotland excluding the central belt. The highest coastal densities are around much of southeast England, part of northeast England, the Firths of Forth and Clyde, part of northwest England, south Wales and around the Severn Estuary. These areas are typically where conurbations are largest and most numerous, although more isolated areas of higher densities are dotted around much of the coast. Higher densities are also observed in several coastal areas of Northern Ireland.

For the UK as a whole, 9.3% of people described their health as “not good” in 2001. Values were lowest in England at 9.0%. Values for Scotland and Northern Ireland were similarly higher than the UK average at 10.2% and 10.7% respectively, with Wales the highest at 12.5%. The proportion of people with a limiting long term illness showed a similar pattern, with the lowest proportion in England and highest in Wales. Further information, including Regional Sea-specific statistics, is provided in Appendix 3g.

Other users, material assets (infrastructure, other natural resources)

UK waters are subject to a multitude of uses - particularly in coastal areas. The range and importance of existing and some potential uses of the sea are described in Appendix 3h, with key aspects summarised below. In advance of formal marine spatial planning, this SEA has obtained accurate and recent information on other current and likely uses of the sea in the foreseeable future.

The UK is heavily reliant on shipping for the import and export of goods, and will remain so for the foreseeable future. Over 95% of the goods entering or leaving the UK are transported by ship, with substantial numbers of vessels also transiting UK waters en route to European and more distant ports. In recognition of the vessel traffic densities and topographic constraints on various routes, the International Maritime Organisation (IMO) has established a number of traffic separation schemes and other vessel routeing measures to reduce risks of ship collision and groundings. In addition, IMO regulations required that from 2005, an Automatic Identification System (AIS) transponder be fitted aboard all ships of >300 gross tonnage engaged on international voyages, all cargo ships of >500 gross tonnage and all passenger ships irrespective of size. AIS data allow precise tracking of individual vessels, and provide accurate information on important areas for larger vessel navigation.

Fishing in the UK has a long history and is of major economic and cultural importance. In 2007, there were nearly 13,000 working fishermen in the UK (of which 79% were full time), operating over 6,700 vessels, many of which are smaller inshore boats. These vessels landed 610,000 tonnes of fin- and shellfish in 2007, with a total value of £645 million. On top of this, fish processing provides over 22,000 jobs in the UK. The livelihoods of individual fishermen depend on their ability to exploit traditional fishing grounds and to adapt to changing circumstances to maximise profit. Consequently, they are vulnerable to competition within the UK industry and with foreign vessels, and to being displaced from primary grounds. Various sources of information on fishing effort show that while the majority of UK waters are fished to some extent, certain areas receive considerably more effort than others. In general, the greatest density of fishing effort takes place in coastal waters, for both static (such as pots, traps or gillnets) and mobile (such as trawls and dredges) gears. Further offshore, the density of effort was greatest to the northeast of Scotland (particularly the Fladen Ground), around the Northern Isles and to the southwest of the UK.

Offshore wind farms have the potential to affect civilian aerodromes and radar systems. The UK air traffic control service for aircraft flying in UK airspace has made available mapped data indicating the likelihood of interference from offshore wind turbines on its radar network. Similarly, the Civil Aviation Authority (CAA) produces an Aerodrome Safeguarding Map and Local Planning Authorities are required to consult on relevant Planning Applications which fall within a 15km radius.

Military use of the coasts and seas of the UK is extensive, with all 3 Services having defined Practice and Exercise Areas, some of which are danger areas where live firing and testing may occur. Additionally, several military radars - Air Surveillance and Control Systems (ASACS) - are present around the coasts of the UK; these have been mapped along with corresponding buffers relating to potential conflict with wind farms.

Tourism and recreational use of UK coasts and coastal waters is of major importance in many areas. Annually, the British public take some 28 million days on seaside holidays in the UK spending £5.1 billion, split between England (£4 billion), Wales (£0.52 billion), Scotland (£0.44 billion) and Northern Ireland. Major recreational uses of the sea beyond beaches and coastal paths include yachting (for which the Royal Yachting Association has published charts of cruising and racing routes) and sea angling, which in England and Wales generates some £82m for charter boats and £278m for own boat activities. Many visitors to the coast cite unspoilt and beautiful natural scenery as the important factors influencing their selection of location to visit. The importance of such attributes are widely recognised and protected through designations such as National Parks, Areas of Outstanding Natural Beauty, and National Scenic Areas.

Various areas of sea are used or licensed/leased for marine aggregate extraction, telecommunications and other cables, disposal of capital and other dredging wastes, Round 1 and Round 2 offshore wind farms, surface and subsea oil and gas production and export infrastructure. These have a combined turnover of some £34 billion, employing nearly

320,000 people. Potential future uses of the sea include gas storage (both natural gas and carbon dioxide) in geological formations, aquifers or constructed salt caverns. The locations of these features, along with greater information, are provided in Appendix 3h.

Cultural Heritage

The collective inventory and knowledge of maritime sites in particular is quite poor and may be subject to recording biases. Archaeology associated with human and/or proto-human activities either on the current seafloor of the southern North Sea, in the coastal zone of the British Isles and further inland, has the potential to date back at least as far as 500,000 years BP. Relatively recent finds of flint artefacts from the Cromer Forest-bed Formation, Suffolk date to as early as 700,000 years. The current understanding of marine prehistoric archaeology is based on knowledge of the palaeolandscapes of the continental shelf between the UK and Europe during glacial phases and limited finds of archaeological materials, augmented with knowledge of analogous cultural and archaeological contexts from modern day terrestrial locations. The record for wreck sites is biased towards those from the post-Medieval and later periods, presumably a function of greater traffic and increased reporting associated with the introduction of marine insurance and the Lloyds of London list of shipping casualties in 1741. The strategic military importance of the sea, the importance of the North Sea as a fishing area, the importance of maritime trade routes and the treacherous nature of many near-shore waters, has lead to a large number of ship and aircraft wrecks in UK waters.

A number of coastal sites have been designated as World Heritage Sites for example St Kilda, the Dorset and East Devon Coast and the Heart of Neolithic Orkney.

Further information is provided in Appendices 3i and 3j.

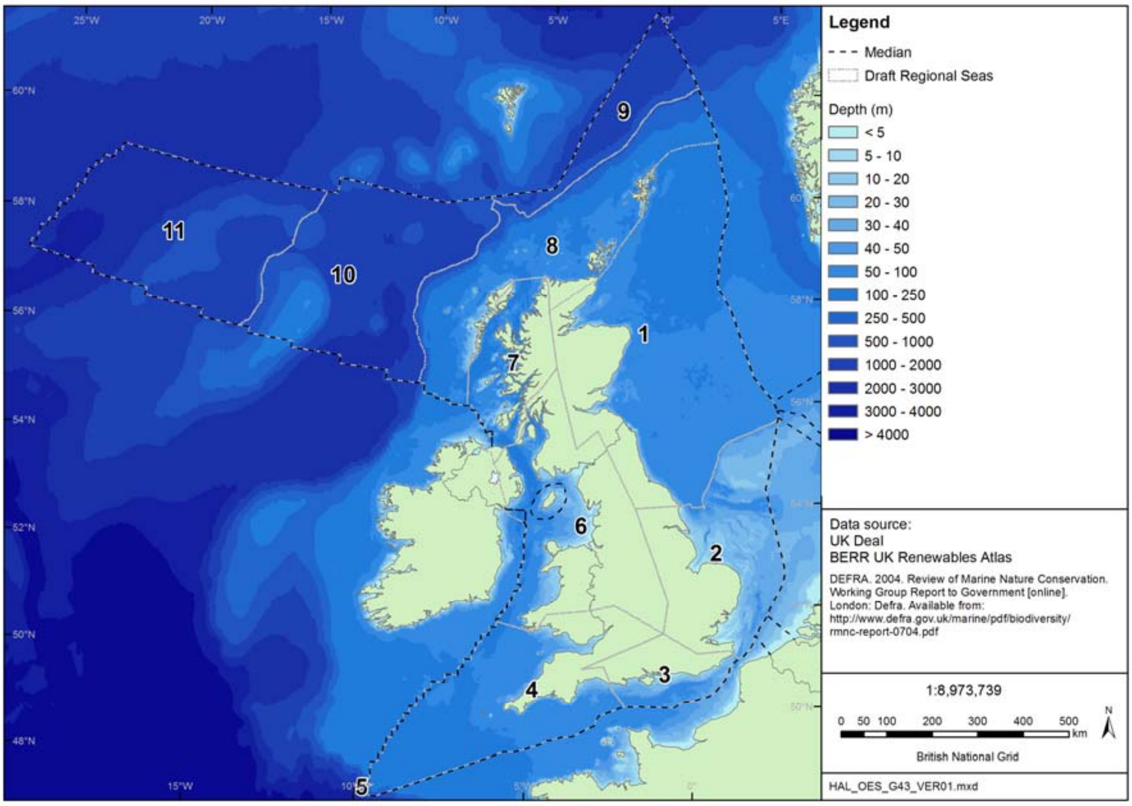
Conservation of sites and species

Designated conservation sites are widespread and abundant around the UK coast; a variety of levels of designations exist from statutory international to voluntary local, affording various levels of protection to habitats, species, and geological, cultural and landscape features. Some of the most widespread designations include the European-level Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) and the national-level Sites/Areas of Special Scientific Interest (SSSIs/ASSIs). The vast majority of currently designated coastal sites are entirely terrestrial or terrestrial with marine components; very few are exclusively marine. However, progress towards further identification of marine sites is ongoing; a number of offshore SACs are in the process of being designated, work is underway to identify new marine SPAs, and the boundaries of some coastal and marine sites are being extended. Additionally, the Marine Strategy Directive through the *Marine and Coastal Access Bill* will introduce further requirements for identification and designation of Marine Conservation Zones (known as Marine Protected Areas in Scotland). Detailed listing and descriptions of conservation sites is provided in Appendix 3j.

4.2.2 Regional Seas

The Offshore Energy SEA uses draft Regional Sea boundaries identified by the JNCC (JNCC 2004) as an appropriate means of considering the broad scale biogeographical regions within UK waters. These boundaries are shown in Figure 4.1. The text below (largely drawn from JNCC 2004) describes the broad physical features of each Regional Sea, including the features upon which their boundaries are based. Detailed information on key features of each of the Regional Seas is provided by the various sub-appendices of the environmental baseline.

Figure 4.1 - Draft Regional Sea boundaries



Regional Sea 1

The *northern North Sea* is bounded by the Flamborough front to the south, marking the transition from the shallow mixed waters of the southern North Sea to the deeper waters (50-200m) in the north which stratify thermally in summer along with a transition from sands to muddier sediments. Waters are generally of coastal origin but with a strong influx of Atlantic water in the north; turbidity is moderate. The northern boundary marks the transition from water dominated by the continental shelf current to the North Sea waters of mixed origin.

Regional Sea 1 supports an increasing diversity of cetacean species from south-north, high densities of seals (particularly around the Northern Isles), and an important population of bottlenose dolphins along the Scottish east coast. The adjacent coastline represents an important migratory pathway for many Arctic-breeding species, while the widespread and often remote cliff habitats support vast numbers of breeding seabirds; seabird densities at sea are relatively high over much of the area. The deeper waters over the mud and muddy sand of the Fladen Ground support an abundance of fish and *Nephrops* - yielding one of the most valuable fishing grounds in UK waters; additionally, inshore waters are heavily fished throughout the area. Oil and gas development is extensive, particularly in the east.

Regional Sea 2

The *southern North Sea* extends from the Flamborough front in the north to the Dover Straits in the south, where a transition commences from North Sea water to Atlantic water. This region is shallow (generally 0-50m), with a predominantly sandy seabed, and mixed water experiencing large seasonal temperature variations. The influences of coastal water are particularly marked in this region, the water is turbid, and it exhibits a characteristic plankton composition.

Much of Regional Sea 2 is less than 50m water depth, with many extensive sandbank features present at less than 25m depth; these include the Dogger Bank draft SAC and the North Norfolk Sandbanks possible SAC. The western flank of the Dogger Bank also supports high densities of seabirds. Harbour porpoise are widely distributed throughout much of the area, with apparently variable densities between 2 major surveys a decade apart. Large numbers of harbour seals breed on the coast adjacent to the Wash; these animals forage widely in adjacent waters. The region experiences high densities of shipping activity, particularly in the south, and major shipping lanes run approximately parallel to the entire length of the coast. Fishing effort is moderate overall, with vessels generally avoiding the shallowest of sandbank areas, although inshore effort is fairly high in the south with international effort high in the southeast. Gas development is extensive south of the Dogger Bank to approximately 53°N, while a number of existing, under construction and planned offshore wind farms are present in the greater Wash and Thames areas.

Regional Sea 3

The *eastern English Channel* is bounded by the Dover Straits to the east and extends to the west to a line drawn between Weymouth and Cherbourg on the north coast of France. Waters are generally shallow (0-100m) and mixed, with strong tidal streams. The seabed is variable; a general transition can be observed from coarser sediments in the west to sand in the east, although localised rock outcrops occur throughout the English Channel basin. Water temperatures vary considerably with season. The western boundary denotes a transition in benthic fauna from the eastern English Channel (Boreal fauna) to a different community in the western English Channel (Lusitanean fauna).

The majority of Regional Sea 3 receives high to very high densities of shipping traffic, and has a water depth of less than 60m. The coastline is one of the most densely populated in the UK, and adjacent waters are used by a great number of recreational vessels. Additionally, very high levels of fishing activity occur, particularly in inshore waters, with high levels of effort by non-UK vessels also observed in this area. Many dredging licence and application areas are present in the region.

Regional Seas 4 and 5

The *western English Channel and Celtic Sea* (Regional Sea 4) is a large region west of a line drawn between Weymouth and Cherbourg and extending to approximately the 500m depth contour on the continental slope in the west. It is bounded to the northeast by the Celtic sea front - marking the transition from oceanic water to the coastally influenced waters of the Irish Sea. Depth in the region varies from 50-200m with a general trend of increasing depth towards the west. The seabed is largely composed of sand and gravels with isolated rocky outcrops. The waters are generally subject to seasonal stratification, although mixing and seasonal temperature variation is greater in the east. The southern boundary is marked by a transition to warmer water and a community containing a greater number of Lusitanean species. The region is heavily influenced by Atlantic water, with reduced coastal influences; turbidity is moderate.

The *Atlantic south west Approaches* (Regional Sea 5) is a region bounded to the east by the shelf break and extends westwards into the northeast Atlantic. Only a very small proportion of this region lies within UK waters, and it is therefore grouped with the adjacent Regional Sea 4 in the majority of Appendix 3. The seabed is generally composed of fine material. The water is oceanic in origin, with negligible coastal influences, low turbidity and is stratified. While comparable to the other deep water Regional Seas 10 and 11, influences from the Mediterranean current are stronger in this region leading to Lusitanean species being present in the water column. The area is intersected by submarine canyons, characterised by the upwelling of nutrient-rich deep waters and with cold-water corals present.

A large area with a water depth less than 60m extends west from the Bristol Channel to approximately 5°W, and also to some distance off the coast of north Cornwall. Recent surveys have observed seasonally high densities of seabirds in coastal waters around southwest England, while densities are also seasonally high in the north of the area around southwest Wales. The Celtic Sea is an important area for cetaceans, particularly common dolphins which may be seasonally present in large numbers. A large proportion of UK's leatherback turtle sightings occur in this region. In offshore waters west of Land's End lies Haig Fras - an area of rocky reef currently designated as a candidate SAC. The inshore waters off the southwest coast of England receive some of the highest levels of fishing effort in UK waters. Fishing effort is also high across the majority of Regional Sea 4, while this area is also of considerable importance to recreational craft and commercial shipping. Several dredging licence and application areas are present in the inner Bristol Channel and off the south Wales coast.

Regional Sea 6

The *Irish Sea* is bounded to the south approximately by the Celtic Sea front, and extends north to a line from the Mull of Kintyre, Scotland, to Fair Head, Northern Ireland, and includes the North Channel. Movements of species suggest the North Channel to represent an area of gradual transition rather than sharp change. The seabed is variable in nature, although dominated by glacigenic deposits re-worked by tidal currents. Waters are strongly influenced by coastal processes and turbid with influxes of water from the Celtic Sea and north from the continental shelf current. Stratification occurs in deeper waters but not in the coastal margin or in the north east of the area.

UK waters within the Irish Sea are generally shallow, with the majority of the area less than 60m depth from the coast west to approximately 5°W. Seabird densities are seasonally high in the west, particularly in the far north and south Irish Sea. Concentrations of Manx shearwaters occur in the Irish Sea, with colonies on islands off Pembrokeshire and in the Inner Hebrides representing the majority of the world breeding population of this species. Bottlenose dolphins occur off the west and north Welsh coast, with sightings focussed in Cardigan Bay where the species is one of the qualifying features for a marine SAC. High densities of shipping are experienced in the central St. George's Channel, off north Wales leading to the Mersey, and in the North Channel. High levels of fishing effort occur in the north, particularly to the west of the Isle of Man and off the Cumbria coast. Considerable gas infrastructure is present in the eastern Irish Sea associated with producing gas fields and there are a limited number of producing oilfields. There are also a number of existing and planned offshore wind farms.

Regional Sea 7

The *Minches and west Scotland* is bounded to the south by a line from the Mull of Kintyre to Fair Head, to the west by the Malin front, and to the north by a line from the Butt of Lewis to Cape Wrath. The region encompasses waters which are largely sheltered from Atlantic swells by Northern Ireland and the Outer Hebrides. The seabed is characterised by muddy sand and mud, although more gravel is present in the south of the region. The waters in the region largely comprise North Atlantic water as part of the continental shelf current but are modified by coastal influences. The majority of the waters in the region stratify in the summer months, and turbidity is moderate-low.

Regional Sea 7 is characterised by relatively deep waters considering its coastal nature. The complex, undulating coastline with many islands is predominantly rural with very low population density and remote from large conurbations. The region is of high environmental sensitivity for a range of features. A high diversity and abundance of marine mammals and seabirds are present, along with many coastal otter populations. This area supports some of the highest densities of harbour seals in UK waters. Fishing effort is very high throughout much of the area, and is dominated by small, inshore vessels. A very large number of designated conservation sites are present along the adjacent coast, including numerous habitat, species and landscape designations. Cold water corals occur in the area, and other reef features are present in many of the sheltered sea lochs. These lochs also support extensive mariculture activities.

Regional Sea 8

The *Scottish continental shelf* runs along the continental shelf to the north and northwest of the UK. It is bounded to the west, south of the Wyville Thomson Ridge, by the 1000m depth contour - reflecting the changes in community composition which has been observed in various studies on shelf slope fauna. To the north of the Wyville Thomson Ridge, the boundary lies along the 600m contour where the influence of cold Norwegian Sea/Arctic Intermediate water commences. The entire continental shelf is dominated by the warm (>8ºC) North Atlantic waters of the continental shelf current until the Orkney and Shetland Isles. The boundary to the east reflects the division between Lusitanean and Boreal fauna in the channel between the Orkney and Shetland Islands, with Lusitanean fauna occurring in the Orkney Islands but not in the Shetland Islands. The seabed is characterised by sand and coarse sediment of glacigenic origin re-worked by tidal processes, and in deeper areas close to the shelf break sediments have been formed into iceberg ploughmarks - a complex matrix habitat of stony ridges and sandy troughs. Water in this region is subject to seasonal stratification, has low turbidity and there is a low level of material of terrestrial origin entering the sea.

Regional Sea 8 covers a large area and range of water depths, although waters shallower than 60m are generally restricted to those immediately west of the Outer Hebrides. The region supports a rich diversity and abundance of marine mammals, with all typical UK shelf species present in addition to many oceanic, deeper water species along the shelf edge to the north and west. Large numbers of grey seals breed on the several small remote islands present, including those around Orkney and Shetland. Seabird densities are high throughout coastal waters and to a considerable distance offshore. Of particular environmental sensitivity is the St. Kilda archipelago. Lying 66km west of the Outer Hebrides, these islands support very large populations of breeding seabirds and receive numerous conservation designations, including dual World Heritage status for both its natural and cultural significance. Large numbers of breeding seabirds also occur on the adjacent coast of the Outer Hebrides, north mainland and Northern Isles. In the far south of the region lies Stanton Banks, recently designated a candidate SAC for reef features. Shipping density is particularly high along the north mainland and through the Pentland Firth, while fishing effort is moderately high throughout the majority of the region. A limited amount of oil and gas activity occurs to the west of Shetland. Population density along the adjacent coast is the lowest in the UK.

Regional Sea 9

The *Faroe-Shetland Channel* is characterised by the influx of dense cold water from the Arctic and Norwegian Sea into the channel at depths below 600m. The western boundary of the region is the Wyville Thomson Ridge which prevents the majority of the flow of cold water from entering the Rockall Trough, which instead exits to the northwest via the Faroe

Bank Channel. The seabed of the channel is mainly composed of silt and clay at the base with more sand and some areas of gravel and cobbles/boulders on the flanks of the continental slope, particularly in areas sculpted in the past by icebergs; glacial dropstones occur throughout the area. Water temperatures vary considerably through the water column, from approximately 0°C at the seabed but above 600m depth, where North Atlantic water flows, between 6.5-8°C. Both waters in the region are oceanic in origin and turbidity is low. The cold waters at depth result in a different characteristic benthic community to that found at shallower depths in adjacent areas or in the Rockall Trough.

Regional Sea 9 supports a diverse and abundant cetacean community, including many poorly understood oceanic and deep-diving species such as sperm whales, beaked whales and large baleen whales. Evidence suggests that this area represents a migratory route for a number of cetacean species. Along the southwest boundary of the area lies the Wyville Thomson Ridge, a large area of full salinity stony and bedrock reef currently designated as a possible SAC.

Regional Seas 10 and 11

The *Rockall Trough and Bank* (10) and *Atlantic North West Approaches* (11) Regional Seas are deep-sea regions west of the Scottish continental shelf. Regional Sea 10 is bounded to the east by the 1000m depth contour and to the west by the 1000m depth contour on the western edge of the Rockall Bank, while Regional Sea 11 extends west of this beyond the UKCS. The seabed supports a different faunal community to that observed at depths less than 1000m, and is mainly composed of muddy sand and mud, with clay mud present in the deep waters to the west. In shallower water, on Rockall Bank and the seamounts, the fauna is likely to be similar to those found at the western edge of the Scottish continental shelf. The waters of these regions are totally oceanic in origin with negligible inputs of material of a terrestrial origin and little seasonal change in primary productivity. Turbidity is very low. Waters are cooler in Regional Sea 11 due to an influx of south flowing Arctic water.

Compared to UK shelf waters, information on the natural environmental of Regional Seas 10 and 11, particularly the latter, is sparse. Known key features include a diversity and abundance of cetaceans, including several large baleen whales species and deep diving species. Evidence suggests that this area represents a migratory route for a number of cetacean species. Several seamounts are present which are known to contain extensive reef habitat, including cold-water corals. In the far northeast of the region lies the Wyville Thomson Ridge possible SAC, and the Darwin Mounds candidate SAC. In the far west of Regional Sea 10 lies the North West Rockall Bank draft SAC. Moderate levels of fishing effort by UK vessels occur over topographical rises in the area, such as the Anton Dohrn seamount and Rockall Bank; these features are also fished extensively by non-UK vessels.

4.3 Relevant existing environmental problems

The SEA Directive requires consideration of 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 problems described in Table 4.1 were identified during preparation of the environmental baseline (Section 4.2 and Appendix 3). No judgement of importance should be inferred from the position of problems/issues in the table. The location of supporting data is signposted in Table 4.1.

Table 4.1 – Environmental problems relevant to offshore oil & gas licensing and wind leasing

Problem	Supporting data	Implications
Potential for near-shore earthquakes	In the North Sea as a whole the expected frequency of occurrence for a magnitude 4 or greater seismic event (sufficient to cause structural damage to developments tied to the seabed) is between 2 and 14 years, and highest peak ground acceleration hazard in UK offshore waters is attained in the northern North Sea. The English Channel is subject to moderate seismic activity with historically few large (>5.5ML) events. An earthquake of 5.2ML or greater may be expected once in 100 years. A number of earthquakes of 5.0-5.9ML magnitude have been experienced in and around the Irish Sea, primarily centred on the Lleyn Peninsula and around Anglesey (Menai Straits fault zone). The most recent event here was recorded in 2005 (2.8ML), with a larger event (5.4ML) having taken place in 1984. Five earthquakes of sufficient magnitude to cause structural damage to developments tied to the seabed have been recorded in the nearshore of Regional Seas 7 and 8 since 1970. None recorded on the outer Hebrides Shelf or further to the west, and few of significant magnitude, are recorded in the wider Regional Sea 8 area. **Further information:** Appendix 3b. EQE International Ltd. (2002), Hitchen *et al.* (2003), Holmes *et al.* (2006), Musson & Winter (1997), Jackson *et al.* (2004).	For oil and gas related activities, potential blocks should be reviewed and the licensee made aware of any activity. Similarly wind leasing sites should be reviewed and the operator made aware.
Instability of Continental Slopes	Steeply sloping areas of the Continental shelf pose geohazards to offshore operations. The eastern margin of Rockall Bank has a steep upper slope which is an area of heavily incised bedrock outcrop. Evidence of landsliding on mid-lower slope. The Faroe-Shetland Channel displays seabed features including landslides and debris flows. **Further information:** Appendix 3b. Long *et al.* (2004), Jacobs (2006)	Ensure awareness. Detailed environmental, oceanographic, and geotechnical studies may be required.
Potential effects of climate change	Potential effects are still not fully known. Large scale climatic and oceanographic processes such as those indicated by changes in the NAO index may affect wave heights and water temperatures. There is some evidence of an increased incidence of stormy conditions. **Further information:** Appendices 3f and 3a. IPCC (2007a), MCCIP (2008)	Maintain awareness of research developments and encourage active participation in relevant research.
Contamination of water and sediments	Existing contamination of sediments and sea water by hazardous substances are concentrated in areas	Review areas to be licensed for oil and gas

Problem	Supporting data	Implications
	close to industrial and population centres, indeed about 80% of marine pollution comes from a variety of land-based activities. Persistent contaminants (e.g. PCBs, PCDD/Fs) and metals tend to accumulate in areas of fine-grained sediments. There is some concern over historical use of oil based drilling muds which are contaminated with hydrocarbons and other toxic compounds – these are largely restricted to the central and northern North Sea and generally in close proximity to drilling and production platforms. Hydrocarbons and other treatment chemicals are discharged to the water column through produced water, although concentrations are highly regulated, low (*ca*. 20mg/l) and continue to decline. Seabed disturbance causing re-suspension of contaminated fine-grain sediment has the potential for pollution to be redistributed over considerable distances in ocean currents. There may also be contamination associated with munitions dump sites although the scale of this potential problem is poorly defined. **Further information:** Appendix 3b.	or offshore wind activities and ensure awareness so that potential activities do not exacerbate problem. Detailed studies may be required to determine risk of pollutant transport.
Introduction of non-native species	Sediments and water in ballast tanks are important vectors for the spread and introduction of invasive planktonic and benthic species. **Further information:** Appendix 3a.1. Edwards (2001), Lindley & Batten (2002), Kennington & Johns (2006)	Ensure licensee awareness. Encourage good practice for vessel management of rigs/support vessels to minimise risk.
Potential climate induced changes to phyto- and zooplankton communities	Considerable increase in phytoplankton colour (production) over the last decade in certain areas of the north east Atlantic. Possible regime shift in all trophic levels of North Sea due to hydro-climatic variations in North Sea inflow. Large-scale reorganisation in zooplankton communities detected. **Further information:** Appendix 3a.1. Lindley & Batten (2002)	Maintain awareness of research developments and encourage active participation in relevant research.
Damage to important benthic habitats	Widespread damage to sessile organisms (e.g. corals and sponges) caused by the trawls of commercial fishing vessels has been observed on the shelf edges of Ireland, the UK and Norway, and on the Darwin Mounds cSAC. Trawling may affect benthic communities through preferential destruction of certain types due to fishing methods (e.g. large, fragile, long-lived species over more robust types). Aggregate extraction removes habitat and destroys fauna, though areas are typically recolonised, often with communities different to that prior to	Review areas to be licensed for oil and gas or offshore wind activities and ensure awareness so that potential activities do not exacerbate problem.

Problem	Supporting data	Implications
	disturbance. General diffuse contamination from large population centres, agriculture and industry may have had a wide range of ecological effects. **Further information:** Appendix 3a.2. Newell *et al.* (1998), OSPAR (2000), Dieter *et al*. (2003)	
Fishing and changes to fish communities	The mixed nature of the demersal trawl fisheries in the North Sea leads to high numbers of unwanted, low-value or immature fish being caught – these fish will be discarded. Sufficient levels of fishing effort can lead to stock decline and a change in trophic status as large, predatory species are removed, favouring short-lived organisms from lower trophic levels such as small, planktivorous fish and invertebrates. Some marine mammal species, notably harbour porpoise and some dolphins, are susceptible to fishing bycatch, particularly by gill and tangle nets. Fishing activity (particularly beam trawling) causes damage to seabed habitats and benthic invertebrates. **Further information:** Appendix 3a.4. Pauly *et al*. (1998).	Review areas to be licensed for oil and gas or offshore wind activities and ensure awareness so that potential activities do not exacerbate problem.
Fish sensitivity to disturbance and contamination	Hydrocarbon contamination can influence the activity of certain enzymes in the liver of fish. Drill cuttings are a potential source of contamination. Biological responses to deleterious levels of contamination have been observed in sandeel and gadoid larvae. It has been observed that cod and haddock are not significantly affected by locally elevated PAH concentrations surrounding platforms in Norwegian waters. A more significant source of contamination in the southern North Sea is that of riverine discharge. There is evidence indicating seismic shooting has a significant effect of the distribution and local abundance of cod and haddock around the source of activity. Such noise has also been shown to cause physiological damage and has the potential to disrupt spawning events which may impact on recruitment to the stock. **Further information:** Appendix 3a.4. Stagg & McIntosh (1996), Engas *et al*. (1993).	Review areas to be licensed for oil and gas or offshore wind activities and ensure awareness so that potential activities do not exacerbate problem.
Vulnerability of seabirds and coastal waterbirds to pollution and disturbance from shipping and industry	Significant populations of seabird and waterbird are found in colonies at the coast of each Regional Sea, often recognised as supporting populations of international importance, albeit in breeding or overwintering populations. Shelf and coastal waters around important seabird colonies, many of which are designated as SPAs, are very vulnerable to surface pollution and disturbance.	Review areas to be licensed for oil and gas or offshore wind activities and ensure awareness so that potential activities do not exacerbate problem.

Problem	Supporting data	Implications
	Many shallow inshore areas contain important aggregations of diving waterbirds such as divers, ducks and grebes. These areas provide key feeding grounds for large numbers of birds during winter, and also during summer for birds breeding on neighbouring land masses, and are particularly vulnerable to surface pollution and disturbance. **Further information:** Appendix 3a.6. Barton & Pollock (2005), Pollock & Barton (2006).	
Marine mammal sensitivity to disturbance, contaminants and disease.	Disturbance is related to existing and any future offshore development activities (e.g. shipping, oil and gas exploration and development, renewable energy development, sonar and explosions), the magnitude and frequency of which differs greatly. Activities are spatially variable, though noise will certainly be concentrated in areas of renewable energy development utilising pile driving, and oil and gas exploration activities using seismic survey methods, principally the North Sea, Irish Sea and west of Shetland. Marine mammals particularly vulnerable to disturbance include: small resident/semi-resident populations with limited ranges; some populations of large whales not yet recovered from the effects of past commercial whaling; deep-diving species which are difficult to detect visually and of which little is known. Marine mammals are exposed to a variety of anthropogenic contaminants, primarily through the consumption of prey which may lead to the bio-accumulation of persistent organic pollutants and heavy metals in affected animals. Sufficient contaminant loads may lead to a variety of sub-lethal and lethal effects. A range of diseases and conditions have been reported in marine mammals, in addition to heavy parasite burdens. Harbour seals have suffered two viral epidemics (PDV), in 1988 and 2002, causing considerable mortality; most colonies have continued to show declines since 2002 despite the absence of PDV. **Further information:** Appendix 3a.7. Hammond *et al*. (2006, 2008).	Maintain awareness of research developments. Review potential blocks to be offered and ensure licensee awareness so that potential activities do not exacerbate problems.
Effects of marine litter, fishing and boat strike on marine reptiles	Turtles may mistake plastic objects for gelatinous prey which, when swallowed, can affect further feeding, diving and reproduction, leading to increased mortality. Turtles may also become entangled in discarded fishing gear and ropes used for pot fisheries. Turtles regularly surface and may be prone to boat collision and propeller damage.	Review areas to be licensed for oil and gas or offshore wind activities and ensure awareness so that potential activities do not exacerbate problem.

Problem	Supporting data	Implications
	Further information: Appendix 3a.5. Pierpoint (2000)	
Unfavourable condition of conservation features and sites.	Over the period 1999-2005, the national conservation agencies carried out a programme of monitoring the designated features of A/SSSI, SACs, SPAs and Ramsar sites (http://www.jncc.gov.uk/page-3521). 57% of A/SSSI sites were reported as in favourable condition, with 37% of SACs, 86% of Ramsars and 73% of SPAs reported as favourable. 60.3% of UK marine and coastal habitats were reported as favourable. Regional Sea specific details are not available, though the following general comments may be made. The features which are least favourable are often being impacted by factors which operate outside the sites on which they are designated (e.g. drainage conditions for some isolated wetlands, pollution) which require concerted effort by many agencies. **Further information:** Appendix 3j.	Review areas to be licensed for oil and gas or offshore wind activities and ensure awareness so that potential activities do not exacerbate problem.
Possible disruption of landscape/seascape due to developments visible from the coast	Water depth restrictions of current technologies may make for the siting of some wind farm developments in areas visible from the coast a likely prospect. Issues are likely to arise where advantageous siting of turbines coincides with areas considered to have a low capacity to absorb the visual impact of a development either due to the natural characteristics of that area, or the potential for cumulative effects. **Further information:** Appendix 3c. Hill *et al.* (2001), DTI (2005), Scott *et al.* (2005), CCW (2008a, b).	Ensure licensee aware of regional seascape studies and areas of particularly low capacity to offshore developments visible from the coast.
Changes to UK countryside	The structure of the flora of the open countryside of the UK shows a long-term (1978-2007) decrease in species richness of 9.2%, with an accompanying increase in competitive and stress resistant types. 'Managed' Hedgerows continue to decline in length and reduced by 6% between 1998 and 2007. Changes in the carbon content of soils may have some influence on greenhouse gas related climate change, and though there has been no net change in soil carbon content between 1978 and 2007, there was a decline between 1998 and 2007. Non-native plant species account for nearly 2% of the vegetation cover of the countryside. There are local impacts from road building and urban expansion which in some areas are changing the character of the countryside. **Further information:** Carey *et al*. (2008), The Countryside Survey (2007).	Aim for any associated onshore infrastructure to minimise footprint and adverse effects
Impact of air quality on	Though the UK's terrestrial air quality is generally	Ensure licensee

Problem	Supporting data	Implications
human health and the environment	improving there are still areas which do not meet current exceedance levels for pollutants, primarily NO_2, SO_2 and PM_{10}s. SO_2 and NO_2 are known to be involved in acid deposition and the human health effects of particulates are still poorly understood. **Further Information:** Appendix 3e.	awareness so that potential activities do not exacerbate problem.
Possible disturbance of features of submerged cultural heritage	There is an increasing awareness of submerged archaeological material located for example in the southern North Sea, though their distribution is speculative. These areas are vulnerable to offshore operations which disturb the seabed (drilling, piling, cabling). **Further information:** Appendix 3i. Flemming (2004b), Gaffney *et al.* (2007).	Ensure licensee aware of areas of potential heritage value.

4.4 Likely evolution of the baseline

Given the extent of the SEA area, and the difficulty in defining quantitative indicators of the likely evolution of the environmental baseline, a qualitative approach has been adopted.

Table 4.2 highlights how key aspects of the environment (as described in Appendix 3) may evolve in the absence of further offshore wind farm leasing and oil and gas licensing. The location of relevant information in Appendix 3 is signposted as are relevant reports.

Table 4.2 – Likely evolution of the baseline

Likely evolution of baseline
Biodiversity, habitats, flora and fauna
Plankton
Plankton ecology is closely coupled with environmental factors. Oceanic inflows and climatic conditions, both linked to the North Atlantic Oscillation (NAO), correlate with changes observed in plankton communities in the northeast Atlantic over recent decades. An increase in phytoplankton biomass recorded since the mid 1980s has been positively correlated with sea surface temperature (SST) and wind strength. North Atlantic inflows to the North Sea may affect plankton communities, and have been linked to the increase in the ratio of *Calanus helgolandicus* to *C. finmarchicus* over the last 20 years. There have been widespread changes in the zooplankton community and in the timing of phytoplankton blooms, with wider consequences throughout the ecosystem. **Further information:** Appendix 3a.1, Beaugrand (2003), Edwards *et al*. (2002, 2007).
Benthos
Over the past ca. 11,000 years, seabed habitats around the UK have been subject to continuous processes of change associated with post-glacial trends in sea level, climate and sedimentation. In the shorter term, seasonal, inter-annual and decadal natural changes in benthic habitats, community structure and individual species population dynamics may result from physical environmental influences (e.g. episodic storm events; hydroclimatic variability and sustained trends) and/or ecological influences such as reproductive cycles, larval settlement, predation, parasitism and disease. Long-term changes in benthos composition have been linked to natural (e.g. hydrodynamic factors) and anthropogenic impacts (e.g. fishing, eutrophication), and analysis of North Sea benthos indicates an increase in biomass and opportunistic short-lived species, and a reduction in long-lived sessile organisms. There is reasonable evidence of a regime change in the North Sea in the period 1982-88, indicated by

Likely evolution of baseline
phytoplankton, zooplankton, benthic biomass, fish spawning stock biomass and fish recruitment. The regime shift may have been brought about by a change in hydro-meteorological forcing, a displacement of oceanic biogeographical boundaries to the west of the European continental shelf and an increase in oceanic inflow to the North Sea. Climatic processes influence species composition of seabed communities which will alter the availability of food for certain fish (e.g. cod) and shellfish populations (e.g. *Nephrops*). **Further information:** Appendix 3a.2, Kaiser & Spence (2002), Beaugrand (2004), Weijerman *et al.* (2005), van Nes *et al.* (2007).
Cephalopods
Although the biology and ecology of many cephalopods is little known, temperature is thought to have an important influence on the recruitment, migration and distribution of some species. There is a trend of decreasing numbers of *Loligo forbesii* in the south of its range and increasing numbers in the north, associated with SST. This has also been linked to the winter abundances of *L. forbesii* in the North Sea and the distribution of *Alloteuthis subulata* in the Irish Sea. **Further information:** Appendix 3a.3, Hastie *et al.* (2008).
Fish
As well as coming under severe pressure from anthropogenic factors, fish communities are likely to be affected by future climate change, which may influence the abundance, distribution, recruitment and migration of species. This could have a major effect on the community structure of the region. Abundances of herring have been linked to cooler winters, with sardines more abundant following warmer winters. The distributions of two-thirds of North Sea fish species have shifted mean latitude in the past 25 years, with a typically northern shift in population boundaries. Species regarded as having a characteristically southerly distribution are increasing in abundance in UK waters. Cod stocks may have completely depleted in the Irish and Celtic Seas by 2100 due to temperature and hydrodynamic changes. SST is thought to influence the recruitment of cod, whiting and mackerel in the North Sea. A changing climate is also likely to affect migration routes of some species. There has been a northerly shift in the mackerel spawning grounds and a change in the timing of adult migration into these grounds. The navigation of salmon and other migratory fish back to home rivers may be severely affected as it relies on a range of environmental cues, potentially affecting recruitment success. Shellfish populations are often tied to particular sediment types and so distributions of these species may be relatively stable. However, the settlement of many bivalve species is dependent on environmental factors and so changes in water temperature, wind strength and current direction may result in altered stock recruitment. Certain fish stocks are subject to considerable fishing pressure in UK waters. The impact of fisheries has had a role in changing the species dominance by the removal of large fish and overfishing will tend to result in a decrease in the mean trophic level of the fish community, but an increase in diversity. **Further information:** Appendix 3a.4, Perry *et al*. (2005), Beare *et al*. (2004).
Marine reptiles
The 15°C isotherm largely determines the range of leatherback turtles, and the average summer location of this isotherm in the northeast Atlantic has moved north by several hundred kilometres over the past two decades. Additionally, the distribution of jellyfish prey species, such as *Rhizostoma*, has been linked to leatherback sightings; as ocean temperatures continue to rise it is expected that gelatinous species will move further north. Warmer temperatures and greater occurrence of gelatinous species in UK waters is likely to result in an increasing and more widespread occurrence of leatherback turtles; however, no such trend is apparent from turtle sighting and stranding records over the past 10 years. **Further information:** Appendix 3a.5, McMahon & Hays (2006), Purcell *et al.* (2007).
Birds

Likely evolution of baseline
One of the variables that strongly affect seabird demography is food: its availability, abundance and distribution. Climate and fishing are two primary drivers behind the availability of seabird prey; with changes in the characteristics of either of these having considerable effects on seabird populations. Recent years have seen a series of generally poor years for breeding seabirds. Throughout most of the UK, breeding seabirds were only slightly more successful in 2006 than they were in 2004 and 2005, which were the worst seasons on record. In 2004 widespread breeding failures occurred in the Northern Isles and in places down the east coast of Britain. The failures were thought to have been caused largely by low availability of sandeels; this was again the case in 2005, with sandeels being less prevalent than usual in the diets of many species or, if still prevalent, of the less-preferred size-class. Observers at many seabird colonies throughout Britain reported a later than average breeding season in 2006; feeding conditions again appeared to be less than ideal, with most species probably affected by a shortage of food. On longer-term trends, the Seabird 2000 project showed that since the mid-late 1980s contrasting trends have been evident in populations of seabirds breeding in Britain and Ireland. Within species, different trends have also been seen among regions. For the UK overall, species showing an increase in breeding numbers since the mid-late 1980s included: gannet, cormorant, great skua, common gull, lesser black-backed gull, guillemot, black guillemot (marginal), razorbill and puffin. Species showing a decrease in breeding numbers over the period included: fulmar (marginal), shag, Arctic skua, herring gull, great black-backed gull (marginal), kittiwake, sandwich tern, roseate tern, common tern, Arctic tern and little tern; no change was observed for black-headed gull. Over the last three decades, many waterbird species have increased in numbers, however, declines are beginning to be detected in species such as dark-bellied Brent goose, shelducks, ringed plovers and turnstones. These species are regularly found in one or more of the Regional Sea areas, and with the exception of turnstone which occurs at sites in Britain in nationally important numbers, the remaining species occur at sites in internationally important numbers. **Further information:** Appendix 3a.6, Mitchell *et al*. (2004), Austin *et al*. (2008).
Marine mammals
Data on cetaceans are typically few and often characterised by considerable uncertainty and both seasonal and spatial gaps, making the identification of trends very difficult. It is even more difficult to establish any causes of potential trends, although it is noted that most large whale populations are still recovering from the era of industrial whaling. Responses of marine mammals, both at individual and population levels, to climate change are currently poorly understood; potential impacts which have been suggested to date include range shifts, changes in physical habitat, changes to food webs and increased susceptibility to contaminants. Increasing temperatures and greater presence of southern fish species in the central and northern North Sea may lead to an increasing occurrence of southern marine mammal species. This could also cause species with affinities for cooler waters to undergo a northward shift in distribution. Additionally, prey distribution and abundance can show considerable variation in response to fisheries exploitation; this is likely to have knock-on effects on marine mammals which predate on the exploited fish populations. After many years of increases, evidence suggests that grey seal populations are generally stabilising. Declines in harbour seal populations have been experienced throughout most major colonies in Britain, with the exception of those on western Scotland. Outbreaks of PDV in 1988 and 2002 were responsible for considerable declines in harbour seals on the east coast of England. In most colonies, declines have continued since 2002, with some colonies showing evidence of decline prior to 2002; the reasons behind such significant and widespread declines are not clear. **Further information:** Appendix 3a.7, Thompson *et al*. (2005), Lonergan *et al*. (2007), Evans *et al*. (2008), MCCIP (2008), Pesante *et al*. (2008a,b).
Sites and species of nature conservation importance
The UK has an extensive suite of coastal conservation sites to protect and promote the conservation

Likely evolution of baseline
value of a variety of features; however, the potential exists for new sites (particularly those with marine components) to be identified and designated, along with opportunities for modification to the boundaries of existing sites. Such new sites and modifications occur in the light of new information, legislation or changes in the relative importance of features at international, national or local levels. Issues affecting the integrity of coastal sites, including SACs and SPAs, are considered on an individual site-by-site basis, with management plans in place to maintain or improve site integrity, typically carried out in association with conservation bodies, land owners and other stakeholders. Five candidate SACs have been identified in UK waters, further UK consultations and submissions of offshore SACs to the EC are expected to take place from 2009-2010. Work to identify marine SACs within English territorial waters is ongoing, with consultation of a range of sites to take place in 2009. Seaward extensions to existing seabird SPAs have been identified; their full designation is currently most advanced in Scotland, where they underwent consultation in 2008. Public consultation on inshore and offshore aggregations and other types of SPA are expected to take place from 2010-11, with site designation in 2012. The Marine Strategy Directive through the *Marine and Coastal Access Bill* will introduce further requirements for the identification and designation of Marine Conservation Zones (known as Marine Protected Areas in Scotland), which will afford protection to individual habitats and species, and also broader ecosystems. The evolution of the baseline with regard to specific species of conservation interest is described in detail in Appendices 3a.1-7. **Further information:** Appendices 3i and 3a.1-7.
Geology and sediments
The large-scale geology of the UKCS is controlled by geological and geomorphological processes which operate over eons. At a local level, the distribution of sediments and sediment bedforms is largely a result of bottom currents and wave action which are tied into large scale oceanographic, geographic and climatic processes, and in some cases structures are part of relict bedforms dating back to the last glaciation, or are more recent structures formed by leaking gasses/fluids. Therefore, the environmental baseline is likely to evolve slowly in the absence of anthropogenic influences. At present there are no anthropogenic activities which are likely to cause significant regional scale changes to geology and sediments, though trawling and dredging activities can generate localised scour and sediment plumes. Historically, large quantities of a variety of contaminants have been discharged into the UK near-shore marine environment, primarily through riverine and other point-source discharges in the vicinity of urban and industrial centres. However, inputs have decreased dramatically in recent decades. Widespread monitoring of UK coastal waters and sediments show that for only a very limited number contaminants do levels exceed those where harm to biota may occur, and these are restricted to a few inshore and estuarine areas (notably Liverpool Bay and the Thames estuary). Offshore areas and those remote from urban and industrial centres generally exhibit contamination levels at or close to background. While contamination in close proximity to some offshore platforms exists from the historical use of oil-based drilling muds, monitoring shows concentrations of organic components to be progressively reducing over time. Additionally, oil concentrations in produced water are at an all time low and are expected to continue to fall. **Further information:** Appendix 3b, Balson *et al.* (2002), Holmes *et al.* (2003, 2005, 2006), Jacobs (2006), OSPAR (2000a, b, c).
Landscape/Seascape
Previous offshore developments in UK waters have primarily been in relation to North Sea oil and gas installations where the only representation of such developments at the coast or on land was in the form of cable and pipe landfall and associated infrastructure (with exceptions including Beatrice in the Moray Firth, exploration wells sites off Dorset and Cardigan Bay and structures in the east Irish sea). Round 1 and 2 offshore wind farms are generally clearly visible from land. There is a reasonable likelihood of major landscape effects from coastal and terrestrial wind generation projects and continued industrial and urban expansion.

Likely evolution of baseline
Further information: Appendix 3c.
Water environment
The environmental baseline is likely to be affected by large scale climatic and oceanographic processes. Variations have been observed in North Atlantic and North Sea circulation patterns in the past few decades which are likely to influence sea surface temperatures. Increased wave heights have been observed in the western and northern UK waters and wave heights in the north-east Atlantic and northern North Sea are known to respond strongly and systematically to the North Atlantic Oscillation. At a local level, topography often interacts with these principal forces, focusing currents and leading to the generation of amplified current flow or eddies. At present there are no local anthropogenic activities within the UKCS area that are likely to change significantly the physical properties of the water environment, though the pH of the world's oceans has been declining due to CO_2 uptake from anthropogenic sources. It can be expected that in the wider environment, global sea-levels may rise by *c.* 1-2mm per annum. **Further information:** Appendix 3d, Cunningham (2007), Holliday *et al*. (2007), Turley (2007), Woodworth & Horsburgh (2007), Woolf & Coll (2007).
Air quality
Air quality is spatially variable, with quality generally increasing to the north where industrial development is sparser and population centres smaller and more dispersed. Air quality is likely to improve as a corollary to a push in the reduction of emissions set out in the renewed Air Quality Framework Directive (2008/50/EC) and its implementation in UK law. Increased renewable energy use and improved efficiency in conventional transport methods (e.g. diesel engines) are likely to make substantial contributions to key emissions associated with environmental and human health issues. **Further information:** Appendix 3e, DEFRA (2007).
Climatic factors
At continental, regional, and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in Arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones. Future trajectories are uncertain, but UK specific scenarios based on current information are presented in the most recent work by UKCIP. **Further information:** Appendix 3f, IPCC (2007), MCCIP (2008), http://www.ukcip.org.uk/ .
Population and human health
The population density and human health of the UK is unlikely to change considerably in the near future. In the UK as a whole, population increased by 4.4% from 1996-2006 and is expected to increase by a further 7.3% in the years leading up to 2016, with growth being most significant in areas adjacent to Regional Seas 2 and 4, and least in Regional Sea 6. **Further information:** Appendix 3g.
Material assets (infrastructure, other natural resources)
Existing marine activities include (in no particular order) shipping and port activities, military exercises, fishing, recreational sailing, oil and gas exploration and production, aviation and offshore wind farm construction and operation. Port activities have been continuously expanding, particularly in the last 5 years and associated with this expansion, shipping tonnage has also increased. The fishing industry is dynamic with frequent and sometimes unpredictable changes in fish abundance and distribution, climatic conditions, management regulations and fuel costs all affecting activity. Consequently the baseline is rapidly evolving. In general, the fishing industry has been in decline in recent years in terms of numbers employed, vessels at sea and catch, and in coming years technical developments, economics, changes in management strategy and changes in target species, abundance, composition and distribution are all likely to be important. A number of demonstrator wave and tidal power electricity generation devices have been deployed which may lead to commercial scale developments in the future. Similarly there are a number of proposals under consideration for the development of

Likely evolution of baseline
barrages or lagoons to harness tidal power for renewable electricity generation. There is the potential for use of offshore geological features for carbon capture and storage, a proportion of which may use some existing oil and gas infrastructure for CO_2 transport and geological injection. The Marine and Coastal Access Bill/draft Scottish Marine Bill is likely to be important in determining future evolution in UK waters as it will put in place a system for delivering sustainable development of the marine and coastal environment and will address both the use and protection of marine resources. **Further information:** Appendix 3h.
Cultural heritage, including architectural and archaeological heritage
The development of increasingly sophisticated detection methods, mapping, and underwater excavation means that the recovery of archaeological information is increasingly likely. Visitor pressure is potentially having a deleterious effect on many coastal heritage sites, for instance St Kilda World Heritage Site, and these are identified in management plans for this and other areas. **Further information:** Appendix 3i, Flemming (2004b), Gaffney *et al.* (2007), Wessex Archaeology (2008c).
Onshore
The Countryside Survey 2007 (Carey *et al*. 2008) indicates general trends in the physical and ecological (flora) structure of 'broad habitats' (e.g. Broadleaved Woodland, Improved Grassland, Neutral Grassland) constituting the countryside of England, Scotland, Wales and Northern Ireland. Structural changes include a 6.2% reduction in hedgerow length (and a 1.7% reduction in the overall length of woody linear features) and a 9.1% reduction in arable land between 1998 and 2007. Much of the lost arable land has been given over to grassland, and agricultural set-aside has contributed to the increasing diversity (30% between 1998 and 2007) of arable land. Broadleaved woodland has increased by 6.9% between 1998 and 2007, though there has been no significant change in coniferous woods. Bracken habitat lost an area of 17.4% between 1998 and 2007, partly due to an increase in acid grassland. There was no significant change in dwarf shrub heath, bog, fen, marsh, swamp or calcareous grassland between 1998 and 2007. The acidity of soils was observed to fall between 1978 and 2007, probably in response to reduced emission and deposition of sulphur, but perhaps also due to the application of lime and organic fertilisers in enclosed farmland. The carbon content of soil was also observed to reduce by 6% which may contribute to greenhouse gas induced climate change. A link between climate change and the UK flora cannot be reliably established, but there has been an increase in plant species casting and preferring shade, and those adapted for wetter conditions. There was no apparent change in the level of urban development including new buildings, roads and trackways between 1998 and 2007 in contrast to between 1984 and 1998, though the random sampling regime employed by the Countryside Survey does not resolve local changes particularly well which may account for this result. **Further information:** Carey *et al*. (2008), The Countryside Survey (2007).

5 ASSESSMENT

5.1 Assessment approach and methodology

This SEA covers an enormous marine area comprising all UK waters with water depth from the intertidal to more than 2,400m. The draft plan/programme includes both hydrocarbon and renewable energy based elements. The assessment therefore has to address complex issues and multiple interrelationships, where a simplistic score based matrix assessment would be inadequate. Following discussion with the SEA Steering Group an evidence based consideration was agreed. In addition, significant use has been made of Geographical Information System (GIS) tools to collate, process, analyse and present spatial information.

The assessment for this SEA is a staged process (Figure 5.1) incorporating inputs from a variety of sources:

- Baseline understanding of the relevant receptors (including other users) grouped according to the SEA Directive (see Environmental Baseline, Appendix 3 and Section 4 and the range of underpinning technical reports produced for the SEA process) together with existing environmental problems and the likely evolution of the baseline conditions.

- The likely activities, and potential sources of effect (see Box 5.1) and the existing mitigations, regulatory and other controls (see Appendix 5).

- The evolving regulatory framework

- The evolution of technology

- The SEA objectives (see Section 3).

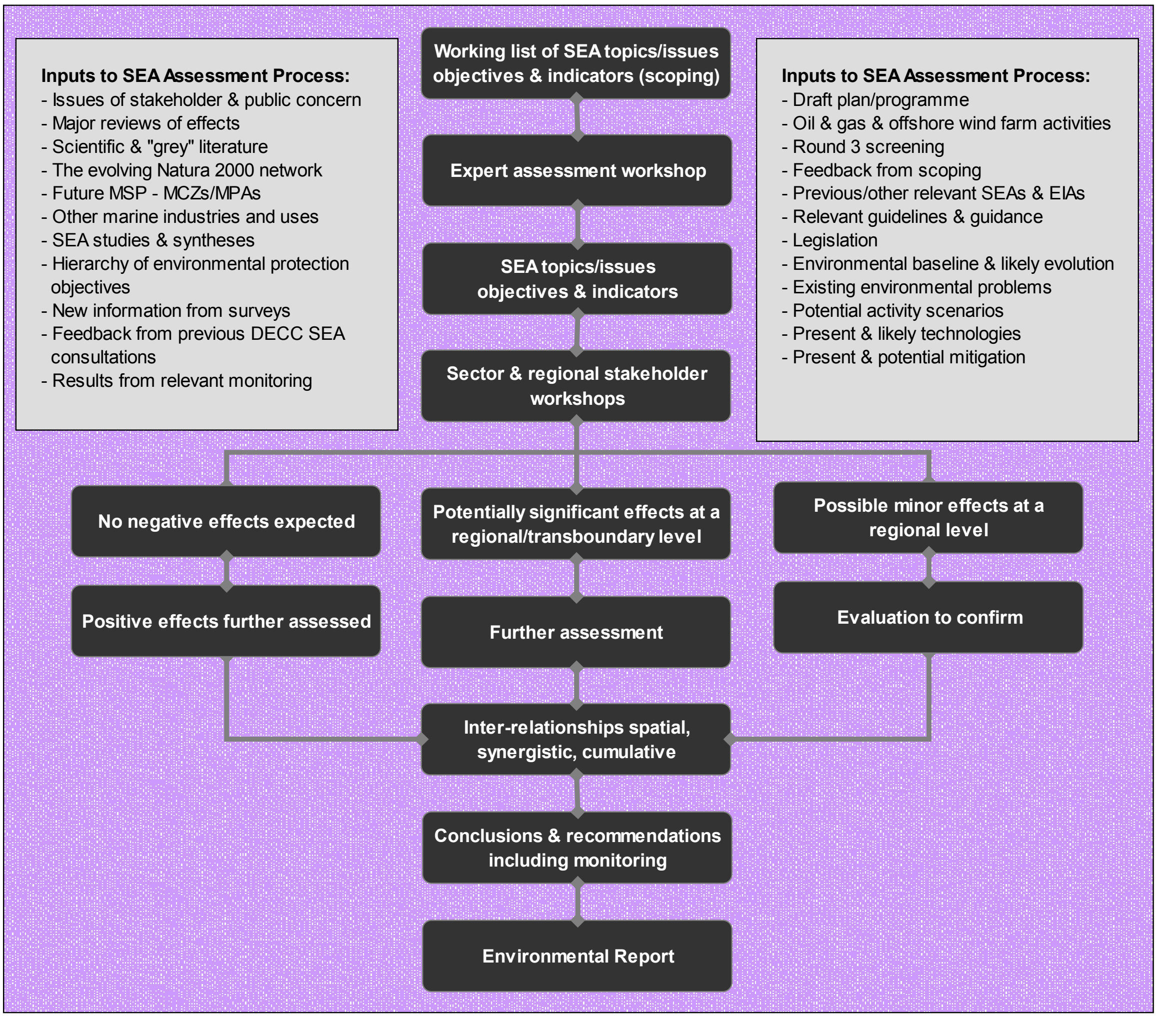
- The evidence base regarding the relative risks and potential for significant effects from offshore wind farm, offshore oil and gas exploration and production and gas storage related activities

- Steering Group, statutory consultee and stakeholder perspectives on important issues, information sources and gaps, and potential areas to exclude from licensing derived from scoping, assessment workshop, regional stakeholder workshops, sector workshops, meetings and other communications – see Appendix 1 and 2.

At a strategic level, a distinction has been drawn for various effect mechanisms between impacts which may be significant in terms of conservation status of a species or population (and hence are significant in strategic terms), and impacts which may be significant to individual animals, but which will not influence sufficient numbers to have a significant effect on population viability or conservation status (and hence strategically significant).

Examples of this approach include the consideration of acoustic effects on marine mammals, collision risk for birds and oil spill effects. This approach does not imply that mortality or sub-lethal effects on individual animals are unimportant (clearly there are welfare considerations, particularly for avian and mammalian species); but it is appropriate that strategic considerations are made at a biogeographic population or species level – as is done for example, in the selection of qualifying features for Natura 2000 sites.

Figure 5.1 – Assessment process



5.2 Potential sources of effect

5.2.1 Sources of potentially significant effect

Potential sources of effects from the activities which could follow adoption of the draft plan/programme have been variously discussed with the SEA Steering Group and stakeholders (see Appendix 1 & 2) in terms of the likely significant effects on the environment, including on the SEA topics – these are listed in the box below. A questionmark indicates uncertainty of potential for effect.

Box 5.1 **Sources of potentially significant effect**	**Oil & Gas**	**Gas Storage**[1]	**Offshore Wind farms**
SEA Topic Biodiversity, habitats, flora and fauna			
Physical damage to biotopes from infrastructure construction, vessel/rig anchoring etc	X		X
Potential behavioural and physiological effects on marine mammals, birds and fish associated with seismic surveys	X	X	
Potential behavioural and physiological effects on marine mammals, birds and fish associated with construction noise	X		X
Potential behavioural and physiological effects on marine mammals, birds and fish associated with operational noise	X	X	X
Potential for non-native species introductions in ballast water discharges	X		
Behavioural disturbance to fish, birds and marine mammals etc from physical presence of infrastructure and support activities	X	X	X
Collision risks to birds			X
Barriers to movement of birds (e.g. foraging, migration)			X
Potential for effects on flora and fauna of produced water and drilling discharges	X	X	
EMF effects on fish			X
Major oil spill risks and associated damage to species, habitats and ecosystem function	X		?[2]
SEA Topic Geology and sediments			
Physical effects of anchoring and infrastructure construction (including pipelines and cables) on seabed sediments and geomorphological features (including scour)	X		X
Sediment modification and contamination by particulate discharges from drilling etc	X	X	
Effects of reinjection of produced water and cuttings	X		
Onshore disposal of returned wastes – requirement for landfill	X	X	
Post-decommissioning (legacy) effects – cuttings piles and footings	X		X
Risk of sediment contamination from oil spills	X		
SEA Topic Landscape/seascape			
Potential visual impacts and seascape effects of development including change to character	X		X
SEA Topic Water environment			
Contamination by soluble and dispersed discharges	X		
Risk of contamination of the water column by dissolved and dispersed hydrocarbons from oil spills	X		
SEA Topic Air quality			
Local air quality effects resulting from exhaust emissions, flaring and venting	X	X	
Air quality effects of a major gas release or volatile oil spill	X	X	
SEA Topic Climatic factors			
Contributions to greenhouse gas emissions	X	X	

Box 5.1 **Sources of potentially significant effect**	Oil & Gas	Gas Storage[1]	Offshore Wind farms
Reduction in greenhouse gas emissions			X
SEA Topic Population Human health			
Positive socio-economic effects of potential activities, in terms of security of supply, employment, expenditure and tax revenue[3]	X	X	X
Positive socio-economic effects of reducing climate change[3]			X
Potential for effects on human health associated with			
- effects on local air quality resulting from atmospheric emissions	X	X	
- discharges of naturally occurring radioactive material in produced water	X	X	
- potential food chain effects of major oil spills	X		
SEA Topic Other users of the sea, infrastructure, material assets & natural resources			
Interactions with fishing activities (exclusion, displacement, seismic, gear interactions, "sanctuary effects")	X	X	X
Other interactions with shipping, military, potential other marine renewables and other human uses of the offshore environment	X	X	X
Socio-economic consequences of oil spills	X		
SEA Topic Potential effects to known or postulated archaeological heritage			
Physical damage to biotopes from infrastructure construction, vessel/rig anchoring etc	X		X
The Interrelationship between issues – Spatial, Cumulative and Transboundary issues			

Notes: 1 Assuming use of existing infrastructure
2 Via shipping collision risks
3 Outline assessment only

5.3 Noise

5.3.1 Introduction

Previous SEAs have considered the potential for acoustic disturbance by noise generated by offshore wind farms (Round 2 SEA) and by hydrocarbon exploration and production activities (SEAs 1-7). In general, marine mammals show the highest sensitivity to acoustic disturbance, and the severity of potential effect has therefore been related principally to marine mammal species composition and abundance in the area under consideration, although effects on fish (including spawning aggregations) have also been considered. For both marine mammals and fish, various effects will generally increase in severity with increasing exposure to noise; a general distinction may be drawn between effects associated with physical injury or physiological effects, and effects associated with behavioural disturbance.

Noise broadly falls into three categories (e.g. Harland & Richards 2006) and its description can be highly technical. Impulsive (pulse) noise is transient in nature and is generally of wide bandwidth and short duration. It is best characterised by quoting the peak amplitude and repetition rate. Continuous wideband noise is normally characterised as a spectrum level, which is the level in a 1Hz bandwidth. This level is usually given as intensity in decibels (dB) relative to a reference level of 1 micro Pascal (µPa). Tonals are very narrowband signals and are usually characterised as amplitude in dB re 1µPa and frequency. Noise levels may also be quoted as zero-peak, peak-peak or root-mean-square (rms) values and a comprehensive introduction to underwater noise measurement in the context of seismic surveys is provided by OGP (2008).

In relation to OWF construction, pile-driving of foundations may also generate high source levels and has been widely recognised as a potential concern, in particular for large developments where many piles may be installed sequentially.

Seismic surveys generate among the highest source levels of any non-military marine activity; the potential for significant effect in relation to oil and gas activities is therefore largely related to the anticipated type, extent and duration of seismic survey. Although less commonly used in recent years, explosive cutting of wellheads or decommissioned structures may also produce high intensity impulsive noise. Pile-driving also occurs in connection with oil and gas facilities, although the pile diameters are smaller than wind turbine monopiles.

The range over which noise propagates (and effects may result) varies with water depth, density stratification, substrate and other factors; and is therefore area-specific. Finally, the sensitivity of species such as marine mammals may be influenced by previous experience (i.e. sensitisation/habituation) and by the level of background ambient noise in the area.

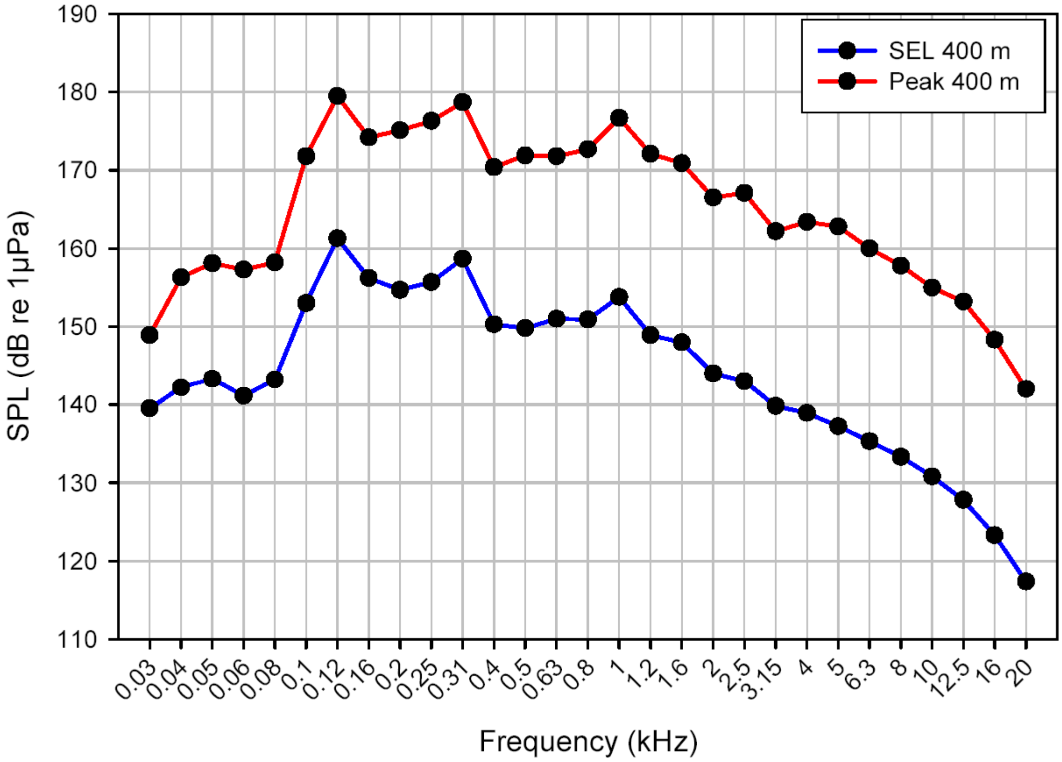
5.3.1.1 Offshore wind farms

Sources of noise associated with offshore wind farms can be considered to fall into two broad categories: construction, particularly of foundations; and operation. Pile-driving of monopile foundations is the principal source of construction noise, which will be qualitatively similar to pile-driving noise resulting from harbour works, bridge construction and oil and gas platform installation. There is now a reasonable body of evidence for wind farm foundation pile-driving (Nedwell *et al*. 2003, Nedwell & Howell 2004, Madsen *et al*. 2006, Thomsen *et al*. 2006, Nedwell *et al*. 2007). Source levels vary depending on the diameter of the pile and the method of pile driving (impact or vibropiling). The frequency spectrum ranges from less than 20Hz to more than 20kHz with most energy around 100-200Hz. Sound produced during pile-driving propagates through the air into water, through the water column and – to a lesser degree – through the sediment and from there successively back into the water column. The single pulses are between 50 and 100ms in duration with 30-60 beats per minute. It usually takes between 1–2 hours to drive one pile into the bottom (Thomsen *et al*. 2006).

McKenzie-Maxon (2000) measured a broadband peak sound pressure level of ~205dB re 1 µPa at 30m distances from the source during pile-driving at Utgrunden, Sweden. The foundation type was a monopile with each pile 34m long and 3m in diameter. Sound exposure levels were measured in 1/3 octave bands at different distances from the source (frequency range = 4–16kHz; distances 30, 320, 490 and 750m).

Elmer *et al*. (2006) and Thomsen *et al*. (2006) report measurements of pile-driving noise as peak sound pressure levels and sound exposure levels in 1/3 octave bands from construction of the FINO-1 research platform in the German Bight, North Sea (jacket-pile, diameter 1.5m, sandy bottom, water depth ~30m; 60 beats per minute). The estimated broadband peak source level was $228dB_{0\text{-}p}$ re 1 µPa at 1m. Third-octave-sound levels were recorded as peak sound pressure levels and sound exposure levels at 400m from the source (Figure 5.2). Sound pressure level was highest at the 125Hz centre frequency ($179.5dB_{0\text{-}p}$ re 1 µPa at 1m) with additional maxima at 315Hz and 1kHz and considerable pressures above 2kHz. Throughout the frequency spectrum, peak levels were about 20dB higher than the corresponding sound exposure levels.

Figure 5.2 - Frequency spectrum (third octave band level) of pile-driving pulse noise at FINO 1-platform; red = $dB_{0\text{-}p}$ re 1 µPa, blue = dB_{AE} re 1 µPa



Source: Thomsen et al. (2006)

Nedwell *et al*. (2007) re-analysed previously reported pile driving data from North Hoyle and Scroby Sands, on piles of 4 and 4.2 metre diameter respectively. The re-analysis includes the effects of sound absorption losses during propagation. Further measurements of pile driving noise were also reported from Kentish Flats during the driving of piles of 4.3m diameter, and at Burbo Bank and Barrow during the driving of piles of 4.7m diameter. The source levels of these five pile driving operations varied between 243 and 257dB re 1 µPa at 1m, having an average value of 250dB re 1 µPa at 1m.

Noise during operation has been measured from single turbines (maximum power 2MW) in Sweden and Denmark and has been found to be of much lower intensity than the noise during construction (reviewed by Madsen *et al*. 2006). The tonal noise from a wind turbine is created by vibrations in the gear-box inside the nacelle, and has both radial and tangential components (see references cited by Madsen *et al*. 2006). The vibrations are coupled to the water column and the seabed through the turbine foundations. Thomsen *et al*. (2006) reported operational noise measured in peak sound pressure levels and equivalent sound pressure levels in third-octave bands at 110m distance from a 1.5MW turbine in Sweden. During operation, the third-octave sound pressure levels ranged between <90 and 142 dB_{Leq} re 1 µPa at 1m, with most energy at 50, 160, and 200 Hz at wind speeds of 12m/s.

The effective noise propagated from an array of operational turbines is less well characterised, although Ingemansson Technology (2003) reported an increased sound level caused by increases in the number of active wind turbines in a wind farm. Nedwell *et al*. (2007) also reported that the level of noise from operational wind farms was relatively low. The noise could be recognised by the tonal components caused by rotating machinery, and by its decay with distance. Typically, even in the immediate vicinity of the wind turbines, the noise from the wind farm turbines only dominated over the background noise in a few limited bands of frequency. Even within this range, the noise was usually only a few dB above the background noise. In some cases, the tonal noise caused by the wind farms was dominated by the tonal noise from distant shipping. In some cases, such as North Hoyle and Kentish Flats, the level of noise measured within the wind farm was slightly greater, by up to 10dB or more, than that measured outside. However, in other cases, such as Barrow and Scroby Sands, the level of noise measured within the wind farm was actually lower than that measured outside.

In general, Madsen *et al*. (2006) note that for additive effects to take place, the sound source levels of the individual sources must be high enough to propagate to ranges at which interference might occur. The interference pattern created by the signals from several wind turbines will create a complex sound field. The received level in some locations may decrease due to negative interference with signals from different wind turbines. Depending on the geometry of the turbines, the received levels within the wind farm and nearby could increase with increasing number of wind turbines at a constant range from the measurement location, depending on the additive nature of the signals.

5.3.1.2 Oil & gas

Noise associated with exploration and production is produced by both continuous and impulse sources and has been discussed, in terms of source characteristics, in previous SEAs and supporting studies (e.g. Hammond *et al*. 2003, 2006). With the exception of explosives, airgun arrays used for seismic surveys are one of the highest energy man made sound sources in the sea; broadband source levels of 248-259dB re 1μPa are typical of large arrays (Richardson *et al*. 1995). Seismic survey duration may extend from a period of a few hours, to several weeks. Smaller sources may be used for specific purposes, including high resolution site surveys and Vertical Seismic Profiling (VSP) or borehole seismic in connection with well operations.

Airgun noise is impulsive (i.e. non-continuous), with a typical duty cycle of 0.3% and slow rise time (in comparison to explosive noise). Most of the energy produced by airguns is below 200Hz, although some high frequency noise may also be emitted. Peak frequencies of seismic arrays are generally around 100Hz; 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.

Airgun arrays are directional and the design, dimensions and orientation of arrays have a substantial influence on received noise pressure in the farfield (i.e. at distances where individual gun sources are not distinguished). A correction factor of 20dB has been suggested as "conservative", to compensate for horizontal array effects (i.e. reduction of effective source levels in the horizontal plane relative to the vertical plane: MMS 2004). Nedwell *et al*. (2003) reported axial directivity of noise from a 3D seismic survey (14 gun array, 3335 cubic inch firing flip-flop) in the northern North Sea of around 10dB; extrapolation of measured sound pressures indicated a source level of 262dB re 1μPa at 1m, higher than expected. This apparent discrepancy was attributed to either non-linear range effects, or to sound trapping in a surface channel. Other reviews have suggested directional correction factors of 10 to >30dB; a value of 15dB has been used in the assessment below.

A significant degree of scattering of measured sound levels, over a range of 10dB, was noted including non-systematic differences between approach and retreat of the array from the measurement location attributed to spatial or temporal inhomogeneities of the sea. Measurement during soft-starts, achieved by gradual increase in the number of airguns being discharged, showed a fairly consistent relationship between the total volume discharged by the array and the resulting level of sound. Frequency-weighting of received sound using an audiogram for harbour porpoise (i.e. emphasising high frequencies) increased the observed scatter in weighted levels, due either to variability in propagation or variability in array characteristics. Nedwell *et al*. (2003) conclude that their results indicate that at the measured range, the effectiveness of the soft start procedure (as perceived by marine mammals) is masked by the random variability in received level.

Sound levels for continuous noise sources are generally defined in terms of root-mean-square (rms) values, broadly equivalent to the average sound pressure over a given time. Although rms values are of little relevance to a periodic impulse sound, such as seismic, virtually all observational data for marine mammal sensitivity to noise (and regulatory criteria, where applicable) are related to rms levels, and conversion from peak-to-peak (p-p) values is therefore necessary.

For an ideal sinusoid, the rms level is 9dB lower than the peak-peak value (Richardson *et al*. 1995). However, seismic and other impulse sources are not ideal sinusoids, and the conversion to rms values is highly dependant on the array duty cycle and integration time. As noted below, the signature of an airgun array also varies with range, due to various factors including multiple reflections and differential frequency propagation, usually resulting in an increase in pulse duration and downward sweep in frequency (or "chirp") – the relationship between p-p and rms levels will therefore also vary. A range of p-p to rms conversion factors have been proposed, although there is very little data in the scientific literature; these range from a theoretical –35dB (based on a theoretical airgun signature, duty cycle 10s) to empirical values of –12 to –18dB for short impulsive sounds without regard to duty cycle (Greeneridge Sciences cited by OGP/IAGC 2004). A value of –18dB has been used in the following assessment.

Dragoset (2000) and Caldwell & Dragoset (2000) provide an introduction to the acoustics of airgun arrays, updated by OGP (2008) *Fundamentals of underwater sound*; and a *Draft Preliminary Comprehensive Overview of the Impacts of Anthropogenic Underwater Sound in the Marine Environment*, prepared by Norway for OSPAR (OSPAR 2008).

Available measurements indicate that drilling activities produce mainly low-frequency continuous noise from several separate sources on the drilling unit (Richardson *et al*. 1995, Lawson *et al*. 2001). The primary sources of noise are various types of rotating machinery, with noise transmitted from a semi-submersible rig to the water column through submerged parts of the drilling unit hull, risers and mooring cables, and (to a much smaller extent) across the air-water interface. Under some circumstances, cavitation of thruster propellers is a further appreciable noise source, as may be the use of explosive cutting methods (e.g. for conductor removal).

Measured farfield sound pressure of around 170dB re 1µPa, in the frequency range 10-2000Hz (Davis *et al.* 1991) is probably typical of drilling from a semi-submersible rig and is of the same order and dominant frequency range as that from large merchant vessels (e.g. McCauley 1994). Drilling noise has also been monitored west of Shetland, in the vicinity of the Foinaven and Schiehallion developments (Swift & Thompson 2000). High and variable levels of noise in three noise bands (1-10Hz, 10-30Hz and 30-100Hz) were initially believed to result from drilling related activity on two semi-submersible rigs operating in the area. However, subsequent analysis showed that noise events and drilling activity did not coincide. In contrast, a direct correlation between the use of thrusters and anchor handlers, during rig moves, and high levels of noise in all three bands was found (Swift & Thompson 2000). Drilling duration may range from a few weeks for an exploration well, to years in the case of a large development programme.

Pipelay operations will result mainly in continuous noise (associated with rotating machinery), with relatively little impulse or percussive noise in comparison to many other marine construction activities. The overall source levels resulting from pipelay operations on the UKCS have not been measured, however, near-field cumulative sound levels associated with pipelay for the Clair project were predicted to be a maximum of 177dB (Lawson *et al*. 2001), with a duration of weeks or months.

Although there is little published data, noise emission from production platforms is qualitatively similar to that from ships, and is produced mainly by rotating machinery (turbines, generators, compressors). The compression required for gas export may be a significant source of noise, but propagation into the water column will be limited. Gas storage developments are predicted to be very similar, in terms of noise, to existing gas production.

A further source of noise associated with all stages of the offshore oil industry is helicopter overflights. There is relatively little quantitative information on the transmission of helicopter airborne noise to the marine environment (Richardson *et al*. 1995). Measurements of an air-sea rescue helicopter over the Shannon estuary (Berrow *et al*. 2002) indicated that due to the large impedance mismatch when sound travels from air to water, the penetration of airborne sound energy from the rotor blades was largely reflected from the surface of the water with only a small fraction of the sound energy coupled into the water.

5.3.2 Consideration of the evidence

5.3.2.1 Marine mammals

It is generally considered that the most sensitive receptors of acoustic disturbance in the marine environment are marine mammals, due to their use of echolocation and vocal communication. Richardson *et al.* (1995) defined a series of zones of noise influence on marine mammals, which have been generally adopted by SMRU commissioned reports for SEAs (Hammond *et al*. 2001, 2002, 2003, 2004, 2005, 2006, 2008); and in relation to which data on marine mammal responses have been exhaustively reviewed (e.g. Richardson *et al*. 1995, Gordon *et al*. 1998, Lawson *et al*. 2001, Simmonds *et al*. 2003). Four zones are recognised which will generally occur at increasing sound level: (1) the zone of audibility; (2) zone of responsiveness; (3) zone of masking; (4) zone of hearing loss, discomfort or injury. Potential acute effects include physical damage, noise-induced hearing loss (temporary and permanent threshold shifts) and short-term behavioural responses. Postulated chronic effects (for which evidence is almost entirely absent) include long term behavioural responses, exclusion, and indirect effects. The most likely physical/physiological effects are generally considered to be shifts in hearing thresholds and auditory damage.

Other effects of sound have been postulated, including triggering the onset of Decompression Sickness (DCS) either through behavioural modification or direct physical activation of microbubbles (Fernandez *et al*. 2005; Jepson *et al*. 2005).

The difficult issue of determining when noise causes biologically significant effects in marine mammals has been addressed by NRC (2005). This clarifies the term *biologically significant* in the context of the US Marine Mammal Protection Act (MMPA), which considers two levels of harassment, level A and level B harassment; in turn specified by National Marine Fisheries Service (NMFS) criteria as noise pressure thresholds of 180 and 160dB re 1µPa rms respectively. These values were derived by the high energy seismic survey panel of experts convened in 1999 to assess noise exposure criteria for marine mammals exposed to seismic pulses. The consensus was that, given the best available data at that time, exposure to airgun pulses with received levels above 180dB re 1µPa (averaged over the pulse duration) was "likely to have the potential to cause serious behavioural, physiological, and hearing effects." The panel noted the potential for ±10dB variability around the 180dB re 1µPa level, depending on species, and that more information was needed.

More recent threshold values for marine mammals were provided by NOAA as part of a ruling on a permit application for a military sonar exercise (NOAA 2006). This provides an acoustic energy threshold for Temporary Threshold Shift (TTS) of 195dB re 1µPa^{2}s. Being energy based, this takes account of the cumulative duration of exposure as well as for level. These thresholds were based on measurements made by Schlundt *et al*. (2000) of TTS induced in bottlenose dolphins and beluga after exposure to an intense 1 second narrow band tone. A threshold for Permanent Threshold Shift (PTS) of 215dB re 1µPa^{2}s was also specified by NOAA (2006) based on the typical values for the additional dB above TTS required to induce PTS in experiments with terrestrial mammals. SMRU (2007) noted that the best acoustic sensitivity of harbour porpoise is higher than that of bottlenose dolphins and beluga whales, albeit at high frequencies, and porpoises may be more vulnerable to TTS than the species tested by Schlundt *et al*. (2000).

The NMFS has continued to use a "do not exceed" exposure criterion of 180dB re 1µPa for mysticetes and (recently) all odontocetes exposed to sequences of pulsed sounds, and a 190dB re 1µPa criterion for pinnipeds exposed to such sounds. These criteria were also used in a study of potential mitigation methods carried out by SMRU (2007). Higher thresholds have been used in the U.S. for single pulses such as explosions used in naval vessel-shock trials. Behavioural disturbance criteria for pulsed sounds have typically been set at an SPL value of 160dB re 1µPa, based mainly on the earlier observations of mysticetes reacting to airgun pulses. However, the relevance of the 160dB re 1µPa disturbance criterion for odontocetes and pinnipeds exposed to pulsed sounds is not at all well-established. Although these criteria have been applied in various regulatory actions (principally in the U.S.) for more than a decade, they remain controversial, have not been applied consistently in the U.S., and have not been widely accepted elsewhere (Southall *et al*. 2007). Similarly, although the MMPA is intended to be precautionary in that it is intended that the burden of proof is placed "not on conservationists, but on any activities with the potential to injure or disrupt marine mammals" (McCarthy 2007), the MMPA has been the subject of criticism on various levels (e.g. McCarthy 2007, Horowitz & Jasny 2007).

NRC (2005) describe a conceptual model framework that identifies the different stages required to move from marine mammal behaviour to a determination of population effects of behavioural change. The proposed model first characterises an acoustic signal, the resulting behavioural change, and a determination of the "life function" or activity affected. It then describes the resulting change in vital rate, such as life span, and finally suggests population effects and effects on following generations. A series of recommendations were made to assist in further development and implementation of the model.

A recent review of marine mammal responses to anthropogenic noise was carried out by Nowacek *et al*. (2007), which although comprehensive, was limited to studies in which noise exposure levels of the subject animals were quantified. Nowacek *et al*. (2007) are of the view that this information is critical to interpretation of animal's responses (in terms of the dose-response relationship). Weilgart (2007) disagreed, pointing out the range of other factors which may be more important (e.g. auditory perception, masking, cumulative effects and long-term population effects). Weilgart's (2007) review focused, in part, on strandings and mortalities of beaked whales in which received sound levels were typically not high enough to cause hearing damage, implying that the auditory system may not always be the best indicator for noise impacts; in addition, mechanisms of population effect and management implications were reviewed.

Southall *et al*. (2007) have recently proposed injury criteria composed both of unweighted peak pressures and M-weighted sound exposure levels which are an expression for the total energy of a sound wave. The M-weighted function also takes the known or derived species-specific audiogram into account. For three functional hearing categories of cetaceans, proposed injury criteria are an unweighted 230dB re 1µPa peak to peak for all types of sounds and an M-weighted sound exposure level of 198 or 215dB re 1µPa^{2}s for pulsed and non-pulsed sounds. For pinnipeds the respective criteria are 218dB 1µPa peak to peak and 186 (multiple pulse) or 203 (non-pulse) re 1µPa^2·s (M-weighted). These proposals are based on the level at which a single exposure is estimated to cause onset of permanent hearing loss (parameterised as PTS) by extrapolating from available data for TTS.

Southall *et al*. (2007) concluded that developing behavioural criteria was challenging, in part due to the difficulty in distinguishing a significant behavioural response from an insignificant, momentary alteration in behaviour. Consequently, they recommended that onset of significant behavioural disturbance resulting from a single pulse is taken to occur at the lowest level of noise exposure that has a measurable transient effect on hearing (i.e. TTS-onset). For multiple pulse and non-pulse (i.e. continuous) sources, they were unable to derive explicit and broadly applicable numerical threshold values for delineating behavioural disturbance. A scoring paradigm was used to numerically rank, in terms of severity, behavioural responses observed in either field or laboratory conditions. However, due to various statistical and methodological problems, much of this data was not considered to provide sufficient scientific credence for establishment of exposure criteria. Southall *et al*. (2007) noted the importance of contextual variables in determining behavioural response; together with the presence or absence of acoustic similarities between the anthropogenic sound and biologically relevant natural signals (e.g. calls of conspecifics, predators, prey). They suggest that a context-based approach to deriving noise exposure criteria for behavioural responses will be necessary.

SMRU (2007) considered work by Lucke *et al*. (2007), at that time unpublished, to measure TTS in harbour porpoise to be "fundamentally important". A specific aim of this study was to assess the likely impact of low frequency impulsive noise from pile driving on harbour porpoise hearing. The hearing sensitivity of a captive harbour porpoise was measured at three frequencies: 4, 32 and 100kHz, using auditory brainstem response techniques before and after exposure to a single pulse from a 20 cubic inch airgun. The airgun generated a strong impulsive signal with most energy content below 500Hz, acoustically similar to pile driving noise. TTS was proven to occur at 4kHz after exposure to a single airgun pulse with received pressure levels above 184dB re 1µPa p-p, and a received energy of 165dB re 1µPa^{2}s. Threshold levels were also elevated at 32kHz but did not exceed the researcher's conservative TTS criterion. There were no indications of a threshold shift at 100kHz. Recovery of full sensitivity at 4kHz took more than a day to occur. Lucke *et al*. (2007) noted that the study animal had an elevated hearing threshold compared to published audiograms which may have been due to auditory masking in the relatively noisy test environments or electrical "masking" in their equipment. They suggest therefore that the measured effects should be considered masked temporary threshold shifts (MTTS). MTTS is detected at higher exposure levels than TTS, thus SMRU (2007) consider that these results overestimate the exposure required to induce TTS.

5.3.2.2 Offshore wind farms – construction and operation

Empirical studies of porpoise behaviour during construction of offshore wind farms at Horns Rev (North Sea) and Nysted (Baltic) were reported by Tougaard *et al*. (2003a, b, 2005). At Horns Rev, acoustic activity of porpoises – indicated by the interval between acoustic encounters (minimum separation 10 min) – decreased shortly after each pile-driving event and returned to baseline conditions after 3-4h. This effect was not only observed in the direct vicinity of the construction site but also at monitoring stations approximately 15km away suggesting that porpoises either decreased their acoustic activity or left the area during construction activity (Tougaard *et al*. 2003a). It was also found that densities of porpoises during construction were significantly lower in the entire area. Behavioural observations showed that during pile-driving, porpoises exhibited relatively more directional swimming patterns compared to observations obtained on days without construction where relatively more non-directional swimming patterns were observed. This effect was found at distances of more than 11km, perhaps also 15km from the construction site (Tougaard *et al*. 2003a). Thomsen *et al*. (2006) note that these distances rather represent the radius of observations than the zone of responsiveness, as no observations or acoustic logging happened at greater distances. These reaction distances might therefore be viewed as the minimum zone of responsiveness.

Similar effects on acoustic activity were found during the construction (combination of pile-driving and vibropiling) of the Nysted offshore wind farm. Porpoise abundance also reportedly declined after construction with no return to baseline levels (Tougaard *et al*. 2005). However, since absolute abundance of porpoises was low from the start, these latter results are difficult to interpret (Tougaard *et al*. 2005). In addition, in both areas, pingers and seal-scarers were used before pile-driving as a mitigation measure to deter porpoises and seals from the vicinity of the construction sites, suggesting the possibility that effects were caused by a combination of the mitigation measures, along with the pile-driving (although decrease of acoustic activity was also found during pile-driving in a harbour close to the Nysted site, with no mitigation measures employed).

Using satellite telemetry, Tougaard *et al*. (2003b) also showed that harbour seals transited Horns Rev during pile-driving. However, at Nysted, Edren *et al*. (2004) found a 10–60% decrease in the number of hauled out harbour seals on a sandbank 10km away from the construction during days of pile-driving activity compared to days with no pile-driving. However, this effect was of short duration, since the overall number of seals remained the same during the whole construction phase.

Koschinski *et al*. (2003) reported behavioural responses in harbour porpoises and harbour seals to playbacks of simulated offshore turbine sounds at ranges of 200-300m, indicated by theodolite tracking and recordings of acoustic activity (porpoises). However, they did not model or measure received sound pressure levels and Madsen *et al*. (2006) discussed other potential pitfalls of the study such as the introduction of playback artefacts. Lucke *et al*. (2007) found that simulated offshore wind turbine noise (1.5 MW) was only able to mask the detection of low frequencies up to 2kHz by a harbour porpoise. The received level necessary for masking was 128dB re 1µPa. This would result in a masking zone of 20m around smaller turbines. These conclusions are only valid for relatively small turbines; it is likely that bigger turbines will be noisier with the sound most likely shifted to lower frequencies.

Madsen *et al*. (2006) used the impact zones of Richardson *et al*. (1995) as defined above (Zones 1 to 4) for assessment of the possible impact of noise generated from constructing and operating offshore wind turbines. Taking into account the problems in comparing effects thresholds (in dB rms) with transient noises, and non-geometric attenuation due to sound-scattering and refraction processes, the calculated ranges clearly indicated that pile-driving sounds are audible to the four species of marine mammals considered (bottlenose dolphin, harbour porpoise, northern right whale and harbour seal) at very long ranges of more than 100km, and possibly up to more than a thousand kilometres. In the light of limited behavioural data (see above) Madsen *et al*. (2006) also concluded that pile-driving operations have the potential to cause disruption of normal behaviour in marine mammals at ranges of many kilometres. However, maximal detection distances by bottlenose dolphin and harbour porpoise of operating turbines were predicted to be somewhere between 200 and 500m; thus, the impact on small toothed whales of known noise levels and spectral properties from operating wind turbines is likely to be minor. The zone of masking for seals in the case of turbine noise was also assumed to be small for all practical purposes.

David (2006) assessed likely sensitivity of bottlenose dolphins to pile-driving noise, concluding that at 9kHz, masking of strong vocalisations could potentially occur within 10–15km and weak vocalisations up to approximately 40km. The potential masking radius was predicted to reduce with increasing frequency to 6km at 50kHz and 1.2km at 115kHz. The impacts of masking are expected to be limited by the intermittent nature of pile driver noise, the dolphin's directional hearing, their ability to adjust vocalisation amplitude and frequency, and the structured content of their signals.

Attenuation of modelled pile-driving noise at different distances from the source have been compared to audiograms of harbour porpoise and harbour seals and to ambient noise levels by Thomsen *et al*. (2006), although with considerable difficulties in consistency of measurement units, time integration and pulse modification during propagation. However, it was concluded that this theoretical assessment indicated that pile-driving noise, under realistic North Sea conditions, would be audible to harbour porpoises and seals over distances of at least 80km. Thomsen *et al*. (2006) also applied the dBht value (ht = hearing threshold) for behavioural reactions postulated by Nedwell *et al*. (2003) (sound pressure levels 75 and 90dB above hearing threshold should lead to mild and strong behavioural reactions in cetaceans); suggesting that mild behavioural reactions (e.g. subtle change in swimming direction) in harbour porpoises might occur between 7 and 20km distance from the pile-driving source. Thomsen *et al*. (2006) noted that this analysis includes considerable speculation and uncertainty, including derivation of dBht values from studies on humans and fish; and problems in calculating the required rms values for transient pulse noises.

In a study for COWRIE, Nedwell *et al.* (2007) developed a simplified, two-zone model of effect from pile-driving noise based on measurements from North Hoyle, Scroby Sands, Kentish Flats, Barrow and Burbo Bank. A Noise Injury Zone, bounded by the 130dBht contour, defines the area in which hearing injury can occur, and, in addition, the areas in which lethal and physical injury could occur, since the ranges at which these will occur are much less than those for hearing injury. This area typically extends to a few hundred metres from pile driving. The Behavioural Effect Zone, bounded by the 90dBht level contour, typically extends from a kilometre up to perhaps 10km or more. Within this area, the modelling suggested that species were likely to display a strong avoidance reaction to the noise.

Another factor that has to be considered is the tonal content of the noise emitted by turbines in operation (Dewi 2004; Wahlberg & Westerberg 2005; Madsen *et al*. 2006). In larger turbines, narrow tones with clearly defined peaks might considerably exceed background noise levels, and the zone of audibility of these rather discrete frequencies might be much larger than for relatively broadband noise (Dewi 2004). For example, Dewi (2004) simulated sound emissions of a 2.5MW turbine based on their measurements of a 1.5MW offshore turbine in operation. They estimated that the sound pressure levels of the simulated 2.5MW turbine would be between <10 to 30dB higher compared to the 1.5MW turbine, depending on frequency. Nedwell *et al*'s (2007) recent results on comparably low operational noise levels from wind turbines up to 3MW do not necessarily contradict these simulations as their ambient noise levels were relatively high.

5.3.2.3 Seismic noise

Until recently, research effort in the effects of anthropogenic noise on marine mammals has concentrated on seismic exploration, with a particular focus on baleen whales. However, airgun arrays also produce significant energy over the frequency range in which behavioural audiograms suggest that dolphins are most sensitive. Behavioural responses to anthropogenic noise have generally been studied by visual or acoustic monitoring of abundance. Visual monitoring of cetaceans during seismic surveys has been carried out for several years throughout the UKCS. Statistical analysis of 1,652 sightings during 201 seismic surveys, representing 44,451 hours of observational effort, was reported by Stone (2003) and Stone & Tasker (2006). Sighting rates of white-sided dolphins, white-beaked dolphins, *Lagenorhynchus* spp., all small odontocetes combined and all cetaceans combined were found to be significantly lower during periods of shooting on surveys with large airgun arrays. In general, small odontocetes showed the strongest avoidance response to seismic activity, with baleen whales and killer whales showing some localised avoidance, pilot whales showing few effects and sperm whales showing no observed effects. A recent programme of marine mammal observation off Angola concluded that the encounter rate (sightings/h) of humpback and sperm whales did not differ significantly according to airgun operational status (Weir 2008). The mean distance to humpback and sperm whale sightings was greater during full-array operations than during guns off, but this difference was not significant. Atlantic spotted dolphin encounters occurred at a significantly greater distance from the airgun array during full-array operations than during guns off. Positive-approach behaviour by Atlantic spotted dolphins (n = 9) occurred only during guns off periods. There was no evidence for prolonged or large-scale displacement of each species from the region during the 10 month survey duration. Sperm whale sightings showed a significant increase during the survey, while Atlantic spotted dolphin encounters occurred at similar rates. A decreased occurrence of humpback whale sightings corresponded with established seasonal migration out of the survey area. Contrary to expectation based on perceived sensitivity, Atlantic spotted dolphins exhibited the most marked overt response to airgun sound of the three cetacean species examined.

There have been far fewer studies of marine mammal responses to continuous drilling noise (Richardson *et al*. 1995), with most available data relating to baleen whales. Sorensen *et al*. (1984) observed distributions of a similar range of small cetacean species to that found around the UK (including common, Risso's, bottlenose and *Stenella* dolphins), in the vicinity of drilling activities off New Jersey, and reported no difference in sightings per unit effort with and without the presence of rigs.

5.3.2.4 Other receptors

In addition to marine mammals, effects of noise are possible in other species. Many species of fish are highly sensitive to sound and vibration (reviewed by MMS 2004), although the mechanisms of hearing and detection of vibration vary widely. Wahlberg & Westerberg (2005) reviewed and assessed the impact of underwater noise from wind turbines on fish. They concluded that operational turbine noise could potentially affect fish behaviour at ranges of several kilometres, but they also pointed out that available data on sound production and fish behaviour is too rudimentary to clarify if noise from wind farms is actually causing any effects on fish. The wind turbine noise is of too low intensity to cause permanent or transient hearing impairment in fishes, even at ranges of a few metres from the wind turbines (Wahlberg & Westerberg 2005).

Hastings & Popper (2005) provide an overview of results from five recent experimental studies of pile-driving on fish; four in the US and one in the UK. Species investigated included the shiner surfperch (*Cymatogaster aggregata*), Sacramento blackfish (*Orthodon* *microlepidotus*), brown trout (*Salmo trutta*), steelhead (*Oncorhynchus mykiss*), Chinook salmon (*Oncorhynchus tshawytscha*) and northern anchovy (*Engraulis mordax*). Behavioural observations were undertaken on caged fish held at different distances from piling. However, experimental conditions were in most cases difficult to control and the conclusions drawn were viewed by Hastings & Popper (2005) as being rather limited. For example, Nedwell *et al*. (2003) filmed brown trout in cages positioned at different distances from vibro and impact pile-driving operations in Southampton harbour. 'Startle-reactions' and 'Fish activity level' observations revealed no evidence that trout reacted to impact piling at 400m, nor to vibropiling at close ranges (<50m; source level of impact pile-driving, 194dB p-p re 1μPa). However, Hastings & Popper (2005) critically review some aspects of this study (e.g. control observations were performed on the same animals as tested; not all of the cage could be observed).

Hastings & Popper (2005) also review reports in the grey literature that pile-driving kills fishes of several different species if they are sufficiently close to the source; for example, mortalities observed after pile-driving in the course of the San Francisco-Oakland Bay Bridge Demonstration Project. Sound levels at a distance of 100-200m from the pile were between 160 and 196dB rms re 1μPa (Caltrans 2001). The zone of direct mortality was about 10-12m from piling, the zone of delayed mortality was assumed to extend out at least to 150m to *ca*. 1000m from piling. Tests on caged fish revealed greater effects when using a larger hammer (1700kJ, as compared with 500kJ). The greatest effects were observed in a range of 30m from piling. Preliminary results indicated increasing damage rates to the fish together with extended exposure times (Caltrans 2001). However, reviewing these and other studies, Hastings & Popper (2005) consider that the results provided are highly equivocal, noting that no clear correlation between the level of sound exposure and the degree of damage could be determined and criticising aspects of the pathological and histological analysis.

Thomsen *et al*. (2006) also considered wind farm (construction and operation) noise effects on fish, reviewing the general aspects of fish hearing and carrying out species-specific assessments for dab, Atlantic salmon, cod and herring. Dab and salmon are considered relatively insensitive and detect particle motion rather than sound pressure. Cod have a gas-filled swim bladder and are able to detect both particle motion and sound pressure; while clupeids including herring have structural specialisations to the swim bladder and inner ear resulting in high sensitivity, particularly at higher frequencies (>1kHz). Most of the energy of pile-driving noise falling in the hearing range of the assessed species exceeds background noise over a range of at least 80km. For dab and salmon sound pressure levels in 80km distance are above the hearing threshold and/or ambient noise at certain frequencies although the more appropriate parameter would be particle motion and not sound pressure. It has to be also noted that for demersal fishes such as dab, the characteristics of the received sounds will be much different from those swimming in the water column as bottom-scattering and other effects will alter the pulse-sound significantly. Another important aspect is the sound propagation through the sediment and its probable detection by demersal species such as dab (for a description of pathways of pile-driving noise see Nedwell *et al*. 2003).

With regard to operational noise, nearfield acoustic effects need to be taken into consideration, since in close proximity to the turbine, the particle motion component will be much higher for the respective sound pressure values. This is especially important for fish species that are primarily sensitive to particle motion, e.g. dab and salmon. Thomsen *et al*. (2006) estimate that the nearfield at 16Hz will extend to about 47m, and to about 14m at 50Hz; suggesting that in a range of probably <100m around the turbines, hearing generalists that are primarily sensitive to particle motion will perceive much higher relevant impulses. Thomsen *et al*. (2006) conclude that dab and salmon might detect operational noise of a wind turbine at relatively short distances of no more than 1km. The zone of audibility for cod and herring will be larger, perhaps up to 4-5km from the source. However, these values have to be viewed as preliminary.

Behavioural responses (Wardle *et al*. 2001) and effects on fishing success ("catchability") have been demonstrated following seismic survey (Pearson *et al*. 1992, Skalski *et al*. 1992, Engås *et al*. 1993). MMS (2004) consider that the "consensus is that seismic airgun shooting can result in reduced trawl and longline catch of several species when the animals receive levels as low as 160dB". However, no associations of lower-intensity, continuous drilling noise and fishing success have been demonstrated, and large numbers of fish are typically observed around North Sea and other production platforms.

Spawning and nursery grounds for most species are dynamic features and are rarely fixed in one location from year to year. Therefore, while some species have similar patterns of distribution from one season to the next, others show greater variability (Coull *et al*. 1998). Discrete banks of clean gravel found in the southern North Sea, Moray Firth and other UK coastal waters are used by spawning herring. The sub-populations of North Sea (and west coast) herring spawn at different times and localised groups of herring can be found spawning in almost every month (Rogers & Stocks 2001). The potential for seismic survey and piling activities to disturb or disrupt spawning shoals of herring (and other species) is recognised and mitigated through the activity consenting processes (PON14 or FEPA licence). Guidance on sensitive periods for fish spawning (based on advice from FRS and CEFAS) is available to developers, and may be incorporated into licence conditions, including prohibitions of some activities in certain months.

Direct effects on seabirds because of seismic exploration noise could occur through physical damage, or through disturbance of normal behaviour. Diving seabirds (e.g. auks) may be most at risk of physical damage. The physical vulnerability of seabirds to sound pressure is unknown, although McCauley (1994) inferred from vocalisation ranges that the threshold of perception for low frequency seismic in little penguins would be high, hence only at short ranges would penguins be adversely affected. Mortality of seabirds has not been observed during extensive seismic operations in the North Sea and elsewhere. A study has investigated seabird abundance in Hudson Strait (Atlantic seaboard of Canada) during seismic surveys over three years (Stemp 1985). Comparing periods of shooting and non-shooting, no significant difference was observed in abundance of fulmar, kittiwake and thick-billed murre (Brünnich's guillemot). It is therefore considered unlikely that offshore seismic noise will result in significant injury or behavioural disturbance to seabirds.

The effects of pile-driving noise from OWF construction, which is more likely to expose inshore bird populations, including wintering seaduck and divers, have not been characterised although behavioural disturbance effects are more likely than physical injury. Baerwald *et al*. (2008) attributed high mortality in bats at onshore wind energy facilities to pulmonary barotrauma (caused by decompression near moving turbine blades) and suggested that the respiratory anatomy of birds is less susceptible to barotrauma than that of mammals; it is uncertain whether similar considerations would apply to exposure to high levels of impulse sound in water. Consideration of disturbance effects in birds such as common scoter (e.g. Kaiser *et al*. 2006) have identified sensitivity to moving vessels (i.e. visual disturbance) rather than acoustic effects, and it seems likely that displacement due to visual cues will be the dominant process in birds. In the case of piscivorous species such as divers and auks, indirect effects through acoustic disturbance of prey species could be postulated, although such effects are likely to be local and not significant at a population scale.

Sharks and turtles are not thought to be sensitive to acoustic disturbance (in comparison to marine mammals and teleost fish, e.g. McCauley 1994) and occur at very low densities in the UKCS. Although the biology of basking sharks is not well understood, including the location of breeding areas, the known distribution in UK waters is concentrated in "hotspots" in western coastal waters (satellite tracking studies are ongoing); turtles are essentially vagrants in UK waters. The risk of significant disturbance to these species is therefore considered to be negligible.

Planktonic and benthic invertebrates generally do not have gas-filled body cavities and are considered less susceptible to acute trauma and behavioural disturbance resulting from noise and vibration. Cephalopods, with a well-developed nervous system and complex behavioural responses, are a possible exception (although they lack resonating structures analogous with the middle ears, lungs, tracheal cavities and sinuses of mammals).

5.3.3 Spatial consideration

General aspects of noise propagation are discussed in Box 5.2. 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 (Figure 5.3). Cylindrical spreading, **SPL = SL – 10log(R)**, is usually assumed in shallow water, depth < **R**. However, several workers have measured or modelled additional signal modification and attenuation due to a combination of reflection from sub-surface geological boundaries, 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 (see SEA 4). 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). 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 the 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.

Box 5.2 - Acoustic propagation

Sound produced by various ambient noise sources propagates to a receiver through the very complex underwater environment. Because of variation in temperature, salinity and pressure the path followed by the sound waves can deviate markedly from a straight line. The structuring is most marked in the vertical plane, causing sound to be refracted upwards or downwards, depending on the temperature gradient, but horizontal structuring can also be encountered. As sound is refracted up or down it may interact with the surface and the sea bed by reflection and scattering. The level of signal arriving at a distant point is a complex sum of many paths that may or may not interact with the seabed and sea surface. Variations of salinity are generally very small, except perhaps at the mouth of major rivers, and pressure variations are due entirely to depth so temperature variations have the major effect on sound propagation in shallow water.

Under some conditions, a mixed isothermal layer forms close to the sea surface that traps the acoustic signals and a source and receiver located within this surface duct experience significantly less propagation loss than when there is no surface duct. During the day the sea surface can heat up and introduce a temperature gradient close to the sea surface that causes downwards refraction and hence increased propagation loss.

Because the sound can interact strongly with the seabed, the sediment types and sea bed roughness can affect propagation loss. Similarly, waves on the surface can also affect propagation loss by scattering the sound interacting with the surface rather than just reflecting it.

Suspended sediments or bubbles can also cause additional propagation loss.

Propagation loss varies on a diurnal basis, particularly during the early summer, and on an annual cycle, as the air temperature variations through the year warm and cool the water. A period of sustained strong wind can also disrupt the temperature structuring.

Multi-path effects

Because of the surface and sea bed reflections sound can travel between a source and receiver by a multitude of paths. This has the effect of dispersing the arrived signal in time. This effect is particularly important for wideband impulsive sounds such as explosions, pile driving or seismic exploration air-guns. If any of the propagation effects are frequency sensitive then frequency dispersion will also occur. A common example of this is the sound of air guns operating at distances of 20-30 miles in which the low frequencies travel more slowly than the high frequencies so the single impulse at the source turns into a pronounced frequency sweep at the receiver. The effect of time dispersion is to reduce the peak energy in the received signal. The integrated level is unchanged by time dispersion, but the peak levels can be significantly reduced. When considering the contribution to ambient noise levels this can be an important factor.

Source and receiver depth

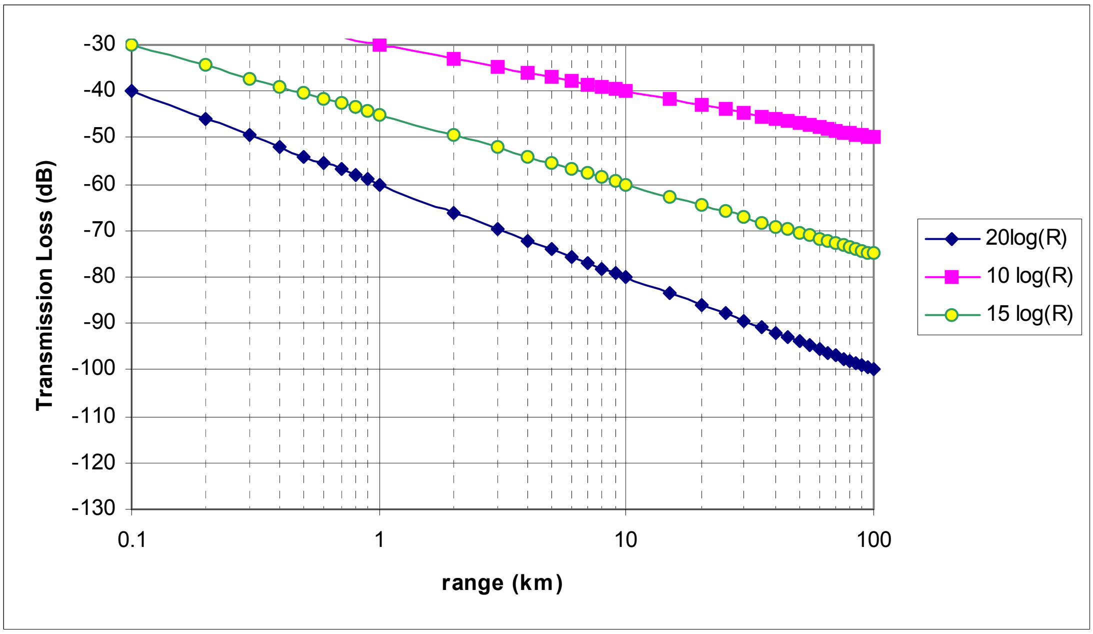
The vertical temperature and pressure structure described above can lead to significant variations in the propagation loss between a sound source and the receiver as the depth of the source and/or the receiver is varied. The most extreme example is the surface duct where a shadow zone may form under the duct. Within the shadow zone levels from a distant sound source in the duct are much reduced compared with the level from the same source within the duct.

Tides

In the relatively deep waters of much of the continental shelf, slope and troughs, variations in depth due to tides are insignificant. However, in inshore waters the effect is much more pronounced and can significantly alter ambient noise fields through the tidal cycle.

Source: Harland & Richards (2006)

Figure 5.3 – Theoretical Transmission Losses (TL) calculated for spherical spreading 20log(R), cylindrical spreading 10log(R) and intermediate spreading 15log(R).



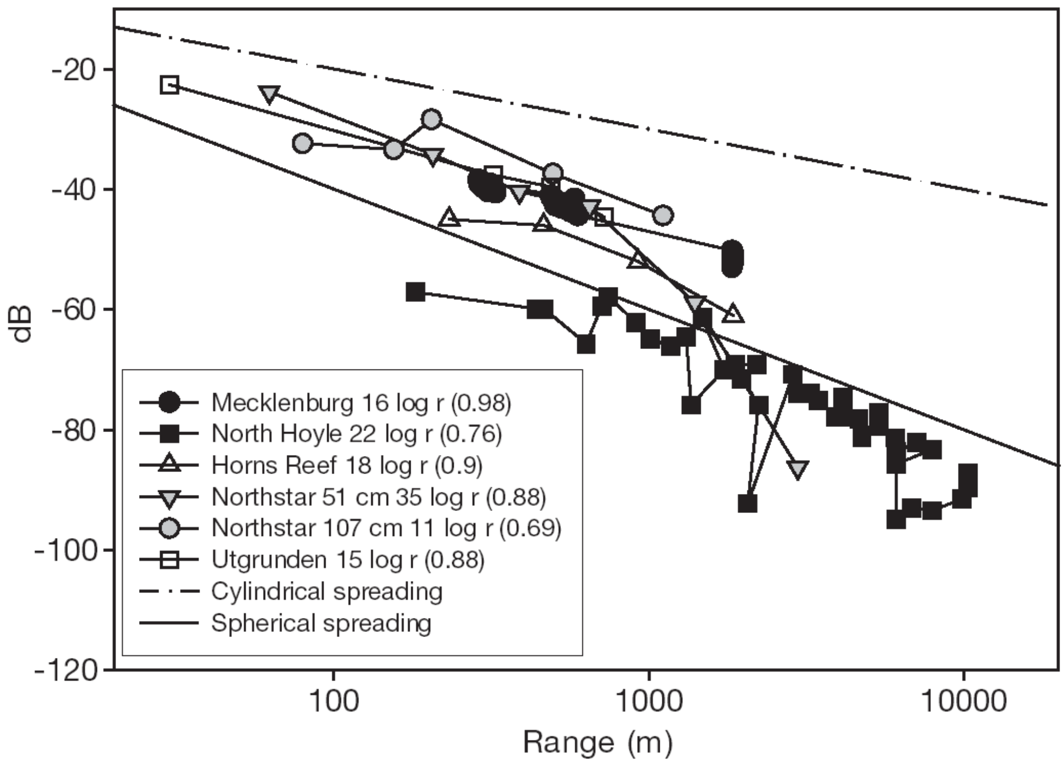
Source: SEA 4 (DTI 2003)

Transmission loss has been measured for sounds from pile-driving as well as sounds from operating wind turbines (Madsen *et al*. 2006; Figure 5.4). For the transient impact sounds from pile-driving, the available data suggest that transmission losses are close to spherical spreading up to ranges of more than 1km. At longer ranges the transmission loss may deviate considerably from what can be predicted by a simple spreading model, e.g. data for Horns Rev reflect a range-dependent attenuation much steeper than the 20dB slope at longer ranges.

Recent quantitative modelling of seismic noise propagation has been carried out in Queen Charlotte Basin, Canada (MacGillivray & Chapman 2005) and in the Rockall Basin (IOSEA3 2008). The Queen Charlotte Basin is characterised by shallow water, complex bathymetry, and a highly variable sound speed profile. In this situation, key findings of the modelling study included:

- Received noise levels in the water are influenced by the source location, array orientation and the shape of the sound speed profile with respect to water depth.
- Received noise levels are lowest in those areas of the basin with shallow bathymetry due to scattering and absorption of sound at the seabed.
- In contrast, surface-duct propagation conditions in deeper water result in the highest received levels at long ranges.
- The effect of the sound speed profile on received levels increases significantly with range from the source, with differences greater than 20dB observed beyond 100km, between down-refracting and surface-duct propagation conditions.
- Mean ranges to the 170dB sound level contour (approximately equivalent to NMFS 180dB 90% rms threshold level) vary from 0.54km to 1.15km. The range to the 170dB contour is greater in shallower water than in deeper water.
- The highest levels from the airgun array are in the broadside direction, which is the direction of maximum energy transmission from the array.

Figure 5.4 – Transmission loss during pile-driving of wind turbine foundations at 5 locations: linear regression of transmission loss model TL = x log (range) is given (regression coefficient in parentheses). Peak sound levels are in decibels relative to back-calculated level at 1m distance.



Source: Madsen et al. (2006)

In the deep water Rockall Basin, a generic 5,000 cubic inch airgun array towed at a depth of 10m was modelled in eight directions radiating outwards to a distance of 100km (IOSEA 2008). In addition to array directionality in the horizontal plane, propagation modelling showed a large asymmetry between upslope and downslope propagation. Sound propagating in the downslope direction couples into the deep sound channel, allowing it to propagate to long range with little attenuation. In contrast, sound propagating upslope suffered rapid attenuation due to frequent interactions with the seabed. Cumulative sound exposures were calculated for a notional 3D seismic survey in a 20 by 30km rectangle (i.e. $600km^2$) with a total of about 49,200 shots fired over some 150 hours: the highest downslope exposure levels are found in the 1,000 to 1,750m depth range which includes the deep sound channel axis. The maximum distance from the survey boundary at which any shots exceeded 140dB re $1\mu Pa^2 \cdot s$ was 80km in the downslope direction and 32km upslope. In the downslope, array broadside direction, all shots exceeded 130dB re $1\mu Pa^2 \cdot s$ at the maximum modelled range of 100km, and it was predicted that some shots would still exceed this threshold out to a range of at least 600km (it was also noted that this propagation path intersects the shallow water of the Rockall Bank at a range of around 300km, which would result in upslope propagation conditions and a consequent rapid reduction in SEL). Upslope, the maximum distance from the survey boundary at which any shot exceeded 130dB re $1\mu Pa^2 \cdot s$ was 82km.

Typical spatial extents of 3D seismic surveys are of the order of 25km in any direction ($625km^2$ area). Assuming propagation distances of audible sound to around 100km in all directions (see above), the theoretical instantaneous area of audibility is a circular area of $31,400km^2$, and the total area of audibility during a survey is a rectangular area of $50,625km^2$.

5.3.4 Controls and mitigation

Both planning and operational controls cover acoustic disturbance resulting from activities on the UKCS, specifically including geophysical surveying and pile-driving. The *Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001* - (the Habitat Regulations, HR), now amended by the *Offshore Petroleum Activities (Conservation of Habitats) (Amendment) Regulations 2007*, to include all areas within territorial waters; and the *Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007* (the Offshore Marine Regulations, OMR) outside territorial waters – all state that it is an offence to deliberately disturb wild animals of any species listed on Annex IVa of the Habitats Directive (which includes all cetaceans), particularly during the period of breeding, rearing, hibernation and migration or to cause the deterioration or destruction of their breeding sites or resting places.

Any proposed activity with a potentially significant acoustic impact within a designated SAC or SPA would also be subject to the requirement for Appropriate Assessment under the above Regulations.

Application for consent to conduct seismic and other geophysical surveys is made using *Petroleum Operations Notice No 14* (PON14) supported by an Environmental Narrative to enable an accurate assessment of the environmental effects of the survey. Consultations with Government Departments and other interested parties are conducted prior to issuing consent, and JNCC may request additional risk assessment, specify timing or other constraints, or advise against consent.

The major operational control and mitigation over seismic surveys in the UK are through JNCC's *Guidelines for minimising acoustic disturbance to marine mammals from seismic surveys (*April 2004; and a further (June 2008) draft has been consulted on to reflect the

OMR has been circulated for comment, but not yet issued). Note, SNH intend to produce separate guidance on cetaceans as European Protected Species for Scottish territorial waters to reflect slightly different legislative provisions which apply in Scotland. For Northern Ireland, DOENI issued guidance to the *Conservation (Natural Habitats, etc.) (Amendment) Regulations (Northern Ireland) 2007* which *inter alia* addressed disturbance of marine EPS. The JNCC guidelines were originally introduced UK wide on a voluntary basis as part of the UK's commitment under ASCOBANS, but have subsequently been required by oil and gas licence conditions and through the PON14 approval process. The guidelines have subsequently been reviewed three times by the JNCC following consultation with interested parties and in the light of experience after their use since 1995.

The guidelines require visual monitoring of the area by a dedicated Marine Mammal Observer (MMO) 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. Passive Acoustic Monitoring (PAM) may also be required. Under the draft (June 2008) guidelines version, seismic operators are required, as part of the application process, to justify that their proposed activity is not likely to cause a disturbance under the amended HR and OMR. This assessment should consider all operational activities including shooting during hours of darkness or in bad weather.

If there is a risk of 'deliberate disturbance' occurring due to night time shooting, JNCC suggest that operators should either:

- only commence seismic activities during the hours of daylight (where visual mitigation by MMOs is possible), or
- only commence seismic activities during the hours of darkness if an effective PAM system is used. Ideally, a PAM system should be used during day and night time shooting.

JNCC would prefer to see operators of PAM systems using the 'PAMGUARD' software (available at http://www.pamguard.org).

In relation to offshore pile-driving, the Marine and Fisheries Agency (MFA) has adopted a standard FEPA licence condition for the use of soft start (where the hammer energy is gradually increased), MMOs and PAM, in consents associated with the installation of Round 2 offshore wind farms. In such cases, MMOs and PAM would be used for the detection of marine mammals, basking sharks and turtles within a monitoring zone and appropriate protocols would specify how construction activities should take place. For example, a licence condition might stipulate that piling activities should not commence until half an hour has elapsed during which marine mammals have not been detected in or around the monitoring zone. It should be noted that additional measures would probably be required in areas where environmental impact assessment suggests that high cetacean densities or site fidelity may occur.

Under the OMR it is now an offence (under Regulation 39(1)(b)) to deliberately disturb wild animals of a European Protected Species (EPS) in such a way as to be likely significantly to affect: a) the ability of animals of that species to survive, breed, or rear or nurture their young; or b) the local distribution or abundance of that species. As a result, JNCC has issued guidance (for English and Welsh territorial waters and the UK offshore marine area) providing assistance with interpretation of the three main elements of the disturbance offence, for marine EPS:

- what is *deliberate disturbance*;

- what are *significant* effects on the ability of the species to survive, breed, or rear or nurture their young, and
- what are *significant* effects on the *local distribution or abundance* of a species.

JNCC state that the following criteria should be taken into consideration when assessing the likelihood of animals being adversely affected:

- the likelihood of potential disturbance factors and their impact on the species concerned
- the best and most recent estimate of the size of the population to which the animals in an area belong, taking into consideration possible geographically 'isolated' populations, e.g. coastal bottlenose dolphins
- grouping patterns (i.e. spatial cohesion, group size) and spatio-temporal variation
- the species Favourable Conservation Status assessment in UK and
- how many animals of each species there are likely to be in the area and time affected by the disturbance, and what percentage of the population might this represent.

The guidelines also state that the following criteria should be taken into consideration when assessing whether the local distribution or abundance of a species would be likely to be significantly affected by the disturbance:

- evidence (from the literature) of species displacement caused by the particular factor of disturbance generated by the activity considered
- the distribution and abundance (including spatial and temporal variability at a comparable scale to that of the activity) of the species and its populations in the area likely to be impacted by the activity and in their natural range
- the area likely to be impacted by the activity (does it include a large proportion of the suitable habitat used by a population, or includes persistent high animal density areas)
- species-specific movements (home range patterns, site-fidelity) and their magnitude
- the context in terms of other potential disturbances in the natural range of the species and its populations.

SMRU (2007) investigated the potential for using acoustic mitigation devices (AMDs) for mitigation during wind farm construction, drawing some general and fairly qualitative conclusions from the exercise:

- Propagation conditions have a very substantial effect. For example, mitigation ranges are low when 20log(R) propagation loss is assumed but can be very high when 15log(R) propagation applies. Both values are likely in some shallow water locations. Propagation can however be modelled and also measured in the field once operations begin
- According to this model, PTS could occur in some circumstances, for example, where there is no soft start and animals show little avoidance. However, this is an unlikely set of circumstances. Observations of avoidance reactions can be made to provide real data on responsive movements
- Thresholds for risk of hearing damage based on single pulses and cumulative exposure maybe exceeded at substantial ranges, especially when transmission loss is low
- This exercise certainly does not support any suggestion that the risk of auditory damage to marine mammals from pile driving can be discounted

SMRU (2007) also conclude that the risk of damage can be substantially reduced if animals can be reliably removed from within hundreds to low thousands of metres before piling is initiated. "*Acoustic mitigation devices will thus need to be able to move animals over these types of ranges to be effective…. using the NOAA (2006) criteria…. if 15log(R) propagation* *loss is assumed then animals could experience TTS at range of over 6km. To reduce this, animals would need to be moved to that range before piling began which would require an effective AMD to be used for 120 minutes before the initiation of piling*" [in view of estimated swimming speeds]. Soft starts are of some help (provided animals respond to them appropriately) but will not, on their own, reduce risk sufficiently.

In a COWRIE-sponsored study, technical options and costs of potential engineering solutions for the mitigation of the impacts of underwater noise arising from the construction of offshore wind farms were reviewed by Nehls *et al*. (2007). In addition to soft starts, technical mitigation measures have so far mainly focussed on bubble curtains (air bubbles released at the seafloor around a source of noise). Bubble curtains can efficiently reduce underwater noise but because of the slow ascent rate of the bubbles, it is considered to be impossible to install bubble curtains in the offshore environment at great water depths and tidal currents.

Attempts to mitigate noise from pile driving by prolonging the duration of the blows of the piling procedure through modification of the pile driver were rejected at this stage. As a prolongation of the blows may result in a loss of piling energy this may impair the success of the piling. However, further research on this method is recommended.

Nehls *et al*. (2007) described two methods considered to be effective and practicable to construct a permanent noise barrier around the piles, using from foam or air: First, an inflatable piling sleeve which can be permanently mounted below the piling gate at the construction platform. The sleeve is meant to be released after insertion of the pile into the piling gate and inflated to a 50mm layer of air during the piling operation. The sleeve is expected to reach an attenuation of 20dB broadband. Second, a telescopic double-wall steel tube with an interspace filled with foam. The tube is constructed in several segments to reduce the height when released on the seafloor underneath the piling gate. The pile is inserted into the tube which is lifted to full length during the piling operation. A 100mm foam layer is calculated to reach an attenuation of 15dB broadband. Both methods are considered to be compatible to the piling process and per pile costs are roughly estimated at €20,000 for the inflatable sleeve and about €25,000 for the telescopic tube. The inflatable sleeve appears to have the advantage of resulting in very little interference in the piling process. The noise attenuation from these methods is considered to be high enough to achieve a substantial reduction of the impacts on marine wildlife. Calculated radii of physical damage may be reduced by more than 90% and radii of disturbance by two-thirds.

In the context of monitoring marine mammal responses, Diederichs *et al*. (2008) reported on methodologies for measuring and assessing potential changes in marine mammal behaviour, abundance or distribution arising from the construction, operation and decommissioning of offshore wind farms. The report reviewed impacts from offshore wind farms on marine mammals and defines the spatial and temporal scope of investigations in order to detect impacts on marine mammals, and assessed the standard methods used in studies on marine mammals. The statistical power of line transect surveys using aircraft and ships and Static Acoustic Monitoring (SAM) using T-PODs was analysed from datasets obtained in German studies.

Diederichs *et al*. (2008) recommend a combination of line transect surveys using aircraft or ships with SAM, with the following specific recommendations:

- an impact study on offshore wind farms should ideally cover two years before construction, the construction period and at least two years of operation

- if longer lasting effects are detected, the study during the operational phase should be extended
- it is recommended to conduct line transect surveys in monthly intervals
- in areas with a marked seasonal occurrence, surveys may be restricted to periods with high abundance, when sufficient data are more likely to be obtained
- continuous recordings of harbour porpoises with SAM are recommended for all areas, where these animals occur in relevant numbers.

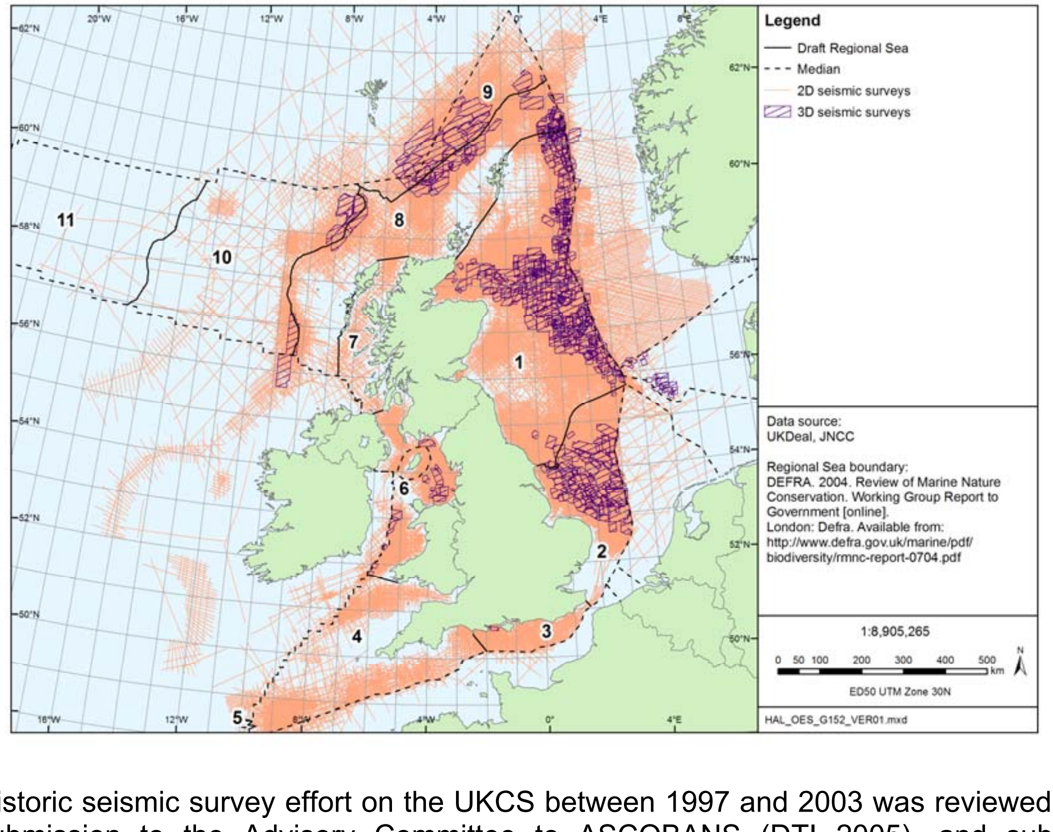
SAM will provide data which are needed to detect short-term changes in behaviour and abundance as expected in response to pile driving, but also to detect changes on a much smaller spatial scale as can be detected by other methods as well as long-term changes in response to construction of operation. For seals and dolphins severe problems in assessing the impacts remain, as their behaviour or low densities make it very difficult to obtain enough data for statistical analysis.

5.3.5 Cumulative impact considerations

5.3.5.1 Seismic survey

Seismic survey coverage of the UKCS is extensive (Figure 5.5), reflecting more than 40 years of activity, and covering virtually all areas of the shelf.

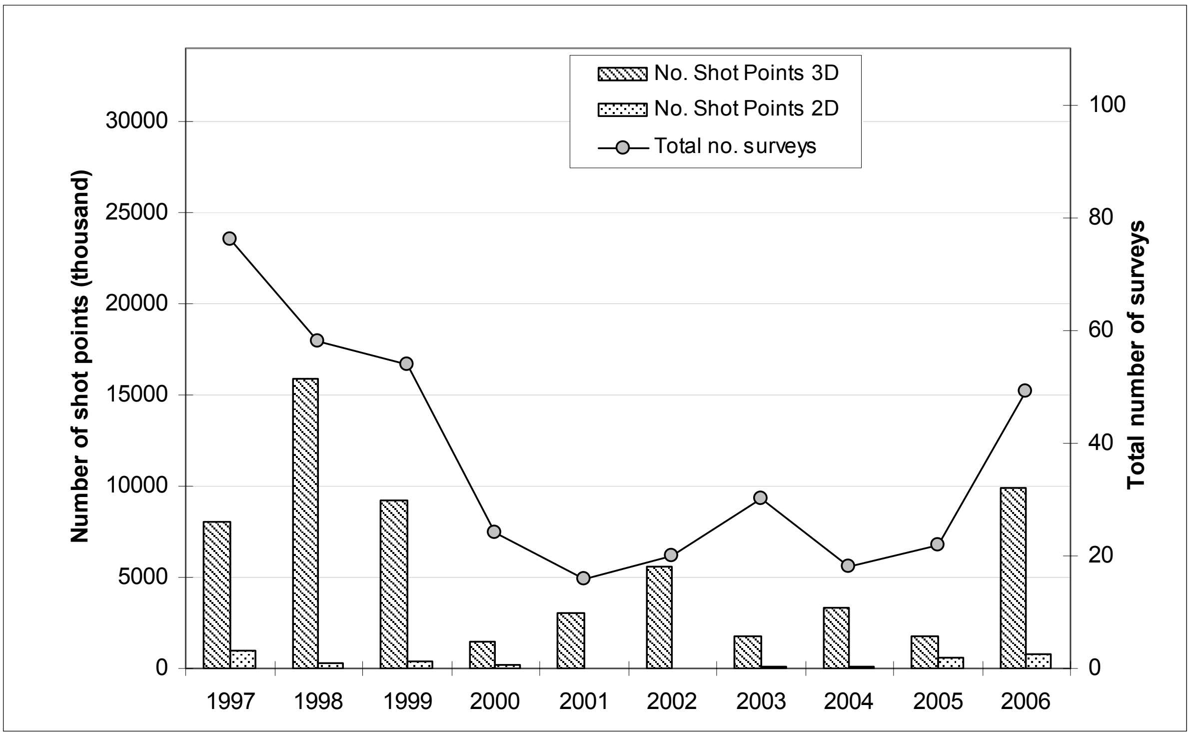
Figure 5.5 – Seismic survey coverage of the UKCS over the last 40 years



Historic seismic survey effort on the UKCS between 1997 and 2003 was reviewed for a DTI submission to the Advisory Committee to ASCOBANS (DTI 2005), and subsequently updated for 2006-2007 (BERR 2008). These reports calculated shot point density information per 1º by 1º rectangle, by dividing the number of seismic shot points per quadrant by the offshore sea area within each quadrant up to the median line. The PON14 database was also analysed to identify both the number of surveys being carried out concurrently and the combined size of airguns in use concurrently for different regions of the UKCS.

A summary of 2D and 3D seismic survey activity is shown in Figure 5.6. The great majority of survey activity (measured by shot points) is 3D, with an overall total over the ten year period of approximately 63 million shot points. Following a decrease over most of the period, survey activity increased in 2005 and 2006.

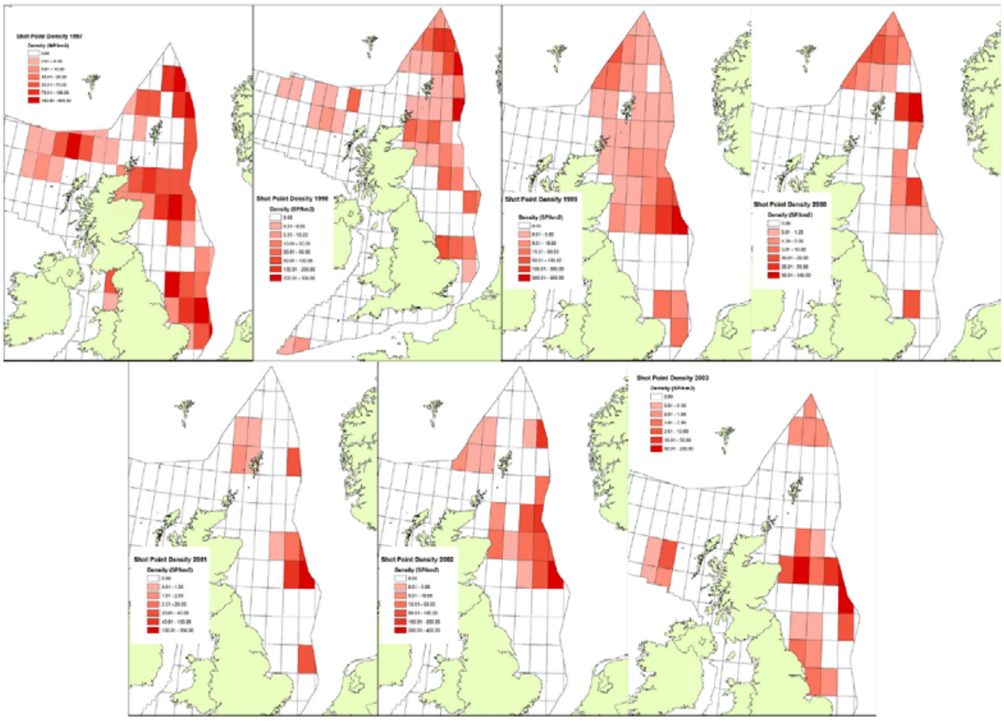
Figure 5.6 – Overview of survey activity 1997-2006



Source: BERR 2008

Between 1997 and 2003, the vast majority of seismic survey effort on the UKCS was undertaken in the developed (in terms of oil and gas) areas of Regional Seas 1 and 9, with a small amount in Regional Seas 2, 4, 6 and 10 (Figure 5.7). The same spatial distribution applied in 2006-2007. In general, it can be seen (Figure 5.8) that there is a tendency for more surveying during summer versus winter, although there is a wide variation. In the UK, surveying is not normally permitted at times when certain fish (particularly herring) are spawning. Assuming a 10s shot interval, the total survey period (2D + 3D) is equivalent to between 188 days/year (2000) to 1195 days/year (2006) – i.e. on average during 2006, more than three surveys were carried out concurrently in the whole of the UK waters. In addition to this UK seismic noise budget, noise propagating from surveys in contiguous national waters (particularly Irish, Faroese and Norwegian deep waters) will be present.

Figure 5.7 - Summary of annual seismic survey activity on UKCS 1997-2003



Source: DTI 2005a

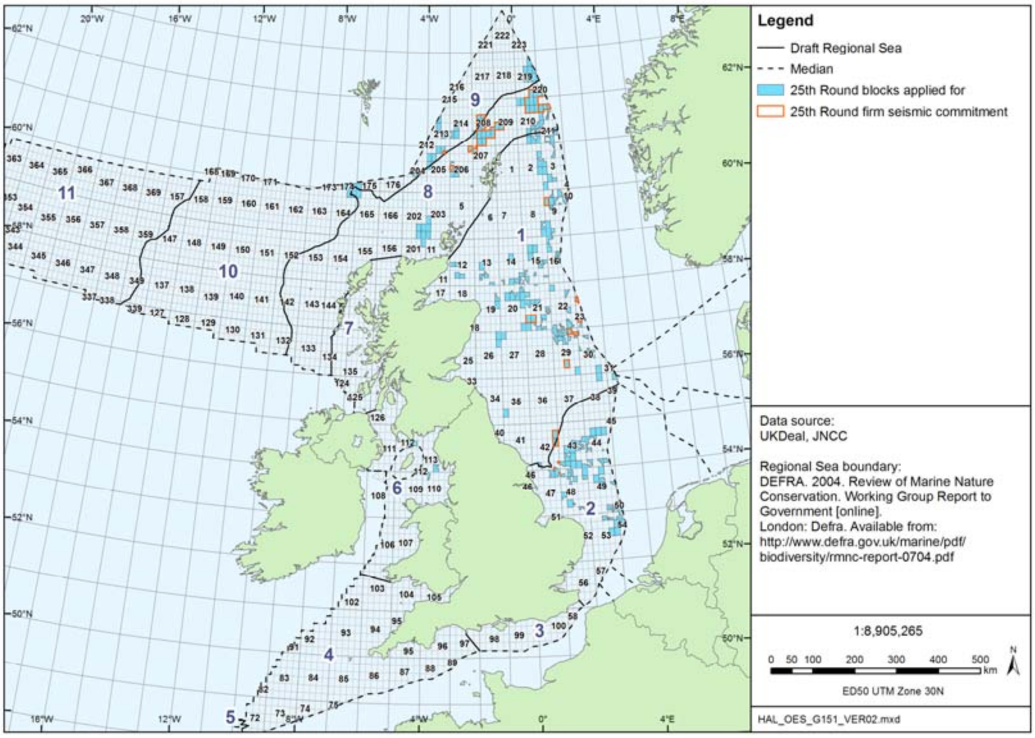
Figure 5.8 – Monthly number of surveys and volume of airguns in operation

Southern North Sea (= south of Dogger Bank); Central North Sea (= Dogger Bank - south of Shetland), Northern North Sea (= east and north of Shetland); Atlantic Margin = West of Shetland and Hebrides, Southwest Approaches = southwest of UK. *Source: DTI 2005a*

The 25th Round of licensing involved the offer of 2300 blocks covering all prospective areas of the UKCS, and has resulted in the offer of 171 Seaward Production Licences ('Traditional', 'Promote' and 'Frontier'). Applications for these included firm commitments for seven 2D and nine 3D seismic surveys in Regional Seas 1, 2 (North Sea), 8 and 9 (west of Shetland) see Figure 5.9 – around 30% of total seismic survey activity in 2006. The proposed programme of oil and gas licensing (i.e. a 26th Round) would be expected to generate a similar pattern of activity both in terms of quantity (subject to uncertainties associated with oil price and general economic climate) and location.

In addition, DECC's analysis of potential activity in Regional Seas 3, 4 and 5 (not previously covered by SEA) suggest a maximum of up to 500km^2 3D seismic acquisition in each of the English Channel, Bristol Channel and Western Approaches.

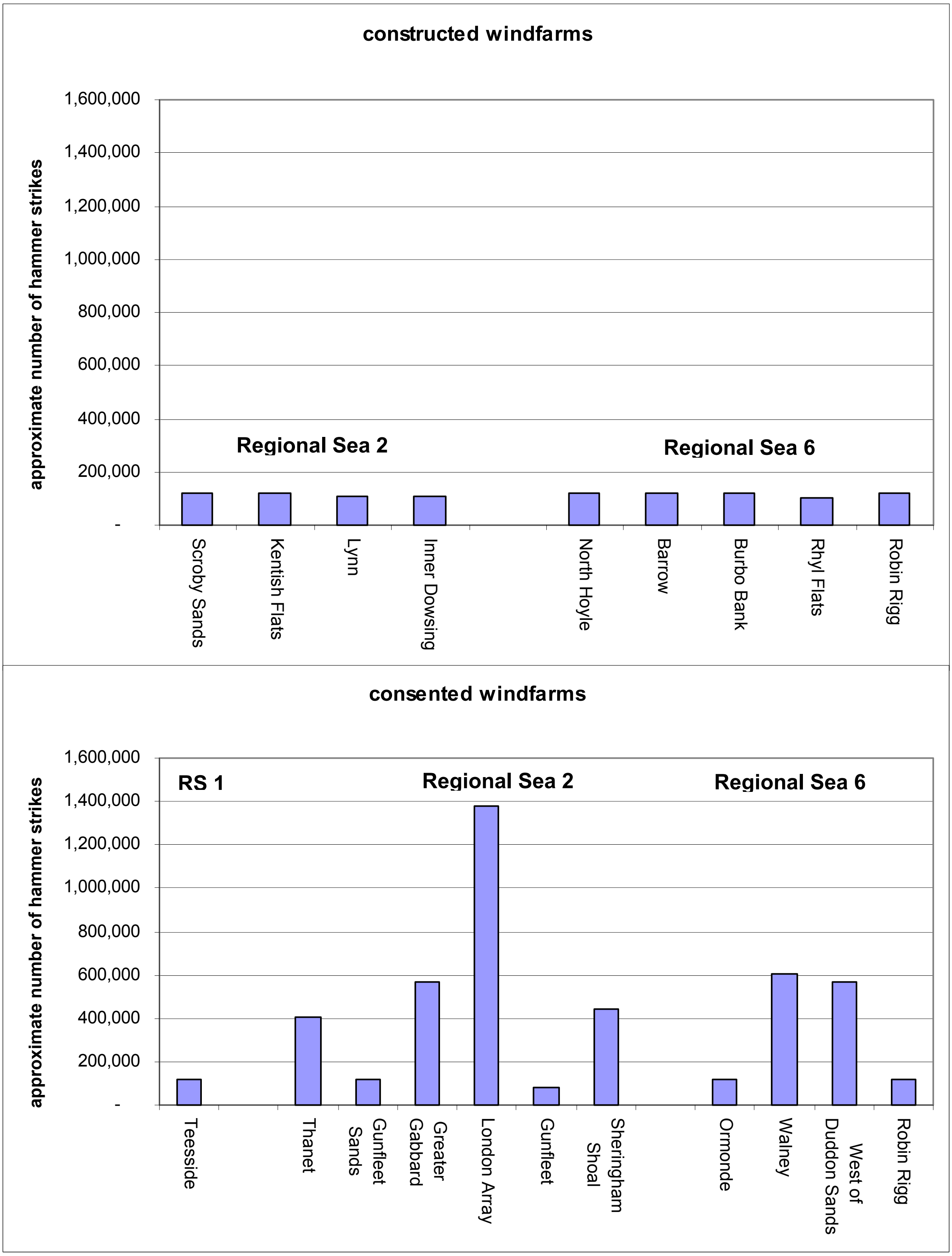
Figure 5.9 – Block applications and firm seismic commitments in the 25th Seaward Round



5.3.5.2 Offshore wind farm pile-driving

As of September 2008, a total of about 260 turbines had been constructed in Round 1 and Round 2 leased areas; with a further 1120 consented for construction. Virtually all of these had foundations of steel monopile construction. Assuming a hammer rate of 45/minute (range 30-60/minute; Thomsen *et al*. 2006) and duration of 90 minutes/pile (range 1-2h; Thomsen *et al*. 2006), this equates to approximately one million (1,048,950) hammer strikes to date, with a further 4.4M consented. These values could be halved or doubled, within the range of operational experience described by Thomsen *et al*. (2006). Making further broad assumptions about the construction rate of consented projects, the approximate strike rate of 0.5-1.5M/year, can be compared to historic seismic shot activity on the UKCS of around 1.7M/year (2000) to 10.6M/year (2006, see above), and predicted shot activity associated with the proposed licensing round of approximately 3.8M/year (derived by comparison with firm commitments resulting from 25th Round, and DECC expectations for effort in previously unlicensed areas of Regional Seas 3 and 4).

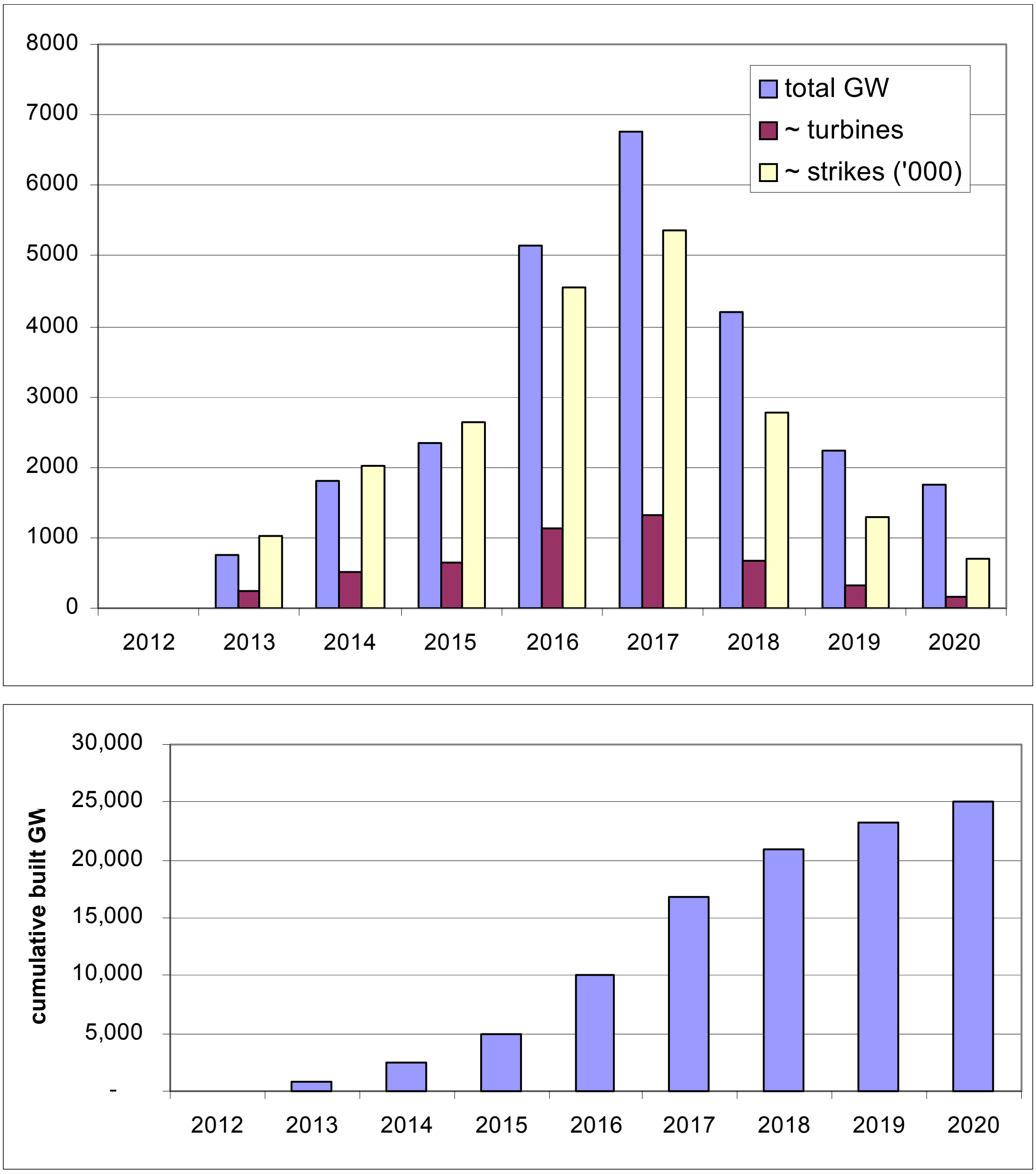
Figure 5.10 – Estimated number of pile-driving hammer strikes, Rounds 1 & 2 sites



Of the ~1M pile driver strikes carried out to date (Figure 5.10), approximately 460,000 have been in Regional Sea 2 (Scroby Sands, Kentish Flats, Lynn, Inner Dowsing) and 587,000 in Regional Sea 6 (North Hoyle, Barrow, Burbo Bank, Robin Rigg, Rhyl Flats). Consented projects expected to be constructed over the next few years are also predominantly in Regional Sea 2 (~3M strikes) and Regional Sea 6 (~1.4M strikes).

A nominal scenario of the potential quantity of pile-driving resulting from the proposed offshore wind leasing, as a function of the target of 25GW by 2020 together with likely developments in turbine size, is shown in Figure 5.11 (note that this assumes that all developments use monopile foundations).

Figure 5.11 – Predicted annual rate of turbine installation and pile-driving. Cumulative total of installed generating capacity also shown.



5.3.6 Summary of findings

As noted above, of the potential acoustic effects under consideration in this SEA, the most likely to be significant are considered to be the effects of pulse sources (associated with seismic survey and pile-driving) on marine mammals and possibly spawning fish. Longer-term, continuous acoustic disturbance effects associated with operational phases of development – both hydrocarbon production and wind turbine generation – were considered less probable in view of the source levels measured from these activities. The following section considers the potential for significant effect, and potential for mitigation, under the following rationale:

- Definition of possible spatial effects ranges; based on synthesis of source level characterisation, propagation characteristics and effects criteria discussed above
- Consideration of the potential for significant effects, using criteria recommended by JNCC guidelines to the OMR, and noise levels in relation to biologically meaningful disturbance effects
- Consideration of potential activity levels, and specific sensitivities of individual Regional Seas
- Identification of specific geographical areas of concern
- Consideration of requirements for seasonal avoidance (temporal mitigation)
- Consideration of operational mitigation
- Consideration of potential cumulative effects.

Based on the criteria developed by Southall *et al.* (2007) and the NMFS harassment criteria, indicative spatial ranges of injury and disturbance for cetaceans and pinnipeds may be calculated as indicated in Table 5.1.

These calculated ranges are broadly consistent with a wide range of environmental assessments for seismic surveys, and suggest that there is negligible risk of auditory damage to cetaceans, and a low to moderate risk of seals being within the required range (136m assuming modified cylindrical spreading) of pile-driving operations. Modified cylindrical spreading is usually considered to occur in water depths <1.5x range, i.e. spherical spreading (20logR) will occur to a range of 60m in a water depth of 40m (indicative of the maximum practicable water depth for monopile construction).

Table 5.1 Indicative spatial ranges of various injury and disturbance indicators for cetaceans and pinnipeds

	cetaceans		pinnipeds	
	seismic	pile-driving	seismic	pile-driving
nominal vertical source level (dB p-p)	260	250	260	250
horizontal array correction	-15	0	-15	0
effective horizontal source level	245	250	245	250
injury sound pressure level (multiple pulses; dB p-p)	230	230	218	218
required propagation loss	15	20	27	32
deep water (20logR) distance (m)	5.6	10.0	22.4	39.8
shallow water (15logR) distance (m)	10.0	21.5	63.1	135.9
behavioural response sound pressure level (single pulse; dB p-p)	224	224	212	212
required propagation loss	21	26	33	38
deep water (20logR) distance (m)	11.2	20.0	44.7	79.4
shallow water (15logR) distance (m)	25.1	54.1	158.5	341.5
NMFS level A harassment (dB rms)	180	180		
Equivalent peak sound level (dB p-p)	198	198		
required propagation loss	47	52		
deep water (20logR) distance (m)	224	398		
shallow water (15logR) distance (m)	1,359	2,929		
NMFS level B harassment (dB rms)	160	160		
Equivalent peak sound level (dB p-p)	178	178		
required propagation loss	67	72		
deep water (20logR) distance (m)	2,239	3,981		
shallow water (15logR) distance (m)	29,286	63,096		

To aid strategic (as opposed to site specific) consideration, using the density (derived from SCANS II data) and postulated significant group size for individual cetacean species, some indicative calculations of the effects threshold level (ETL) at which significant disturbance would occur (as a function of the spatial area a significant group would occupy), has been carried out. The ETL would be the noise level experienced at the edge of the area in which a significant group would occur and is therefore dependent on both population size and density. For species with large significant group size / low density, the ETL is calculated at the edge of a large area; for small groups/high density a small area). The ETL is then the sound level at the edge of this area if a seismic or pile-driving source was at the centre of the area. The ETL is therefore also dependent on source level and propagation loss. If the ETL exceeds a known effects threshold (derived from observational studies), a significant group effect is predicted. If the ETL is relatively low (below observed effects thresholds), there is unlikely to be significant effect. (Note that this makes the ETL somewhat counter-intuitive, in that a low ETL is “good”; a high ETL is “bad”). The advantage of this approach is that it integrates a number of separate “threads” of evidence – species population size, species abundance, source levels, noise propagation, and acoustic thresholds of effect) into a single analysis which can be activity-, location- and species-specific.

It is evident that ETLs predicted for all species except coastal populations of bottlenose dolphins are similar; 129.5-145.5dB rms re 1µPa assuming spherical propagation, 153.8-167.1dB rms re 1µPa assuming modified cylindrical propagation. This reflects a strong positive correlation between species density and significant group size. Due to the small significant group size of coastal bottlenose dolphins, this group has a higher ETL in the range 147.6-172.5dB rms re 1µPa, which is therefore more likely to correspond to a significant effect. All of these ETL values (i.e. sound pressures for a biologically significant response) are considerably lower than the behavioural response criteria proposed by Southall *et al*. (2007), based on a comprehensive review of the available data; 224dB (peak) re 1µPa (equivalent to 206dB rms re 1µPa), or of the TTS threshold in harbour porpoise measured by Lucke *et al*. (2007): single pulse 184db p-p re 1µPa (equivalent to 166dB rms re 1µPa). This would suggest that single seismic or pile-driving sources are generally unlikely to have a significant group effect with the possible exception of small odontocetes at locally high population densities.

The maximum densities recorded for bottlenose dolphin (coastal and offshore populations), harbour porpoise (North Sea/west of Scotland and Irish Sea/Celtic margin), white-beaked dolphin, minke whale and common dolphin have been used; with horizontal source levels estimated above, and both spherical and modified cylindrical (15log(R)) spreading considered (see Table 5.2).

Table 5.2 - Calculations of effects threshold levels (ETL) at which significant disturbance of cetacean groups could occur

	Maximum density* (/km²)	Group size**	Radius of area occupied*** (km)	Effects Threshold Level**** (ETL in dB rms required for significant effect			
				Pile-driving, 20log(R) propagation	Pile-driving, 15log(R) propagation	Seismic, 20log(R) propagation	Seismic, 15log(R) propagation
bottlenose dolphin (offshore population)	0.027	160	43.3	139.3	162.5	134.3	157.5
bottlenose dolphin (coastal population)	0.011	3	9.3	152.6	172.5	147.6	167.5
harbour porpoise (North Sea / west Scotland)	0.562	4600	51.0	137.8	161.4	132.8	156.4
harbour porpoise Irish Sea / Celtic margin)	0.408	1900	38.5	140.3	163.2	135.3	158.2
white-beaked dolphin	0.318	450	21.2	140.5	162.1	145.5	167.1
minke whale	0.028	330	61.2	136.3	160.2	131.3	155.2
common dolphin	0.056	1000	75.4	134.5	158.8	129.5	153.8

* the maximum density of animals recorded in relevant SCANS II sectors

** Group size, using 2% thresholds (of population abundance estimates) for species in favourable conservation status

*** the radius of a circular area in which the group would occur, given the maximum density of animals

**** predicted sound level at this radius, for nominal pile-driving (source level 250dBp-p re 1µPa; 232dB rms re 1µPa) and seismic survey (horizontal source level 245dBp-p re 1µPa; 227dB rms re 1µPa). This represents an Effects Threshold Level, at which a biologically significant response would have to occur for a group effect to take place

It is important to note that ETLs calculated above were for SCANS II sectors containing maximum cetacean densities and are therefore worst-case; the main exception to this are coastal bottlenose dolphin populations, for which peak population densities are probably under-estimated by the SCANS II methodology. It should also be noted that the variance of density estimates are relatively high; doubling the maximum density results in a consistent 3.0dB increase in ETL for spherical propagation (2.3dB for modified cylindrical propagation).

It is evident that ETLs predicted for all species except coastal populations of bottlenose dolphins are similar; 129.5-145.5dB rms re 1µPa assuming spherical propagation, 153.8-167.1dB rms re 1µPa assuming modified cylindrical propagation (this reflects a strong positive correlation between species density and significant group size.) Due to the small significant group size of coastal bottlenose dolphins, this group has a higher ETL in the range 147.6-172.5dB rms re 1µPa. All of these ETL values (i.e. sound pressures for a biologically significant response) are considerably lower than the behavioural response criteria proposed by Southall *et al*. (2007), based on a comprehensive review of the available data; 224dB (peak) re 1µPa (equivalent to 206dB rms re 1µPa), or of the TTS threshold in harbour porpoise measured by Lucke *et al*. (2007): single pulse 184db p-p re 1µPa (equivalent to 166dB rms re 1µPa). This would suggest that single seismic or pile-driving sources are generally unlikely to have a significant effect; with the possible exception of small odontocetes at locally high population densities.

However, as noted above, establishing meaningful received sound levels for more subtle behavioural or ecological disturbance has proved difficult, as have efforts to make statistically powerful observations of such disturbance in wild marine mammals. Given a typical visual observational limit of 500m (under favourable conditions), the low number of individuals which comprise the available dataset, and the inherent variability (and complexity) of the behavioural context, this is not surprising. Although Southall *et al*. (2007) were unable to derive explicit and broadly applicable numerical threshold values for delineating behavioural disturbance resulting from multiple pulse and non-pulse (i.e. continuous) sources, they did note that:

"*For all other low-frequency cetaceans* ([i.e. baleen whales excluding migrating bowhead whales, but] *including bowhead whales not engaged in migration), this onset was at RLs around 140 to 160 dB re 1µPa*".

"*The combined data for mid-frequency cetaceans* [most odontocetes] *exposed to multiple pulses do not indicate a clear tendency for increasing probability and severity of response with increasing RL*".

"*Due to….. the overarching paucity of data, it is not possible to present any data on behavioural responses of high-frequency cetaceans* [i.e. porpoises] *as a function of received levels of multiple pulses…. We note the need for empirical behavioural research in these animals using sound sources (such as airgun or pile-driving stimuli) unequivocally classified as multiple pulses*"

Table 9 from Southall *et al.* (2007) (Figure 5.12), based on only four quantitative studies, noting but excluding the seismic survey monitoring reported by Stone (2003) and reproduced below; summarises observed behavioural responses of mid-frequency cetaceans to multiple pulse noise categorised into 10dB bins, and is therefore directly relevant to the analysis of ETL presented above (the estimated range of ETLs cover the range 130-170dB and shown as a black bar in Figure 5.12).

Figure 5.12 – Table 9 reproduced from Southall *et al*. (2007)

	Received RMS sound pressure level (dB re: 1μPa)											
Response score	80 to <90	90 to <100	100 to <110	110 to <120	120 to <130	130 to <140	140 to <150	150 to <160	160 to <170	170 to <180	180 to <190	190 to <200+
9												
8												
7												
6					**0.17** (3)	**0.17** (3)	**0.17** (3)			**1.3** (4)		
5												
4												
3												
2												
1												
0			**0.25** (3)	**0.25** (3)	**3.0** (2)	**4.0** (2)				**6.7** (1, 4)		

Estimated range of ETLs: see above

*Number (in **bold**) of mid-frequency cetaceans (individuals and/or groups) reported as having behavioural responses to multiple pulse noise; responses were categorised into 10-dB RL bins, ranked by severity of the behavioural response (see Table 4 of Southall et al. 2007 for severity scaling), and combined with other observations having the same RL/severity score. A summary of the individual studies included in this table is given in the "Mid-Frequency Cetaceans/Multiple Pulses (Cell 5)" section of Southall et al. 2007. Parenthetical subscripts indicate the reference reporting the observations as listed in Table 8 of Southall et al. 2007.*

The majority of studies reviewed by Southall *et al*. (2007) therefore recorded no observable response (response score zero) within the noise range covered by ETLs required to qualify as a significant group effect; the observed effects (response score 6, corresponding to "*minor or moderate individual and/or group avoidance of sound source*") were recorded in beluga exposed to a 24 gun seismic source (Miller *et al*. 2005; also recording zero response in the same subject animals) and captive false killer whales (Akamatsu *et al*. 1993).

Overall, and at a strategic level, the preceding analysis suggests the following conclusions, in relation to individual seismic and pile-driving sources:

- Although quantitative observational data on behavioural responses to stimuli comparable to seismic and pile-driving sources are very sparse, such data as do exist indicate that responses are not biologically meaningful (i.e. zero response or minor/moderate avoidance) at these sound levels.
- There is a much greater sensitivity, with an ETL range of around 22dB, associated with propagation characteristics (spherical vs modified cylindrical propagation) than with uncertainty of population density estimates (around 3dB). By extrapolation, this implies that outwith coastal locations, there is greater value in mitigation which addresses source level (and specifically horizontal propagation) than in spatial location (over scales of 20-60km) in relation to cetacean distribution.
- The spatial scales of cetacean distribution are at least an order of magnitude greater than those which can be monitored by either visual or passive acoustic methods. Conversely, the spatial scales over which either observable or biologically meaningful effects are likely to result do not support significant groups of animals.

Qualitatively, these conclusions are consistent with those reached by previous SEAs, e.g. that:

"*The balance of evidence suggests that effects of seismic activities are limited, in species present in significant numbers…. to behavioural disturbance which is likely to be of short duration, limited spatial extent and of minor ecological significance. The numbers of individuals likely to be influenced represent a small to moderate proportion of biogeographic populations*." (SEA 7).

Predicted activity levels resulting from both a 26th oil & gas licensing Round, and 3rd Round of offshore wind leasing, are concentrated in Regional Seas 1, 2 and 6; with some additional oil and gas activity likely in Regional Seas 8/9 and OWF activity in Regional Seas 3 and 4. As noted above, it is likely that multiple sources (including simultaneous surveys and pile-driving) will occur at the same time, and that both activities may extend throughout much of the year, and be audible to marine mammals over much of the coastal Regional Seas. However, it seems improbable (given the spatial ranges discussed above) that injurious or strong behavioural levels of effect will coincide.

On the basis of the available data, it is therefore not considered that either regional or local prohibitions on the activities under consideration by this SEA are justified by acoustic disturbance considerations. Given the lack of definition of the actual survey and development programmes which may follow adoption of the draft plan/programme (in terms of duration and extent of acoustic sources, and the potential for temporal or spatial mitigation), it is also not possible to make specific recommendations concerning mitigation. However, it is noted that environmental assessments will be required on a project-specific basis for all areas under the existing regulatory regime, including requirements for consideration of deliberate disturbance of cetaceans (resulting in adverse effects on survival or breeding, or significant effects on local distribution or abundance) under the *Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007*. In addition, screenings/Appropriate Assessments will be required for activities which may affect marine mammal populations within designated SACs (see Appendix 5). Four blocks within Cardigan Bay and the inner Moray Firth applied for in the 25th oil and gas licensing round are presently subject to assessment under the Habitats Directive, which will inform decisions on their licensing.

Marine mammal sensitivities of individual Regional Seas – based on Appendix 3a.7 – are summarised below:

- **Regional Sea 1** is considered to have a moderate to high diversity and density of cetaceans, with a general trend of increasing diversity and abundance of cetaceans with increasing latitude. Harbour porpoise and white-beaked dolphin are the most widespread and abundant species, occurring regularly throughout most of the year. Minke whales are regularly recorded as a frequent seasonal visitor. Coastal waters of the Moray Firth and east coast of Scotland support an important population of bottlenose dolphins, while killer whales are sighted with increasing frequency towards the north of the area. Atlantic white-sided dolphin, Risso's dolphin and long-finned pilot whale can be considered occasional visitors, particularly in the north of the area. Large numbers of grey and harbour seals breed in the area, with high densities observed in many coastal waters and some areas further offshore.

- A small, seemingly resident population of bottlenose dolphins exists off the east coast of Scotland. They typically range from coastal waters of the Moray Firth to the Firth of Forth, with occasional observations from further offshore in the North Sea; the dolphins are most frequently sighted within the inner Moray Firth. The importance of this population, and the Moray Firth, is reflected in the designation of part of this area as a Special Area of Conservation (SAC).

- **Regional Sea 2** – compared to the central and northern North Sea, the southern North Sea generally has a relatively low density of marine mammals, with the likely exception of harbour porpoise. While over ten species of cetacean have been recorded in the southern North Sea, only harbour porpoise and white-beaked dolphin can be considered as regularly occurring throughout most of the year, and minke whale as a frequent seasonal visitor. Bottlenose dolphin, Atlantic white-sided dolphin and long-finned pilot whale can be considered uncommon visitors. Important numbers of grey and harbour seals are present off the east coast of England, particularly around The Wash where harbour seals forage over a wide area.

- **Regional Sea 3** – the eastern English Channel generally has a relatively low density and diversity of marine mammals; it is a transition zone between the communities of the southern North Sea and the western Channel/Celtic Sea. Bottlenose dolphins are the most frequently sighted species in coastal waters, followed by harbour porpoise - although these are considered quite rare. Further offshore, sightings are generally of long-finned pilot whales or common dolphin. The area is not particularly important for seals, with no major colonies present and very little activity recorded.

- **Regional Seas 4/5** experience a relatively high density and moderate diversity of marine mammals. Four cetacean species occur frequently in the Regional Sea 4 area: minke whale, bottlenose dolphin, short-beaked common dolphin, and harbour porpoise. Long-finned pilot whale and Risso's dolphin are also regularly encountered. Grey seals are present in the area, but in low densities relative to the rest of UK shelf waters. Harbour seals are rarely encountered.

- **Regional Sea 6** – five species of cetacean are known to occur regularly in this area: harbour porpoise, short-beaked common dolphin, bottlenose dolphin, Risso's dolphin and minke whale. Grey and harbour seals are also regularly present in certain areas. In the Irish Sea, there are concentrations of bottlenose dolphins off west Wales (particularly Cardigan Bay) and off the coast of Co. Wexford in southeast Ireland. Two areas within Cardigan Bay are designated Special Areas of Conservation (SACs) with this species as an interest feature: bottlenose dolphin is a primary feature of the Cardigan Bay SAC located in the south of the bay off the coast of Cardigan, New Quay and Aberaeron; and a qualifying feature of the Lleyn Peninsula and the Sarnau SAC in the northern end of the bay and around the Lleyn Peninsula.

- **Regional Sea 7** – the Minches and western Scotland support a rich diversity and high density of marine mammals. Harbour porpoise and white-beaked dolphins are widespread and numerous. They are encountered throughout the year, although most frequently during summer months, when Risso's dolphins, common dolphins and minke whales are also sighted fairly frequently. Small numbers of bottlenose dolphins also occur around coastal waters of the Hebrides. Killer whales are occasionally observed throughout the area, most notably around seal haul-out sites during summer. Both grey and harbour seals are abundant throughout the area.

- **Regional Sea 8** north and west of Scotland supports a rich diversity and density of marine mammals, and are considered one of the most important areas for these animals in northwest European waters. Containing a variety of habitats, the region supports species commonly associated with shallower coastal areas, offshore shelf waters, and those occupying the deeper waters of the shelf edge and slope. Ten cetacean species are known to occur regularly in this area: harbour porpoise, white-beaked dolphin, Atlantic white-sided dolphin, Risso's dolphin, bottlenose dolphin, short-beaked common dolphin, killer whale, long-finned pilot whale, sperm whale and minke whale. Large numbers of grey and harbour seals breed in the area, with high densities observed in many coastal waters and some shelf areas further offshore.

- **Regional Sea 9** – the Faroe-Shetland Channel supports a rich diversity and high density of marine mammals. Cetaceans known to regularly occur include: Atlantic white-sided dolphin, bottlenose dolphin, killer whale, long-finned pilot whale, and sperm whale. Beaked whales, common dolphins, Risso's dolphins, and fin, sei and minke whales are also recorded to a lesser extent, while other species of baleen whale such as blue and humpback are occasionally observed. Hooded seals occur to a limited extent, particularly in the north; grey and harbour seals are very uncommon.

- **Regional Seas 10/11** – knowledge of marine mammal occurrence in the deep waters beyond the shelf slope to the west of Scotland is poor relative to other areas in UK waters. However, available information suggests that this is an important area for cetaceans, with a variety of species and high densities recorded, both as residents and large whales on migration.

Key areas of marine mammal sensitivity therefore include:

- Fair Isle – Sumburgh Head (harbour porpoise, white-beaked dolphin, grey seal, harbour seal)
- North and east of Orkney (grey and harbour seals)
- The Moray Firth and coastal waters south to the Forth (bottlenose dolphin); including Smith Bank (grey and harbour seals), inner Firths (harbour seal), St Andrews Bay and outer Forth (grey seals)
- Areas adjacent to the Farne Islands and Donna Nook (grey seal)
- The Wash, outer Wash and off the Humber (harbour seal)
- Dogger Bank (harbour porpoise)
- Area between the Channel Islands and Start Point (common dolphin)
- Celtic Sea (common dolphin)
- Cardigan Bay (bottlenose dolphin)
- Ramsey and Skomer (grey seal)
- Hebridean Sea – Kintyre to Skye (harbour porpoise, grey seal, harbour seal)
- Continental shelf edge – Barra Fan to Miller Slide (various cetaceans, hooded seal)
- Stanton Banks (grey seal)
- North Minch and Cape Wrath to North Rona (harbour porpoise, white-beaked dolphin, Risso's dolphin, minke whale, grey seal)
- Hebridean shelf – notably around Monachs and Flannans (grey seal)
- Deep waters to the west of the UK (various cetaceans including migrating humpback and blue whales)

Previous SEAs have recommended that consideration should be given to establishment of criteria for determining limits of acceptable cumulative impact; and for subsequent regulation of cumulative impact (for example, in terms of total "exposure days" of individual blocks to received levels in excess of 120dB). A similar acoustic dose concept was recommended for the SEA 7 area – particularly the deep water part – by Harland & Richards (2006); although the relative merits of a limited acoustic dose approach, in contrast to a shorter period of intense activity, are unknown.

However, in view of the probable increase in pulse noise generation associated with the proposed combination of oil and gas licensing and offshore wind leasing, and concerns over cumulative effects (as yet not clearly understood), it is recommended that within the key areas of marine mammal sensitivity identified above, operational criteria are established to limit the cumulative pulse noise “dose” (resulting from seismic survey and offshore pile-driving) to which these areas are subjected. It will be necessary to consult with both industries to define the terms of such criteria; however, a simple approach may be suitable, such as combined number of “shots + strikes” [with a SL >230dB p-p] within a defined area, established to provide a xxkm [derived from 160dB] buffer. Such an approach could be implemented within the existing regulatory framework for activity consenting, particularly if initially developed and adopted voluntarily in collaboration within the industries (as was the case, initially, with the existing JNCC mitigation guidelines). The approach would also require a mechanism to facilitate the exchange of information, for example through a web – based forum hosted by DECC or JNCC.

5.4 Physical damage to features and biotopes

5.4.1 Introduction

Several activities associated with offshore wind farm development, exploration and production of oil and gas, and gas storage can lead to physical disturbance of seabed habitats, with consequent effects on seabed features and biotopes and potentially on archaeological artefacts. The main activities which may result in disturbance are:

- Piling of monopile or jacket turbine foundations
- Placement of gravity base foundations (including works to level the seabed)
- Laying and trenching of cables associated with offshore wind farms
- Anchoring of semi-submersible rigs
- Placement of jack-up rigs (seabed disturbance by spud cans)
- Wellhead placement and recovery
- Production platform jacket installation and piling
- Anchoring of floating production installations
- Subsea template and manifold installation and piling
- Pipeline, flowline and umbilical installation and trenching
- Decommissioning of infrastructure

5.4.2 Evidence base

Previous SEAs have compared the disturbance effects of oilfield activities to those of fishing and natural events (e.g. storm wave action), concluding generally that oilfield effects are minor on a regional scale. Similar considerations would be equally applicable to OWF development, and reflected in the Round 2 SEA. The most important human pressure in terms of its spatial extent and level of impact on the UK marine environment results from fishing (e.g. Dinmore *et al*. 2003, Gage *et al*. 2005, Eastwood *et al*, 2007, Stelzenmüller *et al*. 2008). With the exception of relatively few designated conservation sites and temporarily or periodically closed areas (for fishery stock management purposes), trawl scarring is effectively unregulated in the UK and can be a major cause of concern with regard to conservation of seabed habitats and species (e.g. Witbaard & Klein 1993, de Groot & Lindeboom 1994, Jennings & Kaiser 1998, Kaiser *et al*. 2002a, Kaiser *et al*. 2002b). On the UKCS, concern has focussed on the continental shelf, but with increasing concern in relation to deep water areas (Bett 2000, Roberts *et al*. 2000, Gage *et al*. 2005). The environmental impacts of trawling continue to be catalogued from a range of seabed habitats around the world (e.g. Mediterranean – Smith *et al*. 2000; Clyde Sea area – Hauton *et al*. 2003; Australian seamounts – Koslow *et al*. 2001; New Zealand seamounts – Clark & O'Driscoll 2003, Campbell & Gallagher 2007). However, implementation of effective mitigation measures is difficult at either a national or international scale (Gianni 2004, UNEP 2006).

To date, and for the foreseeable future, both hydrocarbon and OWF developments in the UKCS have taken place in areas which are either too deep, too turbid or of unsuitable substrate for seagrass or macroalgae to be present; the biotopes of concern are therefore dominated by faunal communities.

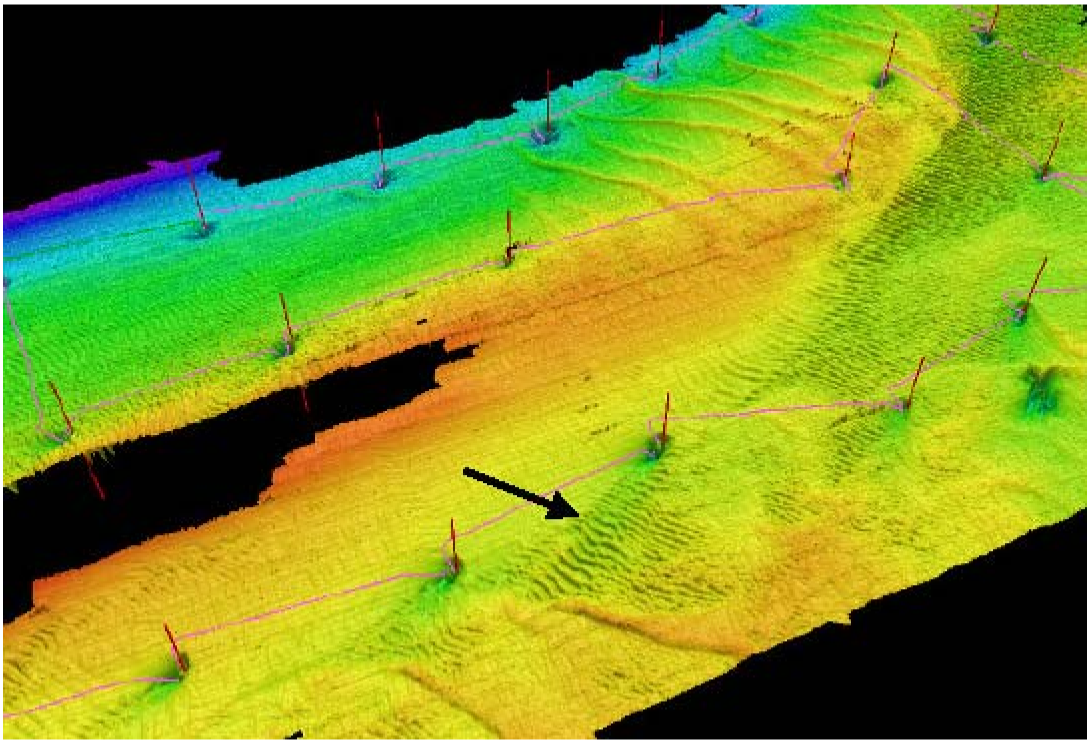
In general, physical damage effects on benthic populations and communities may result from smothering which can be direct (from physical disturbance or discharges of particulate material) or indirect (scour, or winnowing of disturbed material). The scale of direct damage to features and habitat loss associated with long-term placement of structures on the seabed is generally in proportion to the size of the object, and the duration of effect is equal to the operational lifespan of the structure – or may be indefinite if complete removal is not feasible or cost-effective. In the case of scour-related effects, the scale may be significantly greater than that of the fixed structure (see below).

Scour – a localised erosion and lowering of the seabed around a fixed structure – was recognised as an issue in relation to wind farm foundations at an early stage in the development of offshore locations, and has been subject to considerable research and monitoring. A two-stage project to identify, collate and review available field evidence for scour and scour protection from built Round 1 and other European sites was carried out for the UK Government RAG programme (ABPmer 2008, HR Wallingford 2008); these reports also provide a comprehensive bibliography of relevant literature. Five sites formed the principal datasets used in the study (Barrow, Kentish Flats, Scroby Sands, North Hoyle and Arklow Bank); all using monopile structures but representing a range of hydrodynamic conditions. Scour is a complex process, involving various interactions between the structure and water flow patterns and with implications for structural stability of the structure and sediment transport in the vicinity. Scour depth around piles is often quantified in relation to the pile diameter (S/D): HR Wallingford (2008) reported significant scour at Barrow (up to 0.44D), Kentish Flats (up to 0.46D), Scroby Sands (prior to rock dump scour protection, up to 1.38D), and Arklow Bank (prior to rock dump scour protection, up to 0.8D). These values equate to a maximum scour depth of around 6m (at Barrow and Scroby Sands). At both Scroby Sands and Arklow Bank, secondary scour i.e. not adjacent to the foundation itself, followed the installation of scour protection. Little or no scour (<0.125D) was observed at North Hoyle – it is not clear whether this was due to the presence of scour protection, the redistribution of drill cuttings (resulting from pilot hole drilling for the piles) which arose during the installation process or natural infill (HR Wallingford 2008). In the context of physical damage to features and biotopes, the key aspects are the spatial extent, severity and variability of scour, and of increased sediment deposition outside the scour footprint; together with whether the scour exposes seabed habitat which is significantly different from the original surficial sediment.

At Barrow, where the seabed consists mainly of sand overlying tillite and clays to a depth reaching 10m but including bedded muddy sands in this surface layer, the scour hole radius of individual piles varied from 0 to 15.7m at up to 62 days following pile installation. The typical scoured area at this location was of the order of 50-100m^2, and exposed sediments different to the pre-installation substrate (but typical of till exposures in the area). One year later, scour radii were apparently lower, with areas typically in the range 3-12m^2 (excluding the pile itself) and scour depths for most piles had not changed, suggesting that the mobile surficial layer had already been removed. The turbines which experienced greatest scour were located to the west of the wind farm area, where the bed consists of fine to medium sand and the thickness of the surficial layer is greatest.

At Scroby Sands, 30 monopiles of 4.2m diameter were installed between November 2003 and February 2004 with a minimum distance between monopiles of 320m. In addition to baseline and construction surveys, swathe bathymetric surveys have been carried out under FEPA licence monitoring conditions, giving a total 4 year time series. Analysis by CEFAS (2006) indicates the development of scour pits associated with the monpiles (typical depths up to 5m and horizontal diameter 60m); and scour tails (trains of bedforms) extending from one monopile to the nearest downstream neighbour (see Figure 5.13). Seabed biotope within the scour pits is likely to be significantly altered, whereas it is probable that the depositional and more extensive scour tails do not result in significant habitat alteration (NB the whole area is characterised by active sandwaves, which do not appear to be influenced by the construction; CEFAS 2006).

Figure 5.13 – Fledermaus image looking northwest showing swathe bathymetry of February 2005 from the Scroby Sands OWF. Arrow shows bedform “tail” downstream from monopile

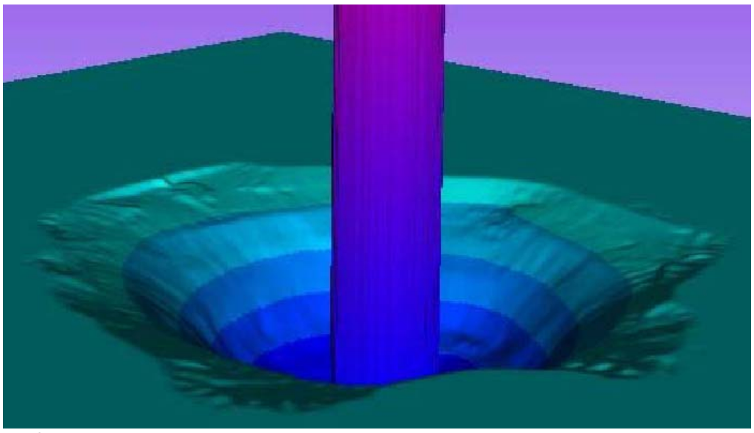


Source: CEFAS (2006)

The seven wind turbine monopiles at Arklow Bank Wind Park (eastern coast of Ireland) are influenced by strong currents (>2m/s) and design wave heights approaching 6m, with a water depth of 5m over the crest of the bank (i.e. depth-limited wave-breaking occurs during storms). In the short delay between monopile installation and scour protection, scour holes (4m depth, 25m diameter; Figure 5.14) developed due to tidal current alone. Scour protection appears to have stabilised the bathymetry, with raised areas around some piles probably representing rock armour. The spatial extent of biotope modification is therefore around $450m^2$ per pile.

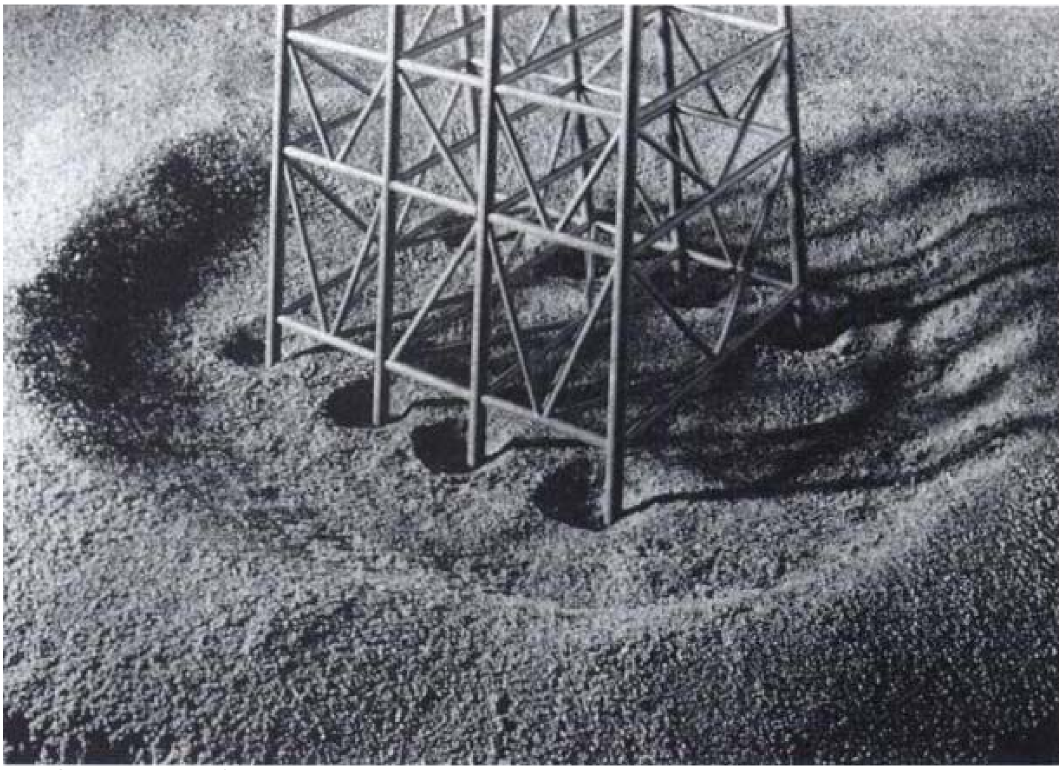
Although jacket structures piled to the seabed have been extensively used throughout the UKCS for oil and gas production, and have experienced substantial scour (and employed scour protection measures) in the southern North Sea (van Dijk 1980), this appears to have been regarded as much less of an environmental concern than for OWF developments. For example, Watson (1973) reported rapid scour around gas platform jacket legs in the southern North Sea to a depth of 1.5-3.5m, with (in some cases) individual scour pits coalescing to form a depression ("dishpan" or "global scour") over a much bigger area, of the same order as the area of the structure supported by the piles (Figure 5.15). Scour protection in the form of gravel, rocks, sandbags, gabions, pre-formed concrete blocks and frond mats is routinely used for subsea structures and for pipelines to prevent free-spanning (with resulting structural and snagging risks), although not always successfully.

Figure 5.14 – Scour hole observed after monopile installation, Arklow Bank



Source: HR Wallingford (2008)

Figure 5.15 – Representation of global and local scour development around a jacket structure



Source: Angus & Moore (1982)

Changes in the benthic communities in the vicinity of the FINO I research platform (German Bight; 28m water depth) were described by Schröder *et al*. (2006). In addition to colonisation of hard surfaces by epifaunal species, changes in sediment composition in the surrounding area due to hydrodynamic effects and the exclusion of trawling were noted. Within scour pits (1-1.5m deep; up to 5m radius), sediment was much more heterogenous following construction, and consisted of a layer of shell hash (sometimes more than 30cm thickness) in contrast to the fine sand baseline substrate. Changes in faunal communities were consistent with this (i.e. loss of typical sand infauna including *Tellina* (*Fabulina*) *fabula*, *Echinocardium cordatum*, *Poecilochaetus serpens*, *Chaetozone setosa*, *Spiophanes bombyx*) and increase in mobile predators (*Pagurus bernhardus*, *Liocarcinus holsatus*). The polychaete *Eunereis longissima* also appeared in large numbers within the scour pit (<5m from the pile). Over a wider scale, observed changes over a one-year timescale were related to the absence of fishing in a 500m exclusion zone – increased densities of sedentary filter and deposit feeders; reduced abundance of mobile predators and scavengers compared to fished areas. These effects are probably widespread in relation to exclusion zones around oil and gas infrastructure in the North Sea, but have not been well characterised in monitoring studies (which are focussed on the detection of point source disturbance and contamination effects from the installation). However, Bergman *et al*. (2005) documented a distinct difference between the fishery-closed area around gas production platform L07A in the southern North Sea (Frisian Front) and those from the regularly trawled reference areas. Conspicuous differences included higher species richness and evenness in dredge samples and higher abundances of mud shrimps (*Callianassa subterranea*, *Upogebia deltaura*) and sensitive bivalves (*Arctica islandica*, *Thracia convexa, Dosinia lupinus, Abra nitida*, *Cultellus pellucidus*) in the non-fished area near the platform. Boxcore samples confirmed the higher abundance of mud shrimps in the non-fished platform subarea and also demonstrated higher densities of the brittlestar *Amphiura filiformis*.

There has been considerable monitoring at two Danish OWF sites, Horns Rev and Nysted since their construction in 2002-2003 (DONG Energy *et al*. 2006). Overall, the main effect from establishing the wind farms was the introduction of hard bottom structures (turbine foundations and scour protection) onto seabeds that almost exclusively consisted of sandy sediments. This has increased habitat heterogeneity and changed the benthic communities at the turbine sites from typical infauna communities to hard bottom communities. There were only negligible or no impacts detected from the changes in the hydrodynamic regimes on the native benthic communities, seabed sediment structure or established epifouling communities. At Horns Rev, a general increase in sediment coarseness and changes in infaunal community structure was found from the pre-construction to the post-construction situation. The changes were not attributable to the presence of the wind farm because parallel changes were found at the reference sites. Similarities in the establishment, succession and distribution of epifouling communities on structures and scour protection were found between the Horns Rev and Nysted Offshore Wind Farms. The differences in species composition were mainly attributable to differences in salinity between the two sites.

Benthic monitoring has been carried out under FEPA licence conditions at constructed Round 1 OWF sites in the UK; resulting in a monitoring timescale of several years at some sites. In general, community disturbance outside the immediate area around piles has been minimal, and difficult to distinguish from natural variability. As noted above, exclusion of fishing activity is likely to be a significant factor at most locations, and is difficult to control for in experimental design. For example, at North Hoyle a combination of grab survey and beam trawls were used to assess effects on infauna and epifauna: changes were observed in numbers of species and individuals, but with no uniform pattern, similar changes at control stations and no substantial evidence for changes to biotopes from baseline conditions

(Npower 2007). At Barrow, an epifaunal survey carried out eight months after installation of the piles (RSK ENSR 2006) reported a typical fouling community dominated by barnacles, mussels, anemones (*Metridium senile*), and hydroids; shrimp (*Crangon*) and whiting were observed in large numbers, particularly where mussel populations were well developed. Despite the scour previously observed at this development (see above), the epifaunal survey noted no effects on seabed habitats, which were variable and ranged from fine sand to cobbles (consistent with a patchy sand veneer over glacial till).

Habitat recovery from temporary disturbance caused by, for example, anchor scarring, anchor mounds, cable scrape and trenching will depend primarily on re-mobilisation of sediments by current shear. Benthic population recovery takes place through a combination of migration, re-distribution (particularly of microfaunal and meiofaunal size classes) and larval settlement. On the basis that seabed disturbance is qualitatively similar to the effects of wave action from severe storms; it is likely that sand and gravel habitat recovery from the processes of anchor scarring, anchor mounds and cable scrape is likely to be relatively rapid (1-5 years) in most of the shallower parts of the UKCS. Muddier sediments support benthic communities characterised by the presence of large burrowing crustaceans and pennatulid sea-pens (*Virgularia mirabilis* and *Pennatula phosphorea*). Pennatulid mortality is probably high following physical disturbance, although crustacea are probably able to restore burrow entrances following limited physical disturbance of the sediment surface (a few cm). However, mud habitats are probably more sensitive to physical disturbance than the coarser sediments typical of high wave- and current-energy areas.

Herring are demersal spawners and dependant on localised areas of suitable substrate (in relatively shallow water); herring eggs are believed to be particularly susceptible to smothering, and there has therefore been a requirement for many years that potential herring spawning areas are identified by sidescan sonar and seabed sampling in advance of oil and gas drilling and development; and that appropriate mitigation such as timing and/or avoidance of specific areas is undertaken with the prior approval of regulatory agencies. Similar controls are applied through the EIA and FEPA licensing processes to OWF developments.

In addition to the potential effects of smothering, sediment plumes in the water column and settling to the seabed from construction activities and cable or pipeline trenching activities can potentially result in effects on pelagic and benthic 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 (see also studies of thin-layer (<15cm) disposal of dredged material, Wilber *et al*. 2007). Near-bed concentrations of suspended particulate material (SPM) in coastal and southern North Sea areas and in the Irish Sea are high, and the effects of anthropogenic sediment plumes are unlikely to be significant or long-term.

On the UKCS, habitats which potentially qualify as biogenic reefs under the Habitat and Species Directive Annex I are associated with several species: blue mussels *Mytilus edulis*, horse mussels *Modiolus modiolus*, ross worms *Sabellaria* spp., the serpulid worm *Serpula vermicularis*, the bivalve *Limaria hians* and cold-water corals such as *Lophelia pertusa*. These habitats may be vulnerable to physical damage and smothering. In the case of designated, proposed or candidate Natura 2000 conservation sites (including potential offshore sites which may be designated in future), existing controls include the requirement for an Appropriate Assessment before consent for the proposed activity can be given.

In relation to OWF development, because of the likely distribution of these, *Sabellaria* reef is the most likely qualifying habitat to be affected by direct physical damage. *Sabellaria* is probably relatively tolerant of indirect disturbance (e.g. turbidity resulting from sediment mobilisation or scour), with high potential for recovery; but reefs are clearly susceptible to damage from direct impacts such as fishing (Holt *et al*. 1997, Jackson & Hiscock 2008). Subtidal *Sabellaria spinulosa* reefs are reported to have been lost due to physical damage in at least five areas of the northeast Atlantic. In the Waddensee, Riesen & Reise (1982) reported that extensive subtidal *S. spinulosa* reefs were lost from the Lister Ley, island of Sylt, between 1924 and 1982; they reported that local shrimp fishermen claimed to have deliberately destroyed them with "heavy gear" as they were in the way of the shrimp trawling. Reise & Schubert (1987) reported similar losses from the Norderau area, and attributed them to similar causes. Shrimp trawling still occurs in these areas and the *S. spinulosa* have not reappeared, but have effectively been replaced by mussel *Mytilus edulis* communities and assemblages of sand dwelling amphipods (Reise & Schubert 1987). In Morecambe Bay, fisheries for pink shrimp *Pandalus montagui* have been implicated in the loss of subtidal *Sabellaria* reefs in the approach channels to the Bay (Mistakidis 1956, Taylor & Parker 1993). Aggregate extraction is also clearly implicated in damage to *Sabellaria* reefs (Holt *et al*. 1997); although this activity is subject to licence controls and compared to fishing impacts, gravel extraction is likely to be more limited in extent, more controlled, and less likely to continue for very long time periods, so that although direct damage would obviously be severe, recovery from adjacent undamaged areas seems more likely.

Sabellaria spinulosa and *S. alveolata* (which also forms reefs) are both widely distributed, and reef-forming populations are known to be spatially patchy and temporally variable (see Appendix section A3a.2.5.5 for discussion of observed changes of the Saturn reef). Direct impact of OWF foundations will be of relatively limited spatial extent, and in view of the wide habitat tolerance of *Sabellaria* it is likely that scour protection would be as likely to support aggregations as surrounding seabed (particularly when overlain by a sand veneer). Cable placement and trenching, both within the array and shore cables, may have a greater spatial extent of disturbance, but will be of short duration and biotopes will recover rapidly over buried cables. OWF development would therefore have little effect at a population level; and local disturbance may well be offset by protection from mobile fishing effects over a substantially wider area. Conversely, decommissioning plans (e.g. Thanet Offshore Wind Ltd 2007) have already conjectured that removal of foundations or scour protection may have an adverse effect on any *Sabellaria* reef aggregation which is expected to develop during the operational life of the farm; and that it will be necessary to adopt an approach to decommissioning that makes the wind farm area safe for users of the sea, whilst also maintaining the extent and distribution of any *Sabellaria* aggregations conjectured to be of importance to nature conservation.

Two areas currently under consideration as offshore SACs are the North Norfolk Sandbanks and Dogger Bank (JNCC 2008a, g, h). Although both are under consideration as Annex I sandbanks which are slightly covered by sea water all the time, the physical geology of the two areas is very different. The North Norfolk sandbanks as a group are the best example of tidal linear sandbanks in UK waters; sandwaves are present on the banks indicating that the surface sediment is regularly mobilised by tidal currents (JNCC 2008a). The North Norfolk banks are active systems that are thought to be progressively, although very slowly, elongating in a north-easterly direction although it is difficult to demonstrate whether or not such migration occurs today and at what rate (Cooper *et al*. 2008). However, recent observations of water movement, sand wave asymmetry and sand tracers support an offshore sand transport component (Collins *et al*. 1995) with material transported offshore partly contributing to the development and maintenance of the sandbank system, and eventually dissipated into deeper waters. It has been suggested that new embryonic sandbanks are present in the swales between the banks.

In contrast, the Dogger Bank was formed by glacial processes before being submerged through sea level rise. Tidal current velocities across the Dogger Bank are considered insufficient for initiating sediment transport although large parts of the Dogger Bank are however situated above the storm-wave base: Klein *et al*. (1999) estimated that during a storm event, sediment up to medium sand was mobilised in 60m water depth at the northern slope of the Dogger Bank. The morphology of the Dogger Bank is largely controlled by the extent of the Dogger Bank Formation, a geological formation up to 42m thick that was deposited at the end of the last ice age (Cameron *et al*. 1992) and is overlain by Holocene sands of variable thickness. Coarser gravelly sand and sandy gravel substrates together with isolated patches of larger pebble and cobble-sized particles have been recorded in southern and western sections of the bank.

Hypothetically, therefore, anthropogenic structures or activities which interfered with sediment mobility could – over an extended timescale – influence the physical structure and habitat of the North Norfolk banks but would be very unlikely to significantly influence the Dogger Bank. However, scour, scour tails (as observed at Scroby Sands) and the required extent of scour protection are of limited spatial extent in relation to the overall OWF footprint (see below) and it is considered extremely unlikely that OWF development would have a significant influence on the physical habitat in either area.

OWF and oil and gas activities also have the potential to damage archaeological artefacts and sites, in particular through the trenching of cables and pipelines into the seabed and through rig and other vessel anchoring. However, in addition to the potential for damage, oil and gas activity is also recognised to present the opportunity to provide beneficial new archaeological data, for example through rig site or pipeline route mapping and sediment coring. Flemming (2005) therefore suggested that rather than seeking to prevent or limit oil and gas activities, "it is therefore in the interests of long term preservation of the archaeological sites, and in the interests of acquisition of archaeological knowledge, that we use industrial and commercial activities as a means of identifying archaeological prehistoric sites in the offshore area". The recognition of the importance of prehistoric submarine archaeological remains has led to a number of recent initiatives.

A legal and policy framework for protection of maritime archaeology is in place. Guidance notes for the aggregates industry have been formally published (BMAPA and English Heritage, 2003) covering legislation, statutory controls, possible effects of aggregate extraction, obtaining archaeological advice, application procedures, assessment, evaluation, archaeological investigation, mitigation, and monitoring. Flemming (2005) suggested that an equivalent guide could be produced for the offshore oil and gas industry and its contractors; such a guide was published in the same year for Irish waters by Quinn (2005) but the majority of the information and advice is applicable to operations in the UK.

COWRIE (2008) has also commissioned guidance on the assessment of cumulative impacts on the historic environment arising from offshore renewable energy projects. The guidance focuses on key elements of the cumulative assessment process, including an integrated approach, consideration of other actions, scoping, baseline study, impact dimensions, constraints, mitigation, monitoring and management, and communication.

5.4.3 Spatial consideration

As discussed above, the spatial footprint of OWF monopile foundations is typically in the range 4-6m, with (in many cases) associated scour protection laid to a radius of 10-20m from the pile. The direct footprint of the monopiles would therefore be around 20m^2 (2000m^2 for a nominal 500MW array; 100,000m^2 for a total 25GW development scenario). The scoured area, in the absence of scour protection, would be around 1000m^2 (0.1km^2 for a nominal 500MW array; 4.8km^2 for a total 25GW development scenario)

In the worst case that four-legged jacket foundations are used, with each leg experiencing scour (or requiring scour protection) of the same magnitude as a monopile, the proportion of the seabed within the OWF array under the total "footprint" is <0.2%. For a total 25GW generation scenario, the total footprint associated with monopiles and scour is <5km^2 (or possibly up to 12km^2, if 50% of generating capacity used four-legged jacket foundations).

Although the spatial area of seabed affected by export cables is obviously dependent on the location of OWF developments, a broadly indicative area can be calculated by assuming a 2m corridor width, and 500MW developments at an average of 25km from shore; as 2.5km^2. As a first approximation, the spatial area affected by intra-array cabling would equal the average turbine spacing multiplied by a corridor width of 1m; 0.002km^2/turbine or 10km^2 for the 25GW scenario. It should be noted that seabed biotope disturbance for the cable footprint would be temporary, with rapid recovery expected following trenching of the cables.

5.4.4 Cumulative impact considerations

Estimates of the intensity of trawling disturbance, and of the resilience and recovery timescale of benthic communities, vary for different parts of the UKCS, although for context previous SEAs included a conservative estimate of the scale of effect (assuming a fishing effort of 2000 hours per year per 0.5º ICES rectangle, average trawl speed of 4 knots, twin scars from trawl doors, 1m scar width; neglecting clump weights used in twin-trawl gears) is of the order of several billion square metres (or thousand square kilometres) of trawl scarring per year in the North Sea.

On the basis of known fishing activities, trawl scarring is likely to be present over much of the UKCS seafloor; with the effects of scallop dredging particularly significant in shallow water (since the gear is more damaging and sensitive habitats – such as biogenic reef – may be affected). Trawling in very deep water (>1000m) requires heavy gear, including clump weights of several tonnes, and may therefore also be more damaging than typical whitefish or *Nephrops* trawling. Trawl/dredge scarring is evident in sidescan coverage acquired from all previous SEA areas.

Eastwood *et al*. (2007) describe and quantify the major sources of direct, physical pressure (not chemical or biological) from human activities in 2004 on seabed environments in UK offshore waters (in fact only in England and Wales), by regional sea. This analysis considered oil and gas exploration and production, wind farm construction and operation, cable laying, extraction of marine aggregates, waste disposal, fishing with mobile seabed gear, and wrecks at sea arising from military activity and marine accidents. Likely and known effects of these activities were assigned to pressure categories and types using estimates of the spatial extent or the "footprint" of each activity as a proxy for direct, physical pressure and did not quantify the pressure intensity (e.g. the number of times a pressure was superimposed, such as the number of passes of a trawl per m^2). In the case of wind farms, a buffer area corresponding to a 100m diameter was assumed to estimate the spatial extent of "abrasion" associated with scour. Aggregate extraction footprint was estimated by modelling sediment plumes; while fishing pressure was based on VMS data (i.e. excluding vessels <18m or <15m after 2005), corrected to include the entire fleet by comparison with overflight data.

Unsurprisingly, demersal trawling was estimated by Eastwood *et al*. (2007) to have affected a larger area of seabed than all other pressure types combined. The initial estimate of 13,902km^2 (5.4% of seabed) was adjusted to 55,504km^2 (21.4% of seabed) to take account of track deviation and under-representation of the fleet by VMS data, and is therefore of the same order of magnitude as (but several times larger than) the previous SEA estimate. Eastwood *et al*. (2007) rated confidence in their estimate of trawling footprint as low, since both location and extent were estimated. Sediment plumes resulting from marine mineral dredging had an estimated footprint of 2,995km^2, while oil and gas fixed infrastructure (platforms, wells and pipelines) accounted for 5.4km^2 (NB this analysis excludes the major areas of North Sea development; the total figure for the North Sea might be four or five times greater. A previous estimate for ICES using 1986 data, reported by de Groot (1996) estimated that 399 platforms in the North Sea (UK, Norwegian, Dutch and German sectors) covered 313km^2, whereas pipelines covered 8,374km^2, both of which appear substantially over-estimated (platform footprint may include seabed area contaminated by drill cuttings; pipeline estimate was apparently based on a 1km corridor width). Existing wind farm footprint was estimated by Eastwood *et al*. (2007) to be <0.1km^2, with high confidence.

The depth of sediment over-turned (and possibly therefore the recovery timescale) of OWF cabling and E&P activities may be greater than many other sources of industrial seabed disturbance. However, the combined contribution of 25GW of OWF and further E&P developments on the UKCS to cumulative disturbance of the seabed (~30-50km^2 and ~20km^2 respectively) is not considered likely to be significant over the timescales envisaged. This is particularly so in areas of sediment mobility resulting from strong tidal streams and in shallower waters where periodic sediment disturbance occurs by oscillatory currents from passing waves. The scour- or scour protection-related footprint of fixed installations in hydrodynamically active areas (e.g. the southern North Sea and parts of the Irish Sea) will have a duration equal to or beyond the lifetime of the development.

5.4.5 Summary of findings and recommendations

Physical disturbance associated with activities resulting from proposed oil and gas licensing and OWF leasing will be negligible in scale relative to natural disturbance and the effects of demersal fishing. The potential for significant effects, in terms of regional distribution of features and habitats, or population viability and conservation status of benthic species, is considered to be low.

The broadscale distribution of biotopes of conservation importance is relatively well mapped, and sufficient information is available to assess the probability and sensitivity of sensitive habitats in proximity of proposed activities. Similarly, specific projects can be assessed in terms of likelihood of significant archaeological features. In both cases, however, detailed site surveys (which are routinely acquired prior to development operations) should be evaluated with regard to environmental and archaeological sensitivities.

5.5 Physical presence - ecological implications

5.5.1 Introduction

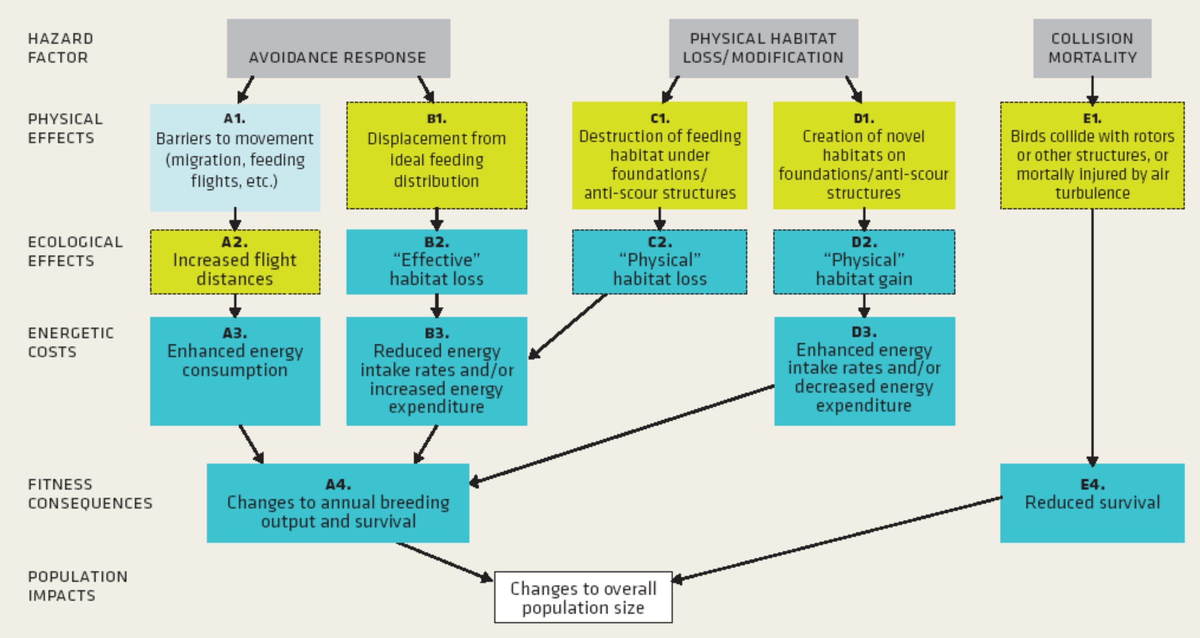
Physical presence of offshore infrastructure and support activities may potentially cause behavioural responses in fish, birds and marine mammals. Previous SEAs have considered the majority of such responses resulting from interactions with offshore oil and gas infrastructure (whether positive or negative) to be insignificant; in part because the total number of surface facilities is relatively small (of the order of a few hundred) and because the majority are at a substantial distance offshore, in relatively deep water. This assessment is considered to remain valid for the potential consequences of future Rounds of oil and gas licensing, including for gas storage. However, the large numbers of individual surface-piercing structures in OWF developments, the presence of rotating turbine blades and considerations of their location and spatial distribution (e.g. in relation to coastal breeding or wintering locations for waterbirds), indicate a higher potential for physical presence effects.

The screening, assessment workshop and consultation processes within the SEA process identified the following broad categories of potential physical presence effect:

- Displacement and barrier effects – distributional effects associated with displacement from ecologically important (e.g. feeding, breeding) areas; or with disturbance of regular movement (e.g. foraging, migration) of receptor species: principally fish, birds and marine mammals
- collision risk – in part based on experience with onshore wind turbines, the risk to birds (and potentially bats and insects) of collision with turbine blades and other overhead structures. Also within this category, there is a potential risk of interaction with gas flares, or fixed structures
- the disturbance effects of light, particularly where this may interact with barrier or collision risks
- fouling - the presence of artificial substrate for colonisation by plant and epifaunal species
- stepping stones – the potential for artificial substrates, or effects on natural habitats (such as localised warming) to facilitate colonisation by non-indigenous species
- electromagnetic fields (EMF) – although indirectly related to the physical presence of structures, EMF has been identified as a potential source of effect resulting from marine electricity transmission.

These potential effects, particularly displacement, do not represent simple causative relationships, with assessment in many cases complicated by subtle and unpredictable interactions between functional ecological processes (e.g. between behavioural modification and energetic cost); feedback processes (for example Maclean *et al*. 2007a) note that mortality resulting from wind farm collisions may reduce competition for resources, thus reducing the rate of natural mortality); the importance of stochastic events, particularly to small populations (also noted by Maclean *et al*. 2007a); habituation; and the presumed functioning of processes which are difficult or impossible to measure (Figure 5.16). Figure 5.16 illustrates the “Danish model” describing the three major hazard factors (grey boxes) to birds from offshore wind farms, showing their physical and ecological effects on birds, the energetic costs and fitness consequences of these effects, and their ultimate impacts on the population level (white box). The light green boxes indicate potentially measurable effects, the dark blue boxes indicate processes that need to be modelled.

Figure 5.16 – "Danish model" flow chart for the three major hazard factors to birds



Source: Dong Energy et al. (2006) (a similar chart is used by Fox et al. 2006)

There is also a considerable range in the quantity of, and confidence in, information relating to these issues. Some (e.g. displacement and collision risks for birds) have been subject to a considerable research effort, although this is largely predictive; others (fouling) have been extensively monitored over a substantial time period; and some are relatively speculative. Furthermore, some receptors (birds and marine mammals) are the focus of considerable attention from a range of NGO and conservation organisations with occasional lack of distinction between conservation, welfare and ethical concerns. This assessment aims to draw balanced conclusions based on credible scientific evidence, while recognising that some precautionary concerns are valid given current uncertainties and information gaps.

5.5.2 Consideration of the evidence

5.5.2.1 Displacement and barrier effects

In relation to birds, the potential displacement and barrier effects of OWF have been extensively recognised (Percival 2001, Exo *et al*. 2003, Drewitt & Langston 2006, Fox *et al*. 2006, Stienen *et al*. 2007, Norman *et al*. 2007) although there remains little convincing data. Garthe & Hüppop (2004) suggest that both birds on migration and those resting or foraging locally could potentially be affected: at sea, this therefore includes both migrating birds, from the smallest songbirds to large birds such as cranes and birds of prey, and seabirds during their local movements (Exo *et al*. 2003). Despite the concern, and construction of a number of OWF developments, the evidence base for biologically meaningful displacement or barrier effects is relatively sparse.

At Tunø Knob in the Danish Kattegat, Guillemette *et al*. (1998, 1999), demonstrated a decrease in the number of common eiders and common scoters in the development site in the two years following construction. Although eider numbers subsequently increased, supporting the view that the decline following construction was not due to the wind farm, there was only a partial recovery for common scoter. It is also possible that the increase in eider numbers post-construction may have occurred as a result of increased abundance of mussels or due to birds habituating to the wind farm. This work is subject to a number of caveats regarding its application to other developments, in particular relating to the small size of the wind farm (ten 500kW turbines) and the small size of the flocks studied (Drewitt & Langston 2006). Later work reported by Larsen & Guillemette (2007) concluded that eiders reacted strongly to the presence of wind turbines, with the number of flying birds significantly related to flight corridor location and position of a decoy group. That behavioural reaction was interpreted to be a consequence of this species' high speed and low-manoeuvrability flight occurring within the vertical height range of the wind turbines.

Predictive modelling of common scoter distribution in Liverpool Bay (Kaiser *et al*. 2006) suggested that under some circumstances a significant adverse effect on common scoter mortality would occur; specifically, in the predicted presence of a wind farm on Shell Flat in combination with others in the region, and on the assumption that the radius of the buffer zone around them all extends to 2km. However, only in the scenarios in which a 2km buffer zone around the Shell Flat location was included did the model predict that common scoter would be excluded from a number of grid cells in which the model predicted they would otherwise feed heavily. The model may underestimate the magnitude of this effect, but nonetheless, a significant effect is predicted. However, this cumulative adverse effect may be negated if: i) the radius of the buffer zone is smaller than 2km, ii) common scoter redistribute to currently unused but apparently profitable feeding areas within Liverpool Bay or iii) common scoter feed during the hours of darkness as well as during daylight. The proposal to construct the Shell Flat wind farm has subsequently been withdrawn.

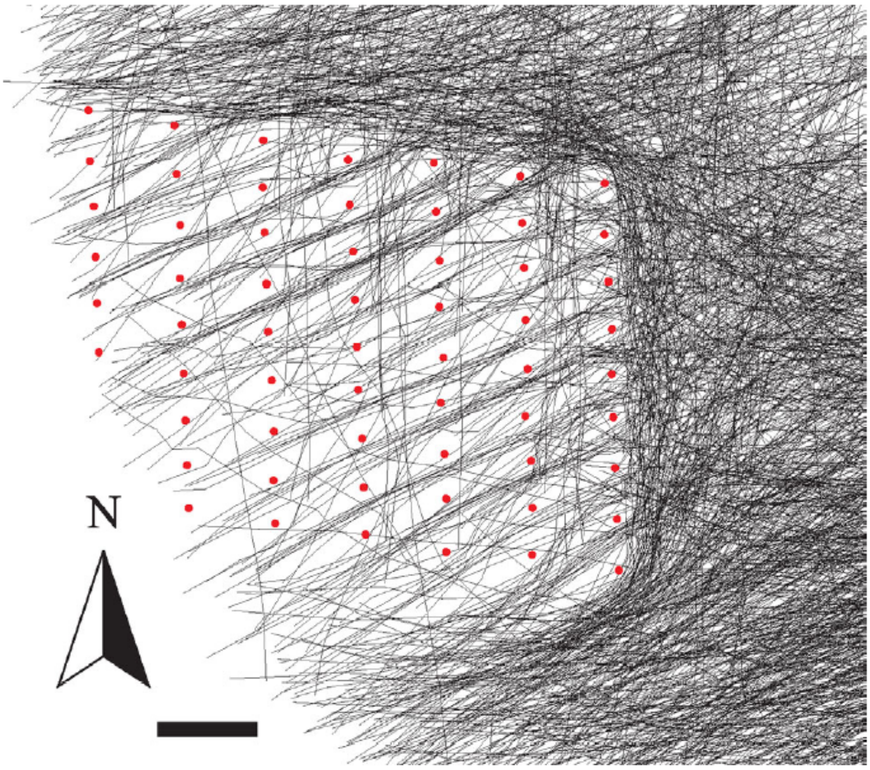
Studies using aerial surveys carried out before, during and following construction at Horns Rev OWF found that divers, gannets, common scoters, guillemots and razorbills occurred in lower numbers than expected in the wind farm area, and the zone within 4km of it, following construction (Petersen *et al*. 2004). Divers and common scoters showed almost complete avoidance of the Horns Rev wind farm area in the first three years post construction (DONG *et al*. 2006), although as proportions of the total numbers present in the wider area, the displaced birds were relatively few. Conversely, gulls and terns showed a preference for the wind farm area following construction. Subsequent surveys indicate that common scoters may now be distributed in comparable densities inside and outside the development; and the possibility cannot be excluded that changes in food availability rather than displacement by disturbance led to the observed changes in distribution (Petersen *et al*. 2007). It is also possible that these changes reflect habituation to wind farm presence and associated activities.

Barrier effects of birds altering their migration flyways or local flight paths to avoid a wind farm is also a form of displacement (Drewitt & Langston 2006). This postulated effect is related to the possibility of increased energy expenditure when birds have to fly further, as a result of avoiding a large array of turbines, and the potential disruption of linkages between distant feeding, roosting, moulting and breeding areas otherwise unaffected by the wind farm.

Radar studies at Nysted offshore wind farm, in the western Baltic, indicated a high degree of avoidance by large waterbirds (mostly eider) during migration, at least in fair weather (Desholm & Kahlert 2005; Figure 5.17). There was a significant ($P<0.001$) reduction in migration track densities within the wind farm area post-construction (40.4% (n=1406) of flocks entered the wind farm area prior to construction of the wind farm (2000-2002) compared with 8.9% (n=779) during initial operation (2003)). Significant differences were also observed between the avoidance response during daylight and at night. The practical problems in demonstrating effects (or lack of effects) with statistical rigour was shown by long-tailed duck monitoring at Nysted, where data from only two (consistent) baseline years in 2001 and 2002 would suggest a dramatic displacement of birds from the OWF in 2003 out to almost 15km (Kahlert *et al*. 2004). However, the baseline data from 2000 showed that the bird distribution during 2003 fell within the variability of the baseline sampling.

Other studies in Denmark (Christensen *et al*. 2004, Kahlert *et al*. 2004) and the Netherlands (Winkelman 1992a, b, c, d), have produced limited evidence to show that nocturnally migrating waterfowl are able to detect and avoid turbines, at least in some circumstances, and that avoidance distances can be greater during darker nights when visibility of navigation and aviation lights is greater (Dirksen *et al*. 1998, 2000).

Figure 5.17 - Westerly oriented flight trajectories during the initial operation of the wind turbines at Nysted OWF. Black lines indicate migrating waterbird flocks, red dots the wind turbines. Scale bar, 1000m.



Source: Desholm & Kahlert (2005)

Overall, although measurable changes in the local distribution of two waterbird species – eider and common scoter – have been reasonably well characterised in Danish studies; and displacement of divers and possibly auks also shown (at Horns Rev), it is not clear to what extent this is a permanent effect (within the lifetime of the development), with habituation or other recovery mechanisms clearly implicated at Horns Rev. Neither is it clear whether any of the observed displacement, or deviation of migratory flightpaths, are biologically meaningful, in terms of population dynamics at a local or biogeographic population level (or would be meaningful even with a substantial increase in the number of OWF developments). Drewitt & Langston (2006) noted that a review of the literature suggests that none of the barrier effects identified so far have significant impacts on populations (although they were able to speculate on specific locational or cumulative circumstances where this might occur).

Speculative concerns have been raised in relation to possible barrier effects of offshore developments (in particular seismic surveys) in relation to marine mammals; there is no meaningful evidence base for assessment of this. Migration, as an organised seasonal behavioural pattern comparable to that of birds, is probably limited in marine mammals to movements of sperm whales and possibly baleen whales along the continental shelf margin and the main investigative approach is through passive acoustic monitoring (using SOSUS arrays). Following the work sponsored through AFEN in the 1990s (e.g. Charif & Clark 2000), further studies were commissioned as part of the SEA programme. The initial report of an assessment of a 10 year dataset (Charif & Clark 2009) indicates the consistent presence of blue, fin, and humpback whales with annual cycles of occurrence of sounds from all three species at Atlantic SOSUS stations. These cycles are apparently consistent with seasonal migrations between high latitudes in summer and lower latitudes in winter.

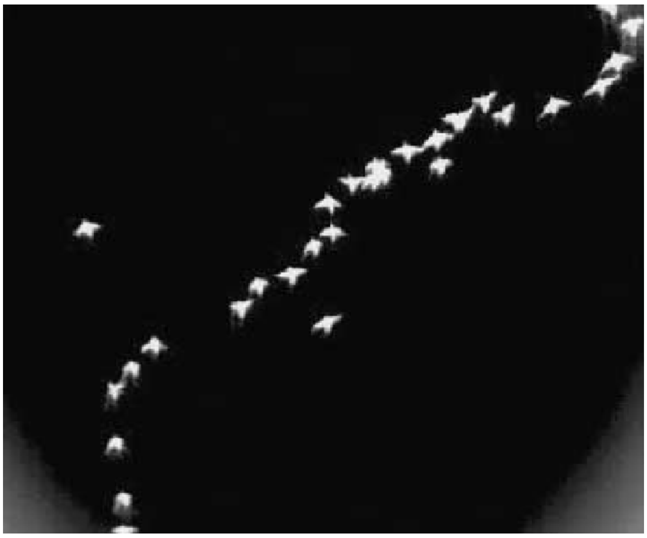
5.5.2.2 Bird collision risk

Collision risk has received considerable attention in relation to both onshore and offshore wind farm development, with substantial effort expended both in empirical studies (e.g. mortality counts; infrared monitoring) and predictive modelling. This subject has been recently and comprehensively reviewed (Desholm *et al*. 2006, Drewitt & Langston 2006) and detailed discussion of the evidence base is provided by these sources.

Collision risk mortality depends on a range of factors related to bird species, numbers and behaviour, weather conditions and topography and the nature of the offshore structure itself, including the use of lighting. The review of the available literature by Drewitt & Langston (2006) indicated that, where collisions have been recorded, the rates per turbine are very variable with averages ranging from 0.01 to 23 bird collisions annually; the highest figure is the value, following correction for scavenger removal, for a coastal site in Belgium and relates to gulls, terns and ducks amongst other species (Everaert *et al*. 2001). In contrast, visual observations of eider movements in response to two small, relatively near-shore wind farms (seven 1.5MW and five 2MW turbines) in the Kalmar Sound, Sweden, recorded only one collision event during observations of 1.5 million migrating waterfowl (Pettersson 2005). Drewitt & Langston (2006) also note that although providing a helpful and standardised indication of collision rates, average rates per turbine must be viewed with some caution as they are often cited without variance and can mask significantly higher rates for individual turbines or groups of turbines.

Hüppop *et al*. (2006) note the problems of quantifying collision rate by carcass collection offshore, and Chamberlain *et al*. (2006), in a review of collision risk modelling, point out that calculation of post-construction mortality rates has typically relied on corpse searches (Langston & Pullan 2003), using tideline searches for off-shore and coastal wind farms (e.g. Winkelman 1992, Still *et al*. 1996, Painter *et al*. 1999). There are potential biases in estimating mortality in this way due to searching efficiency, corpse removal by scavengers, injured birds leaving the area before death, 'obliteration' of birds struck by turbine blades (especially smaller species) and, for coastal locations, corpses sinking or being washed out to sea. Adjustments to mortality rates have been made to try and compensate for these factors by some authors (e.g. Winkelman 1992, Painter *et al*. 1999). Desholm *et al*. (2006) review possible technical developments in remote techniques, including thermal imaging (Figure 5.18).

Figure 5.18 - Thermal image recorded by TADS and showing a flock of common eiders passing the field of view at a distance of ca. 70m



Source: Desholm et al. (2006)

Collision Risk Modelling (CRM) has been extensively used for both onshore and offshore sites globally, including a range of UK offshore developments (Table 5.3); although not always consistently and with appropriate input data. For example, Chamberlain *et al*. (2006) present a critical review of collision risk modelling for the Kentish Flats OWF, where, using survey data and an avoidance rate of 0.9998 taken from Winkelman (1992), Gill *et al*. (2002) estimated mortality rates for terns, divers, gannets and black-headed gull. The estimated avoidance rate was used for all groups, even though it was derived for passerines only (Winkelman 1992). Chamberlain *et al*. (2006) considered this inappropriate when all species considered at Kentish Flats were considerably larger and have very different flight characteristics from passerines. Furthermore, despite the authors' statement that the avoidance rate used is 'the worst case scenario', it produces one of the lowest collision rates presented in the source reference. For example, application of the maximum estimated nocturnal mortality for gulls resulted in over an eight-fold increase in mortality rates. This Kentish Flats study would have been a good candidate for presenting a range of avoidance rates, rather than a single (and arguably inappropriate) rate.

Table 5.3 – Collision Risk Modelling (CRM) predictions taken from various UK Round 1 & 2 Environmental Statements

Location	Species/Taxa	Collision (mortality) rate (in units of number/time) for whole development
Sheringham Shoal - north Norfolk coast[1]	Sandwich tern Common tern Gannet Little gull Lesser Black-backed gull	$23/y_a$ $12/y_b$ $6/y_c$ $3/y_a$ $1/y_b$ $1/y_c$ $31/y_a$ $16/y_b$ $8/y_c$ $8/y_a$ $4/y_b$ $2/y_c$ $33/y_a$ $16/y_b$ $8/y_c$
Kentish Flats - Outer Thames Estuary[2]	Divers Divers	$0.52/y_d$ $0.01/y_e$
Greater Gabbard - Outer Thames Estuary[3]	Red – throated diver Lesser Black-backed gull Great Skua	$0.048/d_d$ $0.076/d_d$ $0.052/d_d$

Location	Species/Taxa	Collision (mortality) rate (in units of number/time) for whole development
Gunfleet Sands - Outer Thames Estuary[4]	Divers	$1.69/y_f$ $0.34/y_b$ $0.03/y_g$ $0.003/y_h$
Lincs - Greater Wash[5]	Pink-footed goose Red-throated diver Gannet Little gull Common gull Lesser Black-backed gull Common tern Guillemot	$4668/y_d$ $317^6/y_f$ $93/y_a$ $47/y_b$ $23/y_c$ $4.7/y_g$ $0.93/y_e$ $77/y_d$ $4/y_f$ $2/y_a$ $1/y_b$ $0/y_c$ $0.1/y_g$ $0.02/y_e$ $427/y_d$ $21/y_f$ $9/y_a$ $4/y_b$ $2/y_c$ $0.4/y_g$ $0.09/y_e$ $74/y_d$ $0/y_f$ $1/y_a$ $1/y_b$ $0/y_c$ $0.1/y_g$ $0.01/y_e$ $2137/y_d$ $107/y_f$ $43/y_a$ $21/y_b$ $11/y_c$ $2.1/y_g$ $0.43/y_e$ $1710/y_d$ $85/y_f$ $34/y_a$ $17/y_b$ $9/y_c$ $1.7/y_g$ $0.34/y_e$ $114/y_d$ $6/y_f$ $2/y_a$ $1/y_b$ $1/y_c$ $0.1/y_g$ $0.02/y_e$ $3/y_d$ $0/y_f$ $0/y_a$ $0/y_b$ $0/y_c$ $0/y_g$ $0/y_e$
Thanet - Outer Thames Estuary[7]	Red-throated diver Fulmar Gannet Common tern Sandwich tern Kittiwake Common gull Herring gull Lesser Black-backed gull Great Black-backed gull Gull sp. Auks	$1/y_b$ $0/y_b$ $1/y_b$ $0/y_b$ $1/y_b$ $1/y_b$ $17/y_b$ $49/y_b$ $32/y_b$ $1/y_b$ $23/y_b$ $0/y_b$
Walney - East Irish Sea[8]	Lesser Black-backed gull	Worst case scenario $572.02/y_f$ $114.4/y_b$ $11.44/y_g$ $1.14/y_h$ Base case scenario $438.96/y_f$ $87.79/y_b$ $8.78/y_g$ $0.88/y_h$
Beatrice - Moray Firth[9]	Kittiwake Great Black-backed gull Herring gull Fulmar Gannet Tern sp.	$47/y_i$ $23/y_f$ $9/y_a$ $5/y_b$ $2/y_c$ $28/y_i$ $14/y_f$ $6/y_a$ $3/y_b$ $1/y_c$ $10/y_i$ $5/y_f$ $2/y_a$ $1/y_b$ $1/y_c$ $1.6/y_i$ $0.8/y_f$ $0.3/y_a$ $0.2/y_b$ $0.1/y_c$ $24/y_i$ $12/y_f$ $5/y_a$ $2/y_b$ $1/y_c$ $2.0/y_i$ $1.0/y_f$ $0.4/y_a$ $0.2/y_b$ $0.1/y_c$

Notes: Probability of avoidance $_a$ 98% $_b$ 99% $_c$ 99.5% $_d$ Based on no avoidance $_e$ 99.98% $_f$ 95% $_g$99.9% $_h$ 99.99% $_i$ 90%.

[1]Two precautionary assumptions are used in impact assessment. First, the annual mortality was calculated with the worst case 108 × 3MW layout (Rochdale Envelope). Second, a precautionary avoidance rate of 98% was used.

[2] Collision mortality analysed using Scottish Natural Heritage (SNH) model (SNH 2000). Collision risk model used makes no allowance for either avoidance behaviour or the orientation of turbines in relation to flight direction.

[3] Estimation of risk of collision uses SNH Collision Risk Model (CRM). This model assumes no avoidance action is taken by birds.

[4] Collision rates calculated using the SNH CRM.

[5] Collision rates calculated using the CRM developed by SNH and BWEA (Percival et al. 1999, SNH 2000).

[6] This figure assumes that pink-footed geese are active at night (night activity constituting 75% of daytime activity levels). If they are treated as entirely diurnal then at 95% avoidance 192 collisions are predicted.

[7] Results for worst case scenario, (60 turbines), as they have the greatest combined rotor swept volume.

[8] Collision rates calculated using the SNH CRM.

[9] Collision rates calculated using the SNH CRM using four different scenarios for flight height distribution and flight speed – results given above are for "most applicable" (Model C, uniform height distribution, flight speed affected by wind for kittiwake; Model D, skewed height distribution and constant speed for great black-backed gull, herring gull, fulmar, gannet and tern sp.).

The main conclusions which can be reached from Table 5.3 are, firstly, that numerical predictions are highly sensitive to assumptions on avoidance rates; and that secondly, excluding scenarios with zero avoidance, the maximum predicted collision rates for any species are of the order of a few tens (per year, per development).

5.5.2.3 Effects of offshore lighting

The potential effects of light on birds has been raised in connection with offshore oil and gas over a number of years (e.g. Weise *et al*. 2001). As part of navigation and worker safety, and in accordance with international requirements, drilling rigs and associated vessels are lit at night and the lights will be visible at distance (some 10-12nm in good visibility). The attractive effect of lights on seabirds on cloudy nights is enhanced by fog, haze and drizzle (Weise *et al*. 2001). Bruderer *et al*. (1999) note that the switching off and on of a strong searchlight beam can influence the flight behaviour of migrating birds.

While well-defined preferred migratory corridors are still unknown, the cuneiform southernmost part of the North Sea (RS2 and RS3) is an important funnel for seabird migration with an estimated 1-1.3 million seabirds possibly using the route annually (Stienen *et al*. 2007). Large numbers of species such as great skua and little gull, as well as terns and lesser black-backed gull, can use the Strait of Dover to exit the North Sea.

Hüppop *et al*. (2006) have studied the migration of terrestrial birds across the German Bight, noting that each year during the migration periods several hundred million birds of roughly 250 species (dominated by passerines) cross the North and Baltic Seas on their journeys between their breeding grounds in northern Asia, North America and especially in Scandinavia and Finland, and their winter quarters, which lie between Central Europe and southern Africa, depending on the species. They report on remote observations, including those of ‘invisible’ bird migration from the FINO 1 research platform, using ship radar, thermal imaging, video and a directional microphone from October 2003 onwards. While providing considerable data regarding the seasonal and diurnal variability in migrating bird numbers, and on the altitude of migrating birds, they also report that a total of 442 birds of 21 species were found dead at FINO 1 (which has no rotating turbine blades, but has a metmast and navigation lights) between October 2003 and December 2004; of which 245 individuals (76.1%) had outwardly apparent injuries. Over 50% of the strikes occurred on just two nights, both characterised by periods of very poor visibility with mist or drizzle and presumably increased attraction of the illuminated research platform. In the second of these nights the thermal imaging camera revealed that many birds flew “obviously disorientated” around the illuminated platform.

Although to date there has been little observational data reported in relation to light effects from OWF developments, similar observations of behavioural responses and mortality of migratory birds have been reported from lighthouses, gas platforms in the southern North Sea (Hope Jones 1980, “Green light paper”) and are commonly observed from vessels of all sizes. It is unclear to what extent relative risks are presented by rotational machinery, gas flares or fixed structures; to what extent natural mortality during offshore migration is increased (or decreased) by the presence of offshore structures; or how significant such mortality is in the context of overall adult mortality in migratory species. Dierschke *et al*. (2003, cited by Hüppop *et al*. 2006) assumed that "an increase of the existing adult mortality rate by 0.5–5%, depending on the individual species, seems to be acceptable for the 250 bird species regularly migrating across the German sea areas" (it is unclear whether this relates to total annual mortality rate, or mortality during migration). For the “several hundred million” migratory population, this would equate to greater than (roughly) one million fatalities per year; a casualty rate which might be expected to be observable as dead birds in the vicinity of installations; the absence of such observations suggests that a casualty rate on this scale does not occur in reality.

5.5.2.4 Fouling

The physical presence of structures in the sea provides hard surfaces for biological colonisation. The development and succession of this fouling growth on North Sea production platforms has recently been summarised by Whomersley & Picken (2003) and similar patterns can be expected in the majority of Regional Seas. Fouling on OWF foundations appears to be generally similar, with dominant species depending on the geographical location (and scour and salinity regime) (e.g. Schröder *et al*. 2006, DONG Energy *et al*. 2006, and Linley *et al*. 2008). However, Wilhelmsson & Malm (2008) found that Baltic Sea turbine foundations differed significantly from adjacent boulders in terms of assemblage composition of epibiota and motile invertebrates although the reasons for this are unclear. Fouling growth can result in a number of subtle ecological impacts (e.g. enrichment) in the immediate vicinity of the structure but these are not regarded as significant effects. There has been considerable speculation that increased numbers of crabs, and perhaps lobsters, on and around OWF foundations, especially where scour protection is used, may lead to increased opportunities for pot fisheries (see Linley *et al*. 2008). However, the practicalities of fishing around turbines, the relatively large distances between turbines, and the likely distance offshore of most Round 3 developments suggest that this may be limited.

5.5.2.5 Stepping stones

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 and there is a possibility that a substantial expansion of the number of hard surfaces (such as OWF foundations, and cable armouring) could provide “stepping stones” allowing species with short lived larvae to spread to areas where previously they were effectively excluded. However, such “islands” are widespread and numerous in continental shelf areas, for example on glacial dropstones and moraines, and it is considered very unlikely that OWF or oil and gas development would result in any significant effect on benthic species distribution through this mechanism.

5.5.2.6 Electromagnetic fields (EMF)

A review (Gill *et al*. 2005) of the potential effects of electromagnetic fields on electrically and magnetically sensitive marine organisms focussed on the electromagnetic fields generated by sub-sea power cables associated with offshore wind farm developments. The results demonstrated that the EMF emitted by industry standard AC offshore cables produced a magnetic (B) field component and an induced electric (iE) field component in the marine environment. Although submarine power cables are fully electrically insulated it is the fluctuating magnetic field which induces the electric field in the environment (CMACS 2003). An electric field is also generated by the movement of water or objects (e.g. an animal) through the magnetic field in the same way that movements through the natural (geomagnetic) field of the earth induce an electric field.

The review of material on electrosensitive species showed that many fish and a number of other species found in UK waters are potentially capable of responding to anthropogenic sources of E and B fields. Certain fish species, including common ones such as plaice, are understood to be both magnetically and electrically sensitive and a range of other species, notably cetaceans and many Crustacea, to be magnetically sensitive. Most attention, however, has focused on elasmobranchs (sharks, skates and rays) which have specialist electro-receptive organs and are capable of detecting very small electric fields of around 0.5µV/m (Gill 2005). This group includes rays, some of which are commercially fished and have suffered severe population declines in recent years (Myers & Worm 2003), usually linked to overfishing (e.g. Walker & Hislop 1998; Rogers & Ellis 2000).

Potential impacts could result from repulsion effects, leading to exclusion of animals from an area of seabed (e.g. for elasmobranchs in the presence of relatively high electric fields); attraction effects, for example causing elasmobranchs to waste time and energy resources foraging around electric fields mistaken for bioelectric fields of prey organisms; and disruption to migrations for magnetically sensitive species such as eels and salmonids that may use the earth's geomagnetic field for navigational cues. However, it is not known whether interactions between the fish and the artificial E or B fields will have any consequences for the fish. The information available on magnetosensitive species is limited, but it does suggest that potential interactions between EM emissions, of the order likely to be associated with wind farm cables, and a number of UK coastal organisms could occur from the cellular through to the behavioural level.

The conclusion of most project-specific environmental impact assessments is that whilst there could be an interaction between these species and the sub-sea cables used the result is unlikely to be of any significance at a population level. Gill *et al*. (2005) highlighted the lack of evidence supporting such conclusions but it was evident that the industry does try to take into consideration the potential environmental effects of EMFs, but it is hampered by a lack of information and understanding. It is clear from the review of industry based material that the issue of electromagnetic (both B and iE field) effects on electrically and magnetically sensitive species has not been addressed in a consistent manner and that there is a lack of clear scientific guidance on the significance of effects (if any) on receptor species. Various recommendations were made by Gill *et al*. (2005) for further work; initially to identify if the species most likely to interact with EMFs responded to fields of a magnitude and character associated with power transmission and to then definitively determine whether these species would be affected.

Recent advances in understanding include measurements of EMF at offshore wind farm locations (CMACS & CIMS 2008) which confirm that EMFs are emitted and, for standard 50Hz AC cabling used in Round 1 developments, that iE fields are likely to lie in the range of potential attraction to elasmobranchs (0.5-100 µV/m (Gill & Taylor 2001). Higher fields, potentially of a magnitude that could be repulsive to elasmobranchs, have not been measured but could occur where cables lie in close proximity (a few metres) and fields are additive (Gill *et al*. 2005). Importantly, provisional results of the most recent work for COWRIE Gill *et al*. (2008) suggest that low level electrical fields of a magnitude and character produced by offshore wind farms did cause a change in swimming behaviour of fish in experimental mesocosms. This suggests that the mechanism for an impact to occur is present but does not yet demonstrate that any impacts will occur; a similar conclusion was drawn by Öhman *et al*. (2007) from field observations.

The work by Gill *et al*. (2005) also highlighted that while cable burial is important to isolate marine organisms from the very highest electric and magnetic fields no significant benefits are likely to be accrued by burying cables to greater depths than traditionally achieved for cable protection purposes (1-3m).

Work on EMF undertaken by Bochert & Zettler (2006) in connection with the FINO 1 test platform concluded that none of the fish (flounder) and several invertebrate species tested responded by attraction or avoidance when exposed to static artificial magnetic fields, although further studies were recommended. The authors did not consider effects of induced electrical fields or AC magnetic fields on the test species although oxygen consumption in two prawn species did not vary significantly between 50Hz AC, static and control magnetic fields.

To date, efforts have focused on the 50Hz AC systems used throughout all UK and most other offshore renewables projects. Longer export cable distances, bigger wind farms and technological advances mean that High Voltage Direct Current (HVDC) cables may be used in future, including for Round 3 wind farms. Although (static) magnetic fields will still be produced in the marine environment this technology offers potential advantages in that fewer cables may be required and bipole systems should retain electrical fields within the cables. It should be noted that an electrical field would be induced when water, or animals, move through the magnetic field, as also occurs with AC systems. There are various environmental concerns about monopole HVDC systems but it is considered unlikely that such solutions would be used.

In summary, further research is required to investigate the potential significance (if any) of artificial electric and magnetic fields for marine organisms. Evidence should begin to accumulate from environmental monitoring at existing UK and other wind farms over the next 1-2 years and, together with more academic work, should help inform planning and design of projects. Attention to this issue should be proportionate to the potential for impacts, e.g. careful consideration should be given to mitigation and monitoring where there are important areas for key species such as elasmobranchs.

5.5.2.7 Fish aggregation

Many fish species are known to aggregate around structures in the sea, including oil and gas platforms and pipelines, probably as they provide shelter from currents and wave action and safety from predators, but possibly also in some cases due to increased feeding opportunities. It is generally considered that such aggregation represents minimal increase in overall biomass of fish in an area. Aggregation is seen not only in midwater fishes (see photo as Figure 6 in Schröder *et al*. 2006) but also many demersal species such as most gadoids, and to some extent flatfish such as plaice and dab. It is reasonable to assume that fish will also aggregate around turbine foundations, although present evidence as to the extent to which it occurs is limited. A gill netting survey at the Svante Wind Farm, Sweden, found higher numbers of cod within two hundred metres of an operating turbine compared to the surrounding open waters, and higher still when the turbines were not operating (Westerberg, 1999). Diver held video surveys of the North Hoyle OWF piles found extremely high densities of juvenile whiting, apparently feeding on dense populations of amphipods amongst the fouling biota on the piles (Bunker 2004). It is generally agreed that fish aggregation probably represents a very minor effect.

5.5.3 Spatial consideration

Given that the major potential receptors identified above were birds, the spatial distribution of potential effect is clearly strongly related to the distribution and relative sensitivities of individual bird species. The use of vulnerability indices for assessment of oil spill risks to birds is well established (see previous SEAs), and a similar approach has been developed by Garthe & Hüppop (2004) for scaling possible adverse effects of marine wind farms on seabirds. Their species sensitivity index (SSI) (also referred to as a Wind Farm Sensitivity Index, WSI) for seabirds was based on nine factors (see below). Each factor was scored on a 5-point scale from 1 (low vulnerability of seabirds) to 5 (high vulnerability). Five of these factors could be dealt with by real data but four (flight manoeuvrability, nocturnal flight activity, disturbance by ship and helicopter traffic and flexibility in habitat use) could only be assessed by subjective considerations using expert review. Species differed greatly in their individual sensitivity index scores. Black-throated diver and red-throated diver ranked highest (= most sensitive), followed by velvet scoter, sandwich tern and cormorant. The lowest values were recorded for kittiwake, black-headed gull and fulmar.

Garthe & Hüppop (2004) have mapped SSI scores for German areas of the North Sea and Baltic Sea, finding that coastal waters in the south-eastern North Sea had values indicating greater vulnerability than waters further offshore throughout the whole year. This exercise does not include all species found around the UK and has not yet been carried out for UKCS areas, although Langston (*pers. comm.*) considers that the SSI could provide a useful measure to assist in prioritising bird species for assessing the risks applicable to the UK's Round 3 offshore wind farm programme, and has included the individual sensitivity index scores from Garthe & Hüppop (2004) in a tabular assessment of UK species (see Table 5.4). Langston (*pers. comm.)* notes that the scores used for the UK represent an initial assessment that is not a substitute for updated baseline data collection, detailed EIA, and targeted research, but is intended to make best use of available information until these sources improve that knowledge base.

Derived from the frequency distribution of the SSI, Garthe & Hüppop (2004) suggest a 'level of concern' and a 'level of major concern' that could act as a basis for the selection of marine wind farm locations.

Table 5.4 - Species-specific Sensitivity Index and other information pointing to focal species in relation to proposed wind farms. Species listed in order of declining SSI.

species	Collision[1]	Displacement[1]	Habitat / prey[1]	SSI[2]	GB/UK min%[3]	Cumulative impact[4]	OVI[5]
Black-throated diver	*	***	*	44	*	***	29
Red-throated diver	*	***	*	43.3	**	***	29
Velvet scoter		**	**	27	*	**	21
Sandwich tern	**		*	25	**	**	20
Cormorant	**	*		23.3	**	**	20
Eider	*	*	**	20.4	*	**	16
Great black-backed gull	**			18.3	**	**	21
Common scoter		*	**	16.9	*	**	19
Gannet	**			16.5	***	***	22
Razorbill		*	Not known	15.8	*	**	24
Puffin		*	Not known	15	*	**	21
Common tern	**			15	*	**	20
Lesser black-backed gull	**			13.8	***	***	19
Arctic tern	**			13.3	*	**	16
Little gull	*			12.8	Not known	Not known	24
Great Skua	**			12.4	***	***	25
Guillemot		*	Not known	12	**	**	24
Common gull	*			12	*	**	13
Herring gull	*			11	*	**	15
Arctic Skua	**			10	*	**	24
Kittiwake	**			7.5	*	*	17
Black-headed gull	*			7.5	*	*	11
Fulmar	*			5.8	*	*	18
Great Northern diver		***	*	ns	**	***	29
Manx shearwater	Not known	Not known	Not known	ns	***	***	23

species	Collision[1]	Displacement[1]	Habitat / prey[1]	SSI[2]	GB/UK min%[3]	Cumulative impact[4]	OVI[5]
Balearic shearwater	Not known	Not known	Not known	ns	Not known	Not known	
European Storm petrel		Not known	Not known	ns	*	*	18
Leach's Storm petrel		Not known	Not known	ns	*	*	
Shag		*	*	ns	**	**	24
Roseate tern	**			ns	*	**	
Little tern	*			ns	*	*	19
Mediterranean gull	*			ns	*	*	
Long-tailed duck		**	**	ns	*	**	17
Goldeneye		Not known	Not known	ns	*	Not known	16
Red-breasted merganser		Not known	Not known	ns	*	Not known	21
Whooper swan	**			ns	*	**	
Bewick's swan	**			ns	**	**	
Pink-footed goose	*			ns	***	***	
Dark-bellied Brent goose	*			ns	Not known	Not known	
Light-bellied Brent goose	*			ns	Not known	Not known	

1. *assessment based on combination of experience from operational wind farms and Garthe & Hüppop 2004.*
2. *ns = no Species-specific Sensitivity Index (SSI) score presented in Garthe & Hüppop 2004; NB this score takes account of Species of European Conservation Concern (SPEC) status.*
3. *the minimum % of the relevant biogeographical population breeding in Britain, is taken from Mitchell* et al. *2004; UK non-breeding population estimates are from Baker et al. 2006 as a % of European populations from BirdLife International 2004, converted accordingly: * <25%; ** 25 – 50 %; *** > 50%.*
4. *cumulative impact taken as the highest score across the table for each species*
5. *JNCC Offshore Vulnerability Index (OVI) (Williams* et al. *1994)*

Source: Primarily Langston pers. comm.

The SSI of Garthe & Hüppop (2004) is calculated as:

$$SSI = \frac{(a+b+c+d)}{4} X \frac{(e+f)}{2} X \frac{(g+h+i)}{3}$$

where the nine vulnerability factors are:

a= flight manoeuvrability
b= flight altitude
c= percentage of time flying
d= nocturnal flight activity
e= sensitivity towards disturbance by ship and helicopter traffic
f= flexibility in habitat use
g= biogeographical population size
h= adult survival rate
i= European threat and conservation status

The Offshore Vulnerability Index (OVI) developed by JNCC and used to assess the vulnerability of bird species to surface pollution, considers four factors (Williams *et al.* 1994):

OVI = 2a + 2b + c + d

where,

a= the amount of time spent on the water
b= total biogeographical population
c= reliance on the marine environment

d= potential rate of population recovery

Although the factors used in the two indices are different, there is a significant correlation between the two (P<0.01), with the main differences being in fulmar, kittiwake, great and arctic skuas, guillemot and razorbill; all of which score relatively higher in OVI than in SSI (Table 5.4); and diver species which score relatively highly in SSI. In view of this, it is considered that the OVI maps (Figures 5.19 and 5.20) developed for the UKCS based on the European Seabirds at Sea (ESAS) database will give a rough indication of spatial sensitivity with regard to OWF development, pending further consideration of the usefulness of producing SSI-based maps, and the inclusion of species not in the OVI e.g. geese species. Figures 5.19 and 5.20 indicate clear spatial (geographical) differences in bird sensitivities (see Appendix 3a.6 for details). It is noted that the inclusion of aerial bird distribution data will also have an influence on final sensitivity mapping, particularly for nearshore areas.

Figure 5.19 - Overall vulnerability to surface pollutants

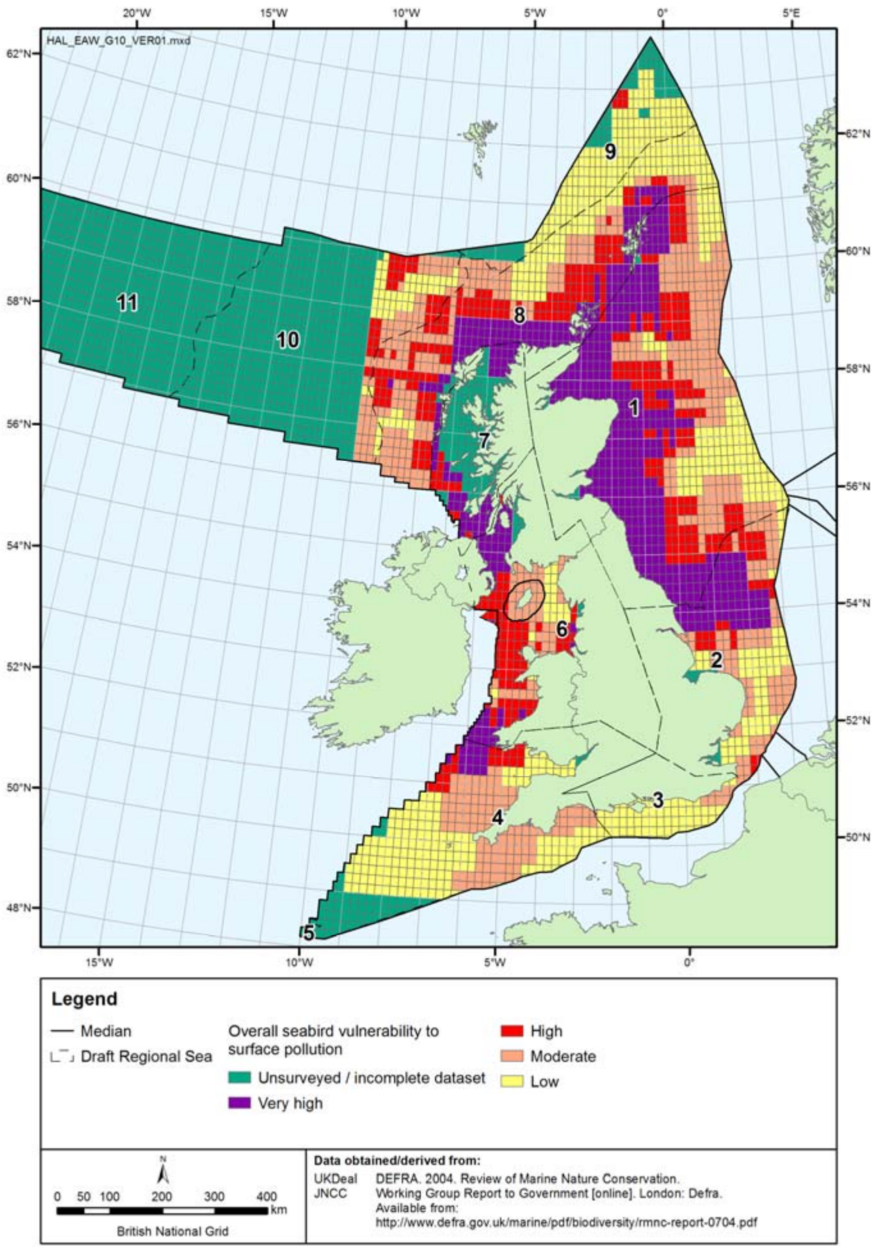
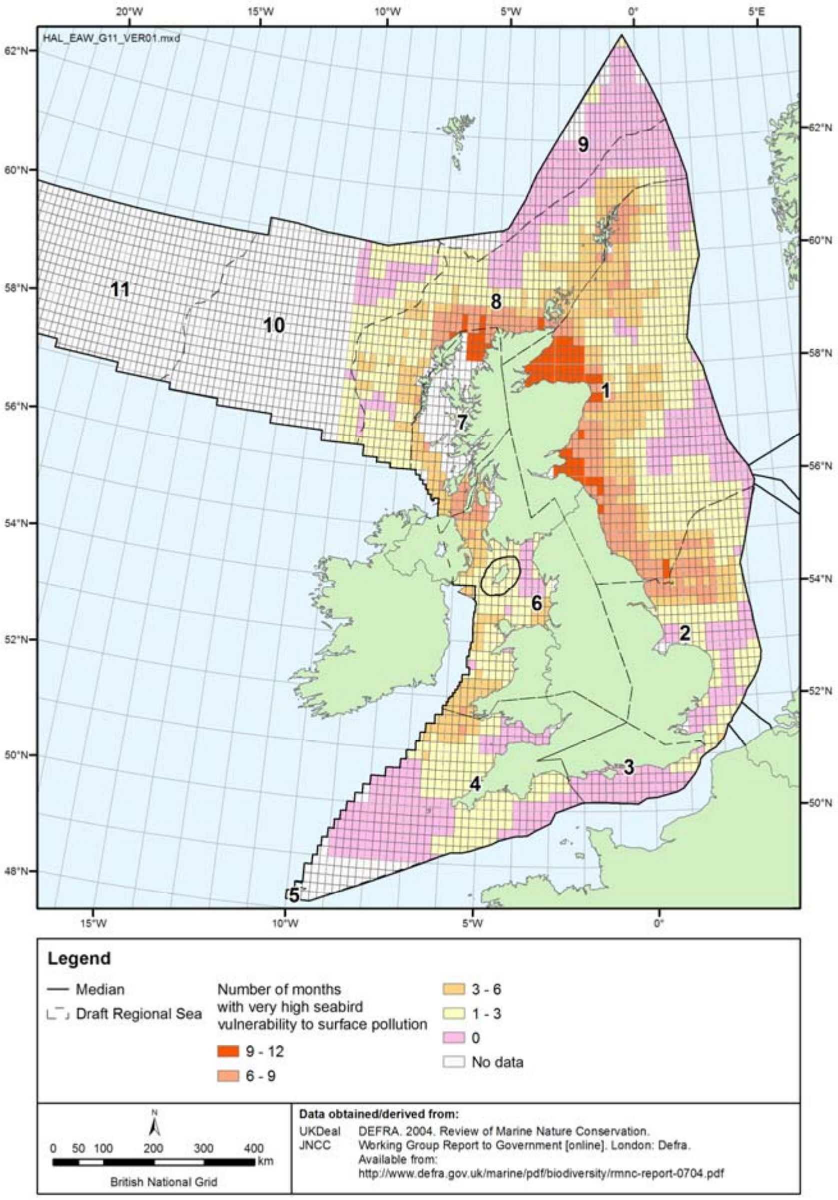


Figure 5.20 – Seasonal vulnerability of seabirds to surface pollution (expressed as numbers of months in which very high vulnerability is present, data gaps for seabird vulnerability are also shown)



As a complementary approach, Table 5.5 provides a preliminary list of species of greatest concern in relation to Round 3 wind leasing, largely derived from a compilation by Langston (*pers. comm.*). This was based on proximity to nearest major breeding colonies (most are SPAs) and likely foraging range for seabirds (RSPB 2000, Stroud *et al*. 2001, McSorley *et al*. 2003, Mitchell *et al*. 2004, Guilford *et al*. 2008) and, for non-breeding seabirds and waterbirds, based on the onshore SPA network, offshore distribution (non-breeding) including marine IBAs (Stroud *et al*. 2001, Skov *et al*. 2005, Stone *et al*. 2005), and migration (Wernham *et al*. 2002). The compilation of Langston (*pers. comm.*) has here been revised to group by Regional Sea. Note that this list relates mainly to water depths <60m.

Table 5.5 – Priority species, and key risks, in relation to Round 3 wind leasing (coastal and shallow waters)

Area	Potential collision	Potential displacement
Regional Sea 1		
Moray Firth	Fulmar Great Black-backed gull Kittiwake Whooper swan Pink-footed goose	Shag Guillemot Razorbill Divers Seaducks
Firth of Forth	Gannet Kittiwake Gulls Little gull Sandwich tern Common tern Arctic tern Skuas Migrating waterbirds	Auks Divers Seaducks Grebes
Dogger Bank	Gannet Gulls Kittiwake	Auks
Regional Sea 2	Gannet Little gull Little tern Kittiwake Migrating waterbirds	Auks Divers
Regional Sea 3	Mediterranean gull Little gull Terns Migrating waterbirds	Balearic shearwater Storm petrel
Regional Sea 4	Gannet Lesser Black-backed gull	Manx shearwater Balearic shearwater Storm petrel Auks
Regional Sea 6	Terns	Manx shearwater Auks Seaducks
Regional Sea 7	Fulmar Common tern Arctic tern Kittiwake Gannet (Firth of Clyde) Geese (Islay)	Manx shearwater Storm petrel Auks
Regional Sea 8	Fulmar Gannet (St Kilda, Sule Stack, Shetland) Arctic tern Kittiwake	Manx shearwater Storm petrel Leach's storm petrel Auks Seaducks (Scapa Flow)

Combining the assessment of spatial distribution of "priority" species with the assessment of sensitivity (as SSI) would indicate that:

- In Regional Sea 1, fulmar, kittiwake and gulls are of relatively low SSI; auks and probably shag are of moderate sensitivity; the species of greatest sensitivity in the area are probably divers, seaduck (mainly scoter and eider in coastal areas), gannets (associated with the Bass Rock colony, and foraging over the Dogger Bank) and possibly swans and geese in the Moray Firth (for which neither SSI nor OVI scores have been calculated). It is also noted that there are potential colony SPA extensions in both the Firth of Forth and Moray Firth.

- In Regional Sea 2, the most sensitive species are gannets (mainly distributed along the Flamborough front); divers and, to a lesser extent, auks in the outer Thames and along the East Anglian coast; and migrating birds.

- In Regional Sea 3, terns and Mediterranean and little gulls in the eastern Channel, and storm petrel and Balearic shearwater in the central Channel (for which SSI scores have not been calculated but might be expected to be moderate, in view of their flight characteristics, biogeographical population size and conservation status) are the highest sensitivities (although population density of the latter will be low in relative terms).

- In Regional Sea 4, gannet and lesser black-backed gull, and auks will all be of moderate SSI. Manx shearwater, for which there is no SSI, will be of relatively high sensitivity because of population density and biogeographical importance.

- In Regional Sea 6, Manx shearwater will again be of high sensitivity, along with terns in nearshore areas in the vicinity of colonies, and scoter in relatively shallow waters of Liverpool Bay and off Morecambe Bay

- In Regional Sea 7, Manx shearwater will be of high sensitivity in the vicinity of Rum and gannet in the vicinity of Ailsa Craig; similarly storm petrel, auks and tern adjacent to various colonies throughout the area. Geese of several species winter in high numbers on Islay, and to a lesser extent other islands of the Inner Hebrides. However, water depths in a suitable range for OWF development are exclusively within Scottish territorial waters (i.e. not under explicit consideration for wind farms in this SEA).

- In Regional Sea 8, a number of internationally important seabird colonies are present, although these are not in areas of interest for OWF development. Scapa Flow, although not a potential area for inclusion in Round 3 (because it is within Scottish Territorial Waters), holds important numbers of seaducks of high sensitivity in relation to displacement. There are various SPA extensions under consideration in Regional Seas 7 and 8, although these are unlikely to coincide with areas of interest for OWF development (outside Round 3).

5.5.4 Cumulative impact considerations

The physical presence of anthropogenic structures in the marine environment is not expected to increase significantly following further oil and gas and gas storage licensing. However, the development of 25GW or more of offshore wind farms will greatly increase the number of structures present; the potential for cumulative effects from such a physical presence requires much consideration.

5.5.4.1 Birds

Considering the evidence presented above in Sections 5.5.2 - 5.5.3, the greatest potential for cumulative impacts resulting from the physical presence of OWFs is with regard to birds. The potential for birds to be impacted cumulatively through collision, displacement and barrier effects has received considerable attention in recent years; methods of assessing such potential effects have been the subject of a number of studies and workshops, and are continuing to be developed.

In terms of assessing the overall conservation significance of the relatively small observed and predicted number of bird collision fatalities (in relation to total population sizes; see above), in a wider context NRC (2007) have considered whether and to what degree they are ecologically significant and how the number of turbine-caused bird deaths compares with the number of all anthropogenic bird deaths in the United States. NRC (2007) concluded that bird deaths caused by wind turbines are a minute fraction of the total anthropogenic bird deaths – less than 0.003% in 2003 of a total that Erickson *et al*. (2005) estimate "may easily approach 1 billion birds per year." Although this assessment is US-specific and almost exclusively for land birds, the major causes of anthropogenic bird mortality – collisions with buildings and overhead power lines, and predation by domestic cats – are probably equally relevant to the UK and other European countries. Set in this context, the evidence for migrating passerine bird mortality from collision with the FINO-1 platform (Hüppop *et al*. 2006b), and by extension to major UK offshore wind farm development, is unlikely to result in cumulative impacts of concern for biogeographic populations of such species. For migrating waterbirds and seabirds commuting between nests and foraging areas, inappropriately sited wind farms could result in cumulative effects of concern.

At a national (and potentially biogeographic) level, Maclean *et al*. (2007a) have reviewed the relevance and practicality of population viability analysis (PVA) as a method of assessing the impact of OWFs on bird populations. PVA is defined as the process of determining the probability that a population will persist over a specified time period; in the context of cumulative impact assessment (CIA) for OWFs, it may be used as a tool to answer the broad question: "do several OWFs acting in combination with each other (and non-OWF-related pressures) have a deleterious effect on bird populations?" (Maclean & Rehfisch 2008). Maclean *et al*. (2007a) recommended its use as "a robust framework for taking a scenarios-based approach in which likely impacts are determined using upper- and lower-bound estimates of unknowns" – while cautioning against its application without critical assessment.

Following this study, it was agreed at a COWRIE workshop on the cumulative impact of OWFs on birds that PVA should form the basis for assessing whether the magnitude of any change in population was likely to be significant (Norman *et al*. 2007). Although there are some concerns over the information dependency and assumptions inherent in population modelling, further development of PVA is supported for a range of key sensitive bird species (red throated diver, common scoter, gannet, lesser black-backed gull and common tern). In addition, a PVA study for the pink-footed goose population potentially affected by wind farms off the East Anglian coast and eastern Irish Sea has been completed, funded by DECC (WWT Consulting 2008b). This concluded that with an additional annual mortality of 1,000 birds per year, the increase in the risk of population decline below the specific thresholds used was less than 2%. However, if 10,000 birds are killed each year the risk of significant population decline increases considerably (e.g. 18% risk of decline below 100,000 within 25 years).

Norman *et al*. (2007) noted that existing guidelines relevant to cumulative impact assessment (CIA) on birds were insufficiently focussed, with various versions open to interpretation. In response, a draft discussion paper on developing guidelines for ornithological CIA (Maclean & Rehfisch 2008) was prepared in contribution to a further COWRIE workshop in October 2008. Maclean & Rehfisch (2008) identify key aspects to CIA for which guidelines are required, and provide suggestions on what these guidelines might consist of:

- What plans, projects and developments should be incorporated into the CIA process?
- Over what time-scale should impacts be considered?

- Over what area should impacts be considered?
- Specific standards for data gathering, analysis and reporting.

They recommend that all sources of potential impact, beyond those from other OWFs, should be considered; however, wider factors associated with environmental change (e.g. climate change, fishing pressure) should generally not be considered. A suggested appropriate time-scale includes all ongoing and proposed projects, with the exception of proposed protected areas for which a conservation value has yet to be assessed. In terms of the area over cumulative impacts should be assessed, it is noted that the strategic benefits of considering very large areas would be subject to practical constraints. Maclean & Rehfisch (2008) propose that CIA is carried out on the Round 2 strategic areas, or the strategic areas/zones which will be identified for Round 3; however, it is noted that these may not necessarily constitute discrete functional units, and that in such cases the principles used to designate SPAs are applied to identify appropriate areas for CIA. With regard to data standards, it is emphasised that the outputs of EIA need to be compatible; specific guidelines on the outputs of EIA are required before more rigorous guidance on CIA can be formulated.

Considering the recommendations of Maclean and Rehfisch (2008), particularly those relating to appropriate spatial scales for ornithological CIA, it is not thought possible at present to conduct a CIA of the offshore wind element of the draft plan/programme in relation to birds. However, the information presented above identifies key areas and sensitivities of birds in relation to OWF development; consideration of this information, in combination with the findings and recommendations below, will assist in the appropriate siting of OWFs and minimising the risk of cumulative effects arising. Following the proposal of Round 3 developments, discrete functional units can be identified over which CIA can be effectively applied. It is recommended that such assessments follow a single set of guidelines supported by the regulatory authorities. While CIA will need to consider potential cumulative impacts in relation to all other ongoing or proposed developments, particular attention will need to be given to any proposed developments within territorial waters of Scotland and Northern Ireland; the scope of functional units must consider such developments.

5.5.4.2 Other potential cumulative effects

Considering the very minor effects identified relating to fouling and fish aggregation, significant cumulative effects seem unlikely. Such effects have been experienced over many decades in relation to offshore oil and gas infrastructure, with no evidence of cumulative effects identified to date. Potential cumulative impacts influenced by lighting on offshore wind turbines relate to bird collision risk; the influence of lighting on this risk should be considered in estimations of collision rates (see above).

Further research is required to investigate the potential significance (if any) of artificial electric and magnetic fields for marine organisms. In the absence of information on the significance of EMF effects, very little can be done to assess the potential for cumulative impacts resulting from EMF. As described in Section 5.4.3, with regard to the 25GW scenario of the draft plan/programme, an approximation of the area affected by inter-array cabling is 10km^2 with a further 2.5km^2 affected by export cables. Such an area represents a tiny fraction of the UKCS seabed, and appears trivial in comparison to the area which is subject to disturbance by demersal fishing gear. However, it is prudent to consider important areas for key species of concern such as elasmobranchs, along with the development of the evidence-base for the ecological significance of EMF effects.

5.5.5 Summary of findings and recommendations

Overall, the assessment outlined above concludes that the available evidence from existing OWF developments suggests that displacement, barrier effects and collisions are all unlikely to be significant to birds at a population level. However, there are some important uncertainties in relation to bird distribution (and temporal variability), the statistical power of monitoring methods (Maclean *et al*. 2007b), and the sensitivity of this conclusion to modelling assumptions (notably avoidance frequency in modelling of collision risk; and several important factors in modelling of population dynamics).

The potential application of a Species Sensitivity Index (SSI) for wind farms (Garthe & Hüppop 2004) is noted; and it is recommended that consideration is given to the practicality and utility of the development of UK-specific individual Species Sensitivity Indices (SSI) and its mapping in UK waters. The recent aerial bird survey data should be incorporated in the distributional database used to map the SSI (if progressed) and an updated version of the Offshore Vulnerability Index (OVI) to surface pollutants. The existing initiatives to develop Population Viability Analysis for sensitive species should also be progressed. Both of these topics will be of strong relevance for site-specific environmental assessment of potential Round 3 and future developments.

It is not considered possible at present to conduct a CIA of the offshore wind element of the draft plan/programme in relation to birds. The recommendations of Maclean & Rehfisch (2008) for specific guidelines on the outputs of EIA and more focussed CIA guidance are supported. Their proposed approach to CIA is also recommended - including the spatial scale of a Round 3 strategic zone level and/or a corresponding functional unit, and the use of PVA (where possible) as a measure of significance.

A large proportion of the bird sensitivities identified are concentrated in coastal waters. Therefore, as part of this precautionary approach for ecological receptors, a coastal buffer of 12 nautical miles is recommended within which major OWF developments would not normally be sited (this recommendation also contributes to minimising adverse effects on a range of other users of the maritime area). This does not preclude OWF developments in this zone but is a recognition of the relative sensitivity of multiple receptors in coastal waters.

Although there has recently been significant survey in coastal waters, the lack of modern data on waterbirds in offshore areas is noted. Developers need to be aware that access to adequate data on waterbird distribution and abundance is a prerequisite to effective environmental management of activities for example in timing of operations, and oil spill contingency planning. An important gap in understanding of relevance to wind farm siting is the marine areas routinely used by breeding birds for foraging, in particular those adjacent to SPAs. To give a specific example, the East Caithness cliffs SPA holds a seabird assemblage of international importance which during the breeding season regularly supports 300,000 individual seabirds including guillemot, razorbill, kittiwake, herring gull, shag (all at numbers of European importance) as well as puffin, great black-backed gull, cormorant and fulmar. The Smith Bank, some 20km from the cliffs, is generally sandy and recorded as having high densities of sandeels and seabirds; ecological energetics would suggest that the area would be an important feeding ground for auks and several other species from the Caithness cliffs with but definitive evidence of this is not available

The potential information gaps relating to electromagnetic fields are also noted, and it is recommended that the research needs identified by Gill *et al*. (2005), and Bochert & Zettler (2006) are reviewed in the context of the DEFRA reviews of Round 1 and 2 wind farm monitoring.

Other potential effects relating to physical presence (e.g. fouling); and effects relating to receptors other than birds, are considered unlikely to be significant at a strategic level.

5.6 Landscape/Seascape

There are three principal considerations for an assessment of the likely impacts of wind turbines on the seascape/landscape of the UK coastline: the limit of visual perception from the coast (i.e. are the turbines visible and what influences their visibility), the individual characteristics of the coast which affect its capacity to absorb a development and how people perceive and interact with the seascape.

5.6.1 Visibility of turbine structures from the coast

5.6.1.1 Curvature of the earth and theoretical visibility

The curvature of the earth influences the visibility of turbines but is negligible except at very long distances – for instance an observer of height 1.7m would still see the nacelle of a 160m turbine at 25-30km from the coast at sea-level, and would observe a similar scene (albeit at a reduced scale) at 45-50km from the coast at 100m above sea-level. The basic formula for calculating the distance over which an object is visible, taking account of the curvature of the earth and atmospheric refraction is (Scott *et al*. 2005):

$$d = \sqrt{2rh}$$

(Where: *d*=visible distance, *r*=radius of the earth (7,430km accounting for atmospheric refraction), *h*=height of observer/to blade tip).

For instance, the sum of the height of an observer at 50m (+1.72m for average height of person) in addition to a turbine height to blade tip of 160m gives 217.2m. The resulting maximum theoretical viewable distance would be 57km. DTI (2005) guidance considers that effects are likely to arise when the nacelle becomes visible at the horizon, as it is debatable as to whether blade tips could be distinguished by the human eye at such long distances. Table 5.6 indicates the 'worst case scenario' of visibility from a range of viewer heights which are available at the coast, or within 10km of the coast, around the UK.

Table 5.6 – Theoretical viewable distance due to curvature of the earth

Viewer height (m)	Viewable distance to nacelle (km)	Viewable distance to blade tip (km)
1.7 (sea level)	26	49
9	28	50
22	32	52
100	47	62
150	54	68
250	66	78
500	90	99

Note: based on a turbine of 160m to blade tip with a rotor diameter of 90m. Lower values of 9, 22 and 100m are based on typical viewing heights stated in White Consultants (2009).

At a project specific scale, seascape studies consider the zone of theoretical visual influence (ZTV) around a development, which is the extent of the potential visibility of a development. Digital terrain models and GIS tools are utilised to perform this calculation which takes into account, amongst others, aspect, height and intervisibility. Such visibility is theoretical in the sense that it assumes no surface cover (e.g. trees and other tall vegetation, buildings, sea defences etc. – though field survey can be used to inform the process) and so has a tendency to overestimate the potential area impacted – a result of this being that if it predicts no visibility then there is no effect (DTI 2005).

5.6.1.2 Haze and meteorological factors affecting visible distance

The above methods of determining viewable distance and visibility fail to take into account haze and meteorological conditions which will greatly affect how far can be seen. Visibility affected by haze, that is the barrier to visual acuity brought about through atmospheric aerosols (Husar & Husar 1998), is likely to reduce an individual's viewable distance. In this case, the viewable distance can be taken to mean, 'the maximum distance at which an observer can discern the outline of an object'. Husar and Husar (1998) present the following formula for calculating such distances (shown here as modified in Scott *et al.* 2005):

$$v=c/e$$

(Where: v=visual range, c=constant determined by the threshold sensitivity of the human eye and the assumed contrast of visible objects against their background, e=extinction coefficient – a measure of how much haze is in the air). Table 5.7 indicates the maximum likely viewable distance at which the outline of an object can be made out given a range of UK specific coefficients. The acuity of an individual's eye and the number, form and lighting of viewable objects will vary this distance (Husar & Husar 1998). This calculation of haze filters out any meteorological phenomenon which might also affect visibility (e.g. rainfall, fog) and therefore represents clear visibility. Urban centres may be adversely affected more than rural areas due to greater amounts of particulate matter in the air (White Consultants 2009). DTI (2005) recommend the use of Met Office visibility data to assess trends in conditions over a 10 year period for stations located landward of proposed wind farm sites.

Table 5.7 – The influence of haze on viewable distance

Applicable area and season	Haze coefficient (e)	Viewable distance (v)
Northern Scotland	0.1	39km
Wales (spring and summer). Central and southern Scotland (summer to winter)	0.15	26km
Central and southern England (spring). Central England, north and south Wales (winter). Parts of south- and north-east England (summer)	0.2	19.5km
Southern England (winter)	0.25	15.6km

Source: after Husar & Husar (1998). Assumes a 'c' value of 3.9 as recommended in Scott et al. *(2005).*

5.6.1.3 Experience from previous studies

DTI (2005) guidance indicates that the limit of any significant effect on areas of moderate sensitivity can be considered at a distance of 30-35km offshore. If the results from Seascape and Landscape Visual Impact Assessments (SLVIAs) for Round 1 and 2 sites are considered, the average maximum distance at which low magnitude effects were assessed to occur was 32km (the maximum being 35.8km for Gwynt y Môr, North Wales). The exception to this is the Beatrice demonstrator in the Moray Firth, where low magnitude effects were calculated at a distance of 41km from the shore.

Table 5.8 indicates the likely maximum and average thresholds for low and medium magnitude effects in relation to the individual scenarios of each site. Turbine size (MW) is taken as a suitable proxy for site size, though number of turbines will also have a significant effect.

Table 5.8 – Average and maximum distance at which low to medium magnitude effects may take place based on previous seascape studies

	2-3.6MW	5-6MW
Average (Average) distance where medium magnitude of effect occurred	10.1km	14.2km
Average (Maximum) distance where medium magnitude of effect occurred	11.9km	15.0km
Average (Average) distance where low magnitude of effect occurred	17.0km	25.8km
Average (Maximum) distance where low magnitude of effect occurred	21.2km	32.0km

Source: White Consultants (2009)

The development scenario will vary for each individual wind farm; though the principal factors affecting visibility other than distance from the coast are lighting, turbine arrangement and individual turbine size. Initial results from a study of English seascape units draw the following preliminary conclusions about visibility based on three turbine sizes – these results must be viewed as indicative (Table 5.9).

Table 5.9 – Thresholds of significance for turbines of English seascape development scenario (at 22m asl)

Turbine size	Height to blade tip	Height to nacelle	Threshold of significance for seascape units of high sensitivity	Threshold of significance for seascape units of medium sensitivity
3.6MW	137m	83.5m	18km	13km
5MW	175m	112.5m	24km	18km
10MW	190m	115m	24km	18km

Source: White Consultants (2009)
Note: Based on development scenarios of 50 (10MW), 98 (5MW) and 155 (3.6MW) turbines in a grid pattern separated by 550m.

5.6.2 International experience in siting offshore wind farms

Siting offshore wind farms within 12.5km of the coast has been subject to local opposition in Belgium, which has led to the adoption of a wind farm zone beyond 12nm (some 22km) from the coast – a similar approach has been adopted by the Netherlands. Denmark has sited wind farms of limited size up to 20km from the coast, though more emphasis is given to public perception of turbine arrays rather than visibility, using public exhibitions held during the planning process. Some sizeable wind farms have been erected within viewable distance from the coast, for instance the Horns Rev 1 site which has 80 2MW turbines located just less than 20km from the Jutland coast. To the east, the Lillgrund wind farm lies between Denmark and Sweden and is highly intervisible between the coasts of both countries. In Germany, seascape assessments are only required with developments within 50km of the coast – the first German wind farm (45km offshore from Borkum Island) consists of six 5MW turbines. Another German project is the BARD Engineering Offshore I wind farm, which consists of 80 5MW turbines located in the German Bight at 89km from the coast – no visual effects are expected at such a range. A high number of wind farms have been approved for development or are in the planning process in Germany, with nearly all of these at 30km or greater from the coast.

Table 5.10 indicates wind farms constructed or approved by a number of European countries – in addition to these some countries have a number of nearshore sites (e.g. Rønland, Denmark; Kemi Ajos 1 & 2, Finland). The average siting distance is 35km offshore, though distances range greatly between most other countries and Denmark and Sweden, reflecting geographical constraints in some circumstances and perhaps also differences in attitudes. For offshore wind turbines in Denmark, the sociological study of Ladenburg (2008) indicates that due to the negative externalities experienced from onshore turbines relative to those offshore, altitudes to increased offshore development are generally positive.

Table 5.10 – Constructed & approved offshore wind farms in the Baltic & North Seas

Country	Name	Turbine size (MW)	No. Turbines	Distance from shore (km)
Germany	Aplha Ventus	5	6	43
	Amrumbank West	3.5-5	80	36
	BARD Offshore I	5	80	89
	Borkum Riffgrund	3	77	34
	Borkum Riffgrund West	3.5	80	50
	OSB Offshore- Bürger-Windpark Butendiek	3	80	37
	Dan Tysk	5	80	70
	Global Tech I	5	80	93
	Offshore North Sea Windpower	4-5	48	40
	Gode Wind	5	80	33
	Hochsee Windpark, He dreiht	3.6-5	80	85
	Hochsee Windpark Nordsee	5	80	90
	Nordsee Ost	4-5	80	30
	Offshore- Windpark Nordergründe	5	25	13
	Nördlicher Grund	3-5	87	86
	Meerwind	5	80	15-50
	Sandbank 24	5	80	90
	Offshore NorthSea Windpower	5	48	39
Netherlands	Egmond aan Zee	3	36	10-18
	Wind-park Q7	2	60	23
Sweden	Lillgrund	3	48	10
	Yttre Stengrund	2	5	4
	Utgrunden I	1.5	7	7
	Bockstigen	0.56	5	3
Denmark	Horns Rev 1	2	80	14
	Horns Rev 2	2.3	92	20
	Tunø Knob	2.2	11	6
	Middelgrunden	2	20	2
	Nysted	2.2	72	10
	Samsø	2.3	10	3.5
Belgium	Thornton Bank phase 1	5	6	27-30
	Thornton Bank phase 2	5	18	27-30
Rep. Ireland	Arklow Bank	3.6	7	7

Source: EWEA (2008), Offshore Wind, Germany website

5.6.3 Contrast and lighting

The atmosphere is thickest at the horizon and appears lighter there, darkening overhead. Turbines which are white and light grey will contrast least and thus be less visible unless silhouetted by sunset or sunrise (White Consultants 2009) – certain viewing aspects are therefore more greatly affected than others.

Lighting of wind farms must meet both Trinity House and CAA standards for marine navigation and aviation respectively. Navigation lights at the corners of wind farms must be visible for 9km, with intermediate ones at 3.6km, though it may be surmised that these lights may be viewable from a greater distance. It is possible that marine navigation lighting may be viewable at the coast in clear night conditions particularly where other light pollution is absent and may therefore have greatest influence in rural areas of high tranquillity. CAP 393 Air Navigation: The Order and the Regulations Amendment 3/2008 issued by the CAA indicates lighting requirements are one medium intensity steady red light positioned as close as reasonably practicable to the top of the fixed structure. This will typically be situated on the nacelle making sites at the limit of the horizon more visible at night, and the lights may flash in a haphazard manner (which may be disconcerting) as the blades pass in front of the light.

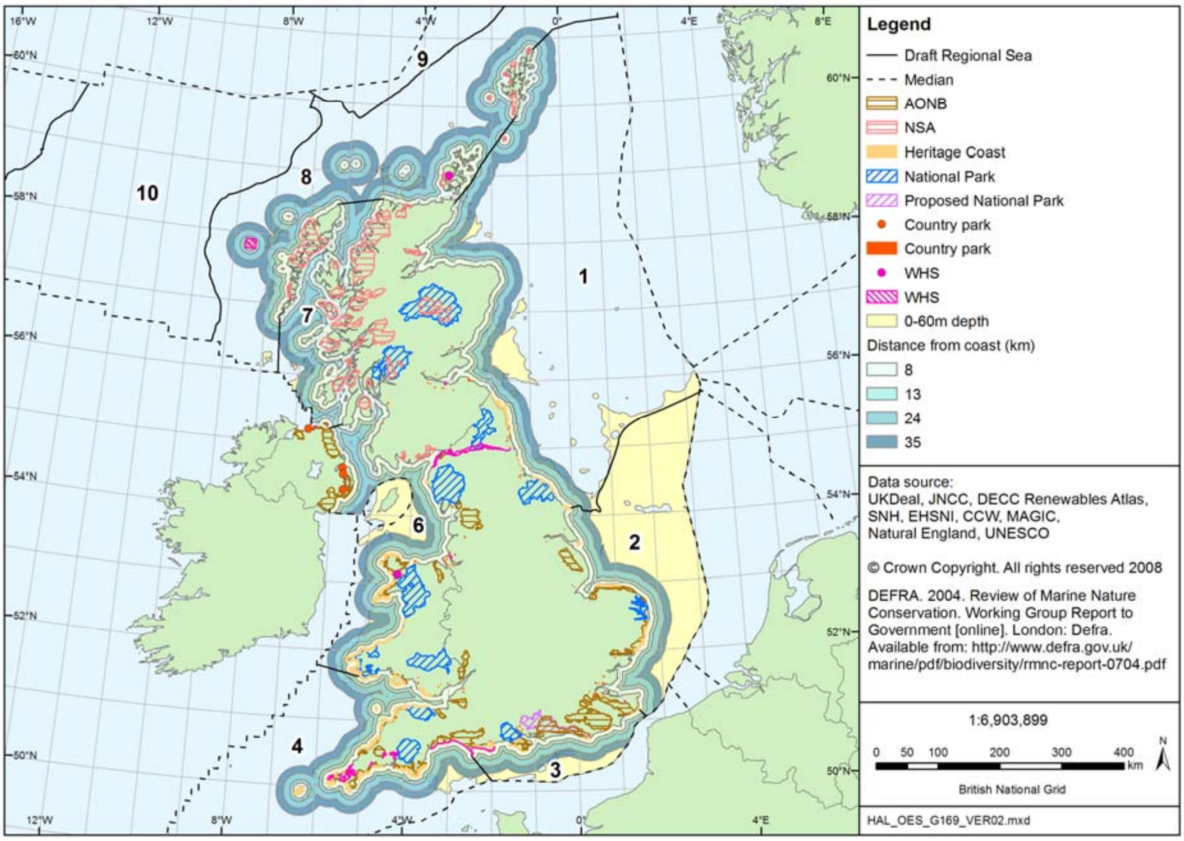
In the absence of any further assessment of landscape sensitivity to offshore wind farm development, it can be seen from Figure 5.21 that those areas likely to generate the most significant visual intrusion are those to fall within 24km of the coast, assuming that future wind farm sites are to use larger, more powerful turbines (e.g. 5MW or greater). The 35km buffer represents an indicative maximum actual visibility based on the studies discussed above, though this is not necessarily as far as an individual may be able to see. The Dogger Bank is well beyond the area of visual significance and development here would not be visible from any location on land.

The visibility of structures from the coast does not preclude development, and any consideration of coastal 'buffers' is perhaps too broad brush to take into consideration the many anthropogenic and natural variations along the coast (at local to regional scales) and the variety of development scenarios which might take place (e.g. height, pattern of turbines). What determines the capacity of a stretch of coastline to accommodate a given development scenario is people's perception of the view. This may be controlled by whether turbines are viewed from an urban or industrial landscape or a more remote or 'wild' area, the occupation of the viewer and their motivation for being in the viewing location (e.g. work, leisure), and indeed where the context of the coast and turbines meet (e.g. leisure craft travelling on coastal routes will have intervisibility with the coast and sea).

Visibility of developments depends on the ability of a people to access the coast. In December 2008, the UK Government introduced the Marine and Coastal Access Bill into Parliament, which aims to create a coastal long distance route and open-air recreation areas around the English coast while balancing this need with environmental protection and coastal planning. A UK wide approach on access has been agreed with the devolved administrations of Wales, Scotland and Northern Ireland and therefore coastal access is likely to improve across the UK in the coming years. Currently in Scotland, the Land Reform Act permits responsible access to coastal and inland areas, and anywhere where the coast is accessible to the public may be a viewing platform to the open sea. The Countryside and Rights of Way Act 2000 enables public access on foot to the countryside in Wales. Improvements in access to the Welsh coast is expected in the coming years as a £1.5m grant was awarded in 2007 to coastal local authorities to improve coastal paths and access. In Northern Ireland, access to the countryside is controlled by the Access to the Countryside

(NI) Order 1983, under which district councils may identify recreational routes and areas of open-air recreation.

Figure 5.21 – Designated landscapes in the UK in relation to likely wind development areas (0-60m)



There are a number of ways set out by the DTI (2005) adopted from previous guidance, and utilised in the regional scale studies of Scott *et al.* (2005) and CCW (2008b) which attempt to identify through objective (and partly quantitative) means the sensitivity and 'value' of a particular coast or defined seascape unit.

5.6.4 Landscape 'value'

Landscape value is assessed on the basis of the importance attached to a certain area because of natural or cultural qualities and these in turn are reflected in value 'scores' included in UK strategic level seascape studies (e.g. Scott *et al.* 2005). National landscape designations can be taken to represent a reasonably objective measure of such value. Figure 5.21 indicates the distribution of landscape designations around the UK in relation to shallow (<60m) waters and also with buffers representing indicative zones of actual visibility from the coast (as discussed above).

5.6.5 Seascape sensitivity

Seascape sensitivity is defined as the inherent sensitivity of a landscape/seascape to any type of change, which is dependent on (Scott *et al.* 2005):

- Sense of scale

- Openness/scale
- Coastal and hinterland form
- Settlement pattern
- Seascape pattern and foci
- Movement
- Lighting
- Aspect
- Tranquillity/remoteness/wilderness
- Exposure
- How the seascape is experienced (Receptor sensitivity)

These factors are accounted for in each regional seascape study used in this section (Scott *et al.* 2005, CCW 2008a, b), and in a discussion of the English coast.

The 'compatibility' or degree to which a wind farm development alters or harmonises with the character of a seascape in which it is observed, is largely determined by these sensitivity criteria, key considerations including how the form and scale of the development interacts with coastal morphology, and the level of development already experienced from coastal positions within viewable distance of the development. These characteristics are highly variable at the regional and even local scale and are difficult to account for in a comprehensive manner at a strategic level.

The horizontal and vertical scale of the coast can influence the sensitivity of a seascape. Where the principal viewing platforms are across bays, inlets, sea lochs and inner firths, developments may take up more of the horizon and be framed by headlands, whereas more open, expansive views have the opposite effect (Scott et al. 2005). The apparent scale of intervisible aspects (e.g. coastal cliffs, mountains) may be diminished by turbines, as the scale of these is often not great but appears so due to the steepness of their slopes (Scott et al. 2005). Aspect influences wind farm visibility during sunset and sunrise, as turbines appear silhouetted against the sky.

Outside of scale, form, aspect and exposure, seascape sensitivity is greatly influenced by the level of coastal development, and this can be highly variable within regional scale seascape units. Urban and industrial settings, areas where other forms of mechanical movement are present (e.g. ships, cars), where artificial light is prominent, and where the observation points are from busy roads or beaches, may be considered more advantageous for development than rural areas. Where there is already considerable urban development, cumulative impacts must also be considered (DTI 2005).

Sensitivity is not just a measure of the compatibility of wind farms with coastal character, but also the users of that landscape. Examples of a range of sea and land based activities along a scale of sensitivity, for instance recreational boating to extractive oil and gas, and tourists/visitors to military and industrial users are provided in DTI (2005). The use of the coast for such activities may be relatively easy to define and measure, though the sensitivity of individuals may be more complex.

Many of the factors influencing perceived aesthetic (landscape) quality are relative and subjective concepts which are bound by any given individual's attitude, perceptions, and *a priori* or *a posteriori* knowledge about wind farm development, or indeed environmental issues more generally. Landscape preservation (and change), like many environmental issues, is an emotive topic. Attitudes range from romantic views of nature as unspoilt 'wilderness' to be preserved for its inherent landscape value, less anthropocentric 'deep ecology' ideas of humans as part of the natural ecosystem, or more recent 'wise use' ideas falling within the umbrella of sustainable development. In any case, the inherent quality or naturalness of some landscapes are valued more than others, as recognised in statutory designations and the landscape 'value' methodology employed in landscape/seascape studies. It is not just 'wild' places where visual intrusion is regarded as deleterious, for the countryside aesthetic is often as important, for instance the recent attention given to 'Character Areas' which are assessed in the context of their natural (though more semi-natural) and cultural heritage qualities, and indeed for more recent urban qualities. Hedgerows are a key example of a largely relict countryside landscape component preserved for their cultural associations and ecological qualities, and the recognition of urban areas as distinct landscapes is highlighted in the new European Landscape Convention, and by association with certain World Heritage Sites (e.g. the Cornwall and West Devon Mining Landscape). Indeed, wilderness may often have more to do with perception than any ecological understanding, for instance recent GIS based research by Carver *et al*. (2002) attempted to identify and map wilderness based partly on perception as derived from public participation – the result is arguably a gradient of development. At a very local level, perceptions may also be affected by prevailing or historical legislation and land ownership; for instance, access rights in England have always been restrictive, which helped to produce a public more restricted in their movements and range of permitted activities (Macnaghten & Urry 1998).

A Countryside Commission (1993) report indicated that over 60% of the UK public regarded the countryside as a vital component to their quality of life as opposed to the perceived 'stress and pollution' of cities (Macnaghten & Urry 1998), and given that over 80% of the UK population are urban dwellers (2001 census data, Pointer 2005) it may be presumed that for many people, experience of the countryside is an important seasonal relief. Surveys of awareness and attitudes to renewable energy, specifically onshore wind, (see DECC website) indicate that people are generally in favour of the use of renewables, including wind power, indicating that the general population perceives advances in renewables as necessary (possibly linked with perceptions/knowledge relating to climate change/depleting hydrocarbon reserves). Opinions on wind farm landscape issues can change during each stage of construction; for instance, a survey conducted for the Scottish Executive by MORI in 2003 found that 15% fewer people had concerns about landscape issues (27 vs. 12%) following turbine construction than in planning.

5.6.6 Regional Sea assessment of seascapes in relation to offshore developments

5.6.6.1 Regional Sea 1

The English section of Regional Sea 1 has not currently been regionally assessed for seascape sensitivity. The results of the Scottish study by Scott *et al.* (2005) are summarised in Table 5.11 and these are used to generate a synthesis for the sensitivity of the Scottish coast below.

A high value score may be expected for the stretch of coast from Flamborough Head to the Scottish border from the combination of Heritage Coasts (e.g. North Yorkshire and Cleveland, Flamborough Head, and North Northumberland), a National Park (North York Moors) and World Heritage Site (Hadrian's Wall). A number of National Trails traverse the area including the Cleveland Way and Yorkshire Wolds Way on which people would be primarily expecting wild and natural views across the land and sea.

Cliffs along the coast between Flamborough Head and Saltburn-by-the-Sea reach between 100 and 150m, affording views over a wide open seascape, and though possibly viewed by few, sunrises would silhouette turbine structures against the sky and make them more visible. On clear nights, navigation or, more likely, aviation lights may be seen from the coast. The rugged coastal form, small coves, bays and coastal towns and fishing villages of the North York Moors area and the lightly settled area of the Yorkshire Wolds may not be compatible with the developed character of turbines. In contrast, turbine structures may be compatible with the Tees and Tyne, and Wear lowland areas which are highly developed low-lying coasts with extensive urban and industrial developments.

To the north of the Tees lowlands area, Magnesian Limestone has formed a varied line of bays and headlands – erosion has generated features such as caves and stacks, increasing the complexity of the coast. This complexity and the unique, incised gorge-like coastal denes may make turbine structures detract from this complexity, particularly where views are focussed down enclosed denes. Further north, the Northumberland coastal plain is sparsely populated and rural, and the coast affords wide open views to the east from both elevated hard-rocked cliffs in the north and soft low-lying coasts to the south.

The east coast of Scotland attains low value scores (Scott *et al.* 2005) due to the paucity of statutory designations which amount to just two – the Dornoch Firth and Fair Isle National Scenic Areas. There are also Local Landscape Designations which stretch around the Fraserburgh Head from Peterhead to Cullen, in the outer Dornoch Firth and parts of the Caithness and Rosshire coast though these are not regarded with the same weight as National Scenic Areas.

The coast north to Aberdeenshire has few large scale industrial features and the area has locally distinctive and natural coastal attributes. The simple landform, relatively linear coastline, general absence of focal features and expansive scale of the sea are key factors in limiting sensitivity to development. Turbines would need to be carefully sited to avoid intrusion on the setting of settlements. Similarly, the Moray coast has simple landform, general absence of focal features and wide open sea views which may limit sensitivity to development. Wind energy may affect the perception of this seascape unit where settlement is small scale and largely of a ‘traditional’ or ‘historic’ nature.

Appreciation of the East Caithness and Sutherland coast hinterland would not be disrupted due to its simplicity of form and limitations of views inland. The expansiveness and exposure of the open sea may accommodate turbine structures, but would also introduce an additional industrial and illuminated feature into this seascape where the Beatrice and Jacky oilfield platforms can be seen from land by day and night. This may further affect the perception of this area as being remote and ‘undeveloped’. Turbines could also potentially visually conflict with the scale of small traditional settlements and the narrow coastal shelf if located too close to the coast.

The open and expansive seascapes viewable from Shetland’s coast may be compatible with the scale of any wind farm development, though they may affect the intricate land/sea relationship and views of outlying islands including Fair Isle and the appreciation of the vertical scale of high cliffs where these are present. The perception of remoteness and ‘wildland’ qualities of some coastal areas and the highly natural character of the outlying islands may also be affected by development.

Firth of Forth and Firth of Tay area

The coast from the English border to the Firth of Forth affords wide open views to the sea from a generally linear coastline. Existing development and transport infrastructure already give a localised developed character in places and busy shipping lanes are present in the sea. The perception of exposure would connect to wind energy, but may conflict with the scale and character of traditional settlements and the dramatic coastal edge which exists in some sections of coastline. The scale of the outer Forth and Tay firths may be compatible with turbine structures, and would have only minor impacts on flatter land profiles, though may detract from the focus of the firths and views east out to the open sea. Distinctive islands/hills of the Forth form a focus which may be disrupted by turbines and careful siting would therefore be necessary. The firths have some industrial elements which may reduce their sensitivity to any proposed development.

Moray Firth

Any development in this area is likely to have some low level visual impact on the coasts of the outer firth. The Beatrice demonstrator seascape study concluded that the average distance at which low magnitude effects occurred was 30.3km from the coast, extending to a maximum of 41km – the area where the water depth is <60m lies between 22 and 35km from the northern coast of the firth. Turbines may have less of an impact in the open expanse of the Outer Firth, though could detract from the focus of the Firth. The existing Beatrice wind demonstrator and oil platforms may reduce the sensitivity of this seascape to further offshore wind development, though care would need to be taken not to generate significant cumulative effects. There are no coasts considered to be of high sensitivity or value, or low capacity to offshore wind developments out to 35km from the coast (Scott *et al.* 2005).

Forces of Landscape Change

For some area such as the Firth of Forth and Firth of Tay, urban expansion is unlikely to significantly alter the sensitivity of the landscape. Onshore wind developments in the Grampian and Highland areas have the potential to generate cumulative effects, and a number of onshore, coastal, wind farms are now operational (e.g. Boulfruich). There may be cumulative effects in relation to the Beatrice wind demonstrator and oil platforms if there is intervisibility between developments. Increased use of the seas around Shetland for aquaculture may conflict with other offshore energy developments.

5.6.6.2 Regional Sea 2

A number of Heritage Coasts recognise the value of this section of coastline, and include Flamborough Head, Spurn Head, and the Norfolk and Suffolk Coasts. In Norfolk and Suffolk these coincide with the Norfolk and Suffolk Coasts and Heaths AONBs and the Broads National Park.

Cliffs are only present along Holderness, North Norfolk, Flamborough Head and the Thanet coastline. Most of these cliffs are soft and eroding, but all provide wide, expansive views of the North Sea. The variation in local cliff height will alter the viewable distance of the observer, though if sufficiently sited offshore this should not significantly influence the impact of a development, though at night aviation lights may be more visible from higher ground.

Extensive areas of saltmarsh are present in the Humber and Wash Estuaries, and these provide low, open and simple landforms which may be incompatible with vertical turbine structures. Numerous smaller examples are located in estuaries draining the outer Thames in Suffolk, Essex and Kent (e.g. Medway, River Stour), and views may be focussed down some more enclosed estuaries.

Table 5.11 – Summary of landscape/seascape assessment for the Scottish coast relevant to Regional Sea 1

#	Area	Seascape character type	Sensitivity	Value
1	Berwick upon Tweed	Mainland Rocky Coastline with Open Sea Views although a small area of Remote High Cliffs encompasses St Abbs Head.	Low/Medium	1
2	Firth of Forth	Outer Firths, Developed Inner Firths	Medium	1
3	East Fife/Firth of Tay	Deposition Coastline with Open Views, Outer Firths, Less Developed Inner Firths.	Medium	1
4	North East Coast	Mainland Rocky Coastline with Open Sea Views/Deposition Coastline with Open Sea Views.	Low/Medium	1
5	North Aberdeenshire/ Morayshire coast	Mainland Rocky Coastline with Open Sea Views/Deposition Coastline with Open Views.	Low/Medium	1
6	Moray Firth	Outer Firths and Smaller and Less Developed Outer Firths. Less Developed Inner Firths and a small area of Developed Inner Firths. Deposition coastline with Open Sea Views occurs in Golspie.	Medium	1
7	East Caithness and Sutherland	Mainland Rocky Coastline with Open Sea Views and a short section Deposition Coastline with Open Views and Narrow Coastal Shelf. A small area of Remote High Cliffs occurs on the north eastern tip of Caithness.	Low/Medium	1
8	North Caithness/Pentland Firth	Remote High Cliffs with Mainland Rocky Coastline with Open Sea Views, occurring to the east. Small areas of Deposition Coastline with Open Sea Views are also present.	Medium	1
33	Shetland	Islands, Sounds and Voes with small areas of Remote High Cliffs.	Medium/High	1

Source: Scott et al. (2005)
Notes: Based on a wind farm development scenario of 100 turbines, 150m to blade tip, 8km from the shore in a grid covering 25km^2
Visibility based on 10km landward, 35km seaward buffer.
Value scores range from; 1=Low value, 5=High value

There are numerous coastal urban areas along the coast though many are small or holiday resorts (e.g. Great Yarmouth, Cromer, Skegness) rather than industrial towns. The low-lying Broads back onto the coast near Great Yarmouth and are a visually intricate landform which will increase the sensitivity of this section of coast to turbine structures. The largest and most developed area is the Hull and Greater London areas which include gas terminals, oil refineries, chemical engineering industries and various coal and nuclear power stations (e.g. Sizewell). Holiday resorts may have less capacity to absorb the visual intrusion of turbine structures than these more industrial areas.

Dogger Bank

The area of the Dogger Bank is unlikely to cause any visual intrusion. The area is well beyond the area of visual significance and will not be witnessed from any location on land. Though no study is currently available for this area, it can be surmised that any development in this location may be seen from ferries (e.g. Newcastle to Amsterdam) and gas field support ships and platforms within viewable distance.

Holderness area

Water depths of <60m extend well offshore from the Holderness coast so wind farm development is possible where any visual impacts are likely to be only experienced by people on passenger ferries, recreational craft and commercial and fishing vessels. The landscape designations that attach value to this coast are the Spurn Head, Flamborough Head and the North Yorkshire & Cleveland Heritage Coasts. The other adjacent designations are the North York Moors National Park and the Lincolnshire Wolds AONB, though the latter is perhaps too far away and inland from the coast to be of significant concern. Views from the coast here will be large scale and open, with the exception of the Humber, though the industrial nature of much of this area may be compatible with turbine structures. Open, eastern facing views may mean that there is a strong contrast between turbines and the sky during sunrise.

Norfolk to Kent area

The vast open views of the North Sea afforded from Norfolk, Suffolk, Essex and Kent coasts are likely to reduce the perceived visual intrusion of any wind farm development. Cliffs tend not to be high, and their scale may be further diminished by large turbines. The coastline is made up of a combination of cliffs and low-lying shingle, sand and saltmarsh, and where these views are simple and horizontal; they may be undesirably interrupted by the vertical form of turbines. The development in this area is largely rural and existing developments (e.g. Sizewell and Bradwell nuclear power stations) are extremely visible in this very flat and open landscape. There are a number of industrial centres which may decrease the sensitivity of this part of the coast.

Forces of Landscape Change

Pressures come in the form of further industrial and urban development around Hull and the Thames, and there is limited pressure from caravan, theme park, golf course and water sport development. There is a continuing spread of holiday resorts and homes (e.g. around Cleethorpes, between Mablethorpe and Skegness). Beach nourishment and coastal defence and other engineering is altering the physical form at a number of locations along the coast which may continue in the future and the coastal squeeze of mudflat areas is likely to be exacerbated by any sea-level rise. In some other places, cliff erosion (e.g. Holderness, North Norfolk, Suffolk Coast) will continue to change the form of the coast. Some coastal areas have developed onshore wind energy sites (e.g. Out Newton, Humberside and Conisholme Fen). These, and any subsequent developments, could generate cumulative impacts if there is sufficient intervisibility of onshore and offshore structures.

5.6.6.3 Regional Sea 3

The value of the Regional Sea 3 coast varies from east to west, with progressively more designated landscapes or features of natural and cultural importance to the west. Potential offshore wind farm development areas are primarily in the shallower waters of the central and eastern English Channel but are likely to be curtailed by the presence of major shipping lanes for vessels transiting the Channel.

5.6.6.4 Eastern Channel area

Between Dover and Beachy Head, the coast includes elements of the Kent Downs, High Weald and Sussex Downs AONBs and the South Foreland, Dover-Folkstone and Sussex Heritage Coasts in addition to numerous country parks within 10km of the coast. These designations afford the landscape a high value where they meet the coast, and the North and South Downs Ways provide access to coastal cliffs at Beachy Head and between Dover and Folkstone, frequented by people seeking the unspoilt views of the accompanying AONBs. Dover and Folkstone are urban areas which may be compatible with offshore structures, though the elevation of the landscape around the towns, which includes cliffs and high ground in excess of 150m, will increase the viewable distance and may diminish the scale of the cliffs if they are intervisible with developments. The potential impact of turbine lights and movement may be reduced due to the lights of the French coast and busy shipping traffic, though development here is probably not likely given that UK waters only extend to *ca.* 13km from the coast.

Further to the west, the Dungeness Foreland and Romney Marshes are low lying, with coasts affording expansive views across the English Channel. The coastal strip has numerous 20th century developments, and includes industrial elements such as the Dungeness nuclear power stations which may make the coast less sensitive to additional components with an industrial character. To the west of the Foreland, the Saxon Shore Way travels along a rugged, cliffed coast towards the town of Hastings which has low lying, open views out to sea. Hastings, Bexhill and Eastbourne are large urban centres, but are also tourist destinations and retain a largely non-industrial character which may be compromised by offshore turbines.

The area off Hastings is likely to interact with two contrasting landscapes. There are a number of designated areas including the Sussex Downs AONB, the proposed South Downs National Park and the Sussex Heritage Coast. The coastal sections of these designations suggest low to moderate impacts from the developments with 5MW turbines between 13 and 24km offshore. Beachy Head has an extensive chalk cliffed area reaching heights in excess of 100m, and includes the distinctive Seven Sisters landform. The elevation of the cliffs will not only increase viewable distance, but may not be compatible with the scale of some developments. In addition, the relatively rural nature of the area around Beachy Head and the presence of the South Downs Way mean that people wishing to perceive a ‘wild’ part of the countryside may be impacted. This area contrasts markedly with lower and more developed urban areas along the coast including Brighton, Littlehampton and Bognor Regis.

5.6.6.5 Central Channel and Isle of Wight area

Designations include the Tennyson and Purbeck Heritage Coasts, the Isle of Wight and Dorset AONB sites, the New Forest National Park and the Dorset and East Devon World Heritage Site – these extend from the Isle of Portland to the Isle of Wight. People on the relatively rural stretch of coast from Weymouth to Bournemouth, which includes the South West Coastal Path, are likely to be impacted by developments of 3.6MW or larger within 13-24km from the coast. Some of the coast along the same route reaches elevations of up to 150m, increasing the viewable distance. The scale of larger developments may diminish the scale of these cliffs though they should be sufficiently offshore for this to be negligible in views from land to sea, but not sea to land or on certain cruising routes. This area of coast is quite complex, with enclosed views through The Solent and out from Weymouth Bay. The urban settlements of Weymouth, Bournemouth, and Portland Island and Harbour may be less sensitive to wind farms due to the level of development in these areas.

5.6.6.6 Regional Seas 4 & 5

The Regional Sea 4 coastline contains a dense array of landscape designations including the Dorset, East Devon, South Devon, Cornwall, Isles of Scilly, North Devon and Quantock Hills AONBs, Exmoor, Dartmoor and the Pembrokeshire Coast National Parks, part of the Dorset and East Devon Coast World Heritage Site and the Cornwall and West Devon Mining Landscape World Heritage Site. Numerous Heritage Coasts are also present in both England and Wales, and the South West Coast Path and Pembrokeshire Coast Path make the coast easily accessible to the general public.

Low and high cliffs continue to dominate the coastline all around the South West Peninsula to the inner Severn to around Burnham-on-Sea, where the elevation of the land near the coast diminishes. Much of this cliffed coastline is rural and sparsely populated, and the South West in general is considered to be one of the most tranquil areas in the country (Countryside Agency 2006). The high coastline affords wide and expansive views out to sea from the coast including Lyme Bay, between Falmouth and Bigbury bays, and out from Mount's Bay, and the scale of these views may decrease sensitivity to development. Any development between the Isles of Scilly and the South West Peninsula would interfere with views to and from the islands and would be incompatible with the rural and complex form of the isles.

Urban population centres include Plymouth and Falmouth, and though such areas are generally considered more compatible with offshore developments than rural coasts, the natural complexity of their setting may be disrupted by offshore structures. Indeed views may be focussed down The Sound, Plymouth, and Carrick Roads into Falmouth Bay. Other Urban areas include Cardiff and Bristol in the inner Severn. Towns such as Lyme Regis, Seaton, Beer and Bude are traditional and rural in nature which may not be compatible with the scale and form of large offshore structures. The northern Cornish coast also includes numerous dramatically sited ruins from 19th century mining buildings to Tintagel Castle, and the coast here in general has a visually complex geomorphology. Tourist centres such as Torbay and Torquay and Newquay have a distinctive character, and high surrounding cliffs and some small islets, the scale of which may be diminished by offshore developments. Views may be filtered down the Axe, Exe and Teign, and make turbines or other offshore structures a focus of attention on the horizon.

The Bristol Channel has surrounding coasts in England and Wales. Landscape value here is recognised in the Hartland, Lundy, North Devon, Exmoor, Glamorgan, Gower and South Pembrokeshire Heritage Coasts; North Devon and Gower AONBs and the Exmoor and Pembrokeshire coast National Parks. Unlike most other areas, the Bristol Channel is viewable from almost all sides from high cliffed coasts. Large developments may interfere with views across the Bristol Channel and down the Severn, where turbines would be silhouetted against sunsets. Views from Devon and Cornwall to Lundy Island may be compromised by developments in the offshore parts of this area, and the rural undeveloped and often secluded nature of much of the coast in this region may clash with the industrial character of turbines.

Table 5.12 indicates the relative sensitivity and value of seascape units identified by CCW (2008a) for the Welsh coast.

Table 5.12 – Summary of landscape/seascape assessment for the Welsh coast relevant to Regional Sea 4

#	Area	Seascape character type	Sensitivity	Value
36	Skomer Island to Linney Head	THMR, TSLD	Medium/High	5
37	Milford Haven	EHMR, EHMU, EHLR	High	4
38	Linney Head to St Govan's Head	THMR	Medium/High	5
39	St Govan's Head to Old Castle Head	THMR	Medium/High	4
40	Old Castle Head to Giltar Point/Caldey Island	THMR	Medium/High	3
41	Giltar Point to Pembrey Burrows [Carmarthen Bay]	THMR, THMU, TSLD	Medium	2
42	Taf, Tywi and Gwendraeth estuaries	EHMR	High	1
43	Loughor Estuary	ESLR	High	2
44	Whiteford Point to Worms Head- Rhossili Bay	THMR	Medium/High	5
45	Worms Head to Mumbles Head- South Gower	THMR	Medium/High	4
46	Mumbles Head to Porthcawl Point [Swansea Bay]	THMR, TSLU, TSLD, THIU	Medium	1
47	Porthcawl to Nash Point	THMR, TSLD, THIU	Medium	1
48	Nash Point to Lavernock Point	THIR, TSLU	High	1
49	Lavernock to Gold Cliff	TSLR, TSLU, THMU, THIR	High	1
50	Gold Cliff to Chepstow	TSLR	High	1

Source: CCW (2008a, b)
Key: T=Tidal, L=Tidal current – lateral, E=Enclosed estuary or ria, H=Hard rocked coastline, S=Soft coastline, I=High (>100mAOD 250m inland), M=Medium (25-100mAOD 250m inland), L=Low (<25m 250m inland), R=Rural, U=Urban, D=Dunes
Notes: Based on a wind farm development scenario of many parallel turbines (160m to blade tip) at 550m intervals, 13km from the shore. Visibility is based on a landward and seaward buffer of 24km.
Value scores range from; 1=Low value, 5=High value

Forces of Landscape Change

Tourist pressure continues to increase in the South West with greater facilities, caravan parks, golf courses, marinas and holiday and retirement homes. In some cases, tourism has generated the sprawl of small coastal settlements. Defence works on the Isles of Scilly and elsewhere are likely to become a priority if sea-levels rise in coming years. There is continuing pressure for onshore wind farms and therefore any offshore structures should be considered in relation to these to avoid any cumulative visual effects.

5.6.6.7 Regional Sea 6

Designations relating to landscape value include NSAs in the Solway (Nith Estuary, East Stewartry Coast) and in the Firth of Clyde (Arran, Kyles of Bute). The Hadrian's Wall World Heritage Site, St. Bees Heritage Coast and the Lake District National Park feature on England's coast. Numerous Heritage Coasts are found in Wales (e.g. Ceredigion Coast, Great Orme) as well as two National Parks (Snowdonia, Pembrokeshire Coast).

Any offshore turbines located in the Firth of Clyde and the nearby sounds would significantly alter the seascape. Views to and from the Mull of Kintyre, Arran and Isle of Bute and the mainland would be compromised by turbines, and high offshore structures would diminish the scale of islands, hills and high coastline. Turbines would be the focus of any views down the sounds into the outer Firth which would not be easily accommodated by the largely undeveloped nature of the coast. To the south, the Ayrshire and Galloway coasts have larger more expansive views which may more easily accommodate turbine structures, though the coast is sparsely settled and largely rural here.

The coast of England in Regional Sea 6 varies from saltmarsh (e.g. Wyre Estuary) and shingle to localised sections of dunes (e.g. Walney Island), sandy beaches (e.g. Morecambe) and cliffs (e.g. St. Bees Head). The wide, open views of the sea will reduce the sensitivity of the area to offshore developments. To the south, the extensive intertidal sands and dunes of the Sefton coast are a distinctive landscape feature of the area and though views of offshore developments may be focussed from enclosed views through dune slacks, the wide, open views afforded at the coast may reduce the impact of the scale of developments. Barrow-in-Furness, Whitehaven and Workington provide an industrial element to the landscape which will likely reduce the sensitivity of the seascape to turbine structures, as will the more developed areas of the Mersey and Dee Estuaries and the various nuclear and gas fired power stations along the coast. Light pollution from these and other urban areas (e.g. Blackpool) will make them less sensitive to navigation and aviation lighting.

Much of the Welsh coast consists of medium to low hard rocked cliffs, located around Anglesey, the Lleyn Peninsula, Cardigan Bay and the Pembrokeshire Coast. Cliffs of more than 80m in height are located around the Gower Peninsula, though most are lower than this at between 30-50m. These cliffs represent a substantial part of the UK's cliff resource and any turbine structures may change the perception of these, diminishing their apparent scale. Lower coastlines are located within Tremadog Bay, parts of Cardigan Bay and the northern coast of the Lleyn Peninsula, and shingle and sandy beaches and sand dunes are found in these areas. The wide, expansive views afforded across Cardigan Bay may accommodate turbine structures (although there are other constraints making potential wind farm development here challenging), though this effect would decrease approaching the cliffed coasts of Pembrokeshire and Lleyn. A number of estuaries support low-lying saltmarsh (e.g. Dyfi, Teifi estuaries), and the simplicity of these landforms may be compromised by vertical structures. This section of Wales is sparsely populated and largely rural, with few heavily urbanised and industrial areas and any development may therefore alter the perception of the coast as 'wild' or remote if improperly sited. The largely western facing aspect of Wales, and indeed most of the coast in Regional Sea 6, would mean that turbines would be highly visible at sunset.

Tables 5.13 and 5.14 indicate the relative sensitivity and value scores for seascape units identified in studies of the Scottish and Welsh coastlines.

Table 5.13 – Summary of landscape/seascape assessment for the Scottish coast relevant to Regional Sea 6

#	Area	Seascape character type	Sensitivity	Value
26	Firth of Clyde	Outer Firth with Islands	Medium/High	3
27	South Arran/South Ayrshire/South Easy Kintyre	Narrow Coastal Shelf, Remote High Cliffs, Sounds, Narrows and Islands	Medium	1
28	Corsewall Point-Mull of Galloway	Remote High Cliffs	Medium	1
29	Outer Solway	Remote High Cliffs, Mainland Disposition Coastline/Open Views, Outer Firths	Medium/High	1
30	Inner Solway	Less Developed Inner Firths	High	3

Source: Scott et al. (2005)
Notes: Based on a wind farm development scenario of 100 turbines, 150m to blade tip, 8km from the shore in a grid covering 25km^2
Visibility based on 10km landward, 35km seaward buffer.
Value scores range from; 1=Low value, 5=High value

Table 5.14 – Summary of landscape/seascape assessment for the Welsh coast relevant to Regional Sea 6

#	Area	Seascape character type	Sensitivity	Value
1	Dee Estuary	ESLR	High	1
2	Point of Ayr to Colwyn Bay	TSLR, TSLU, THLU	Low/Medium	1
3	Rhos Point to Great Ormes Head	THIR, THLU, THMR	Medium	2
4	Conwy Estuary	EHMR, EHLR, EHLU	High	3
5	Great Ormes Head to Puffin Island	THIR, THIU, THLR, THMU, THMR	Medium	3
6	Puffin Island to Point Lynas	THMR, THLR	Medium	2
7	Point Lynas to Carmel Head	THIR, THLU, THLR, THMR	Medium	3
8	Carmel Head to Holyhead Mountain North Stack	THIR, THMR	Medium	2
9	Holyhead Mountain North Stack to Penrhyn Mawr	THIR, THMR	Medium/High	4
10	Penrhyn Mawr to Pen-y-Parc/Maltraeth Bay	THMR, THLR	High	2
11	Holy Island Straits	LHLR	Medium/High	2
12	Menai Straits	LSLR, LHMR	High	2
13	Maltraeth Bay to Trefor	TSLR, THLR, THMR	Medium/High	2
14	Trefor to Porth Dinllaen	THIR, THMR	Medium/High	4
15	Trwyn Porth Dinllaen to Braich y Pwll/Mynydd Mawr	THMR, THIR	Medium	4
16	Braich y Pwll and Bardsey Island	THIR, THMR	High	5
17	Bardsey Island to Trwyn Cilan	THMR, THLR	High	5
18	Trwyn Cilan to Penrhyn Du [Porth Ceiriad and St Tudwal's Island]	THMR	Medium/High	4
19	Penrhyn Du to Pen-ychain [Abersoch and Pwllheli]	THLR, TSLR	Medium/High	3

#	Area	Seascape character type	Sensitivity	Value
20	Pen-ychain to Morfa Dyffryn [Tremadog Bay]	THLR, TSLR	Medium/High	4
21	Porthmadog Estuary	ESMR, ESLR	High	5
22	Morfa Dyffryn to Pen Bwch Point [Barmouth Bay]	TSLR, THMR, THIR, TSMR	Medium	5
23	Mawddach Estuary	ESLR, EHMR	High	5
24	Pen Bwch Point to Upper Borth	TSLR, THMR	Medium	3
25	Dyfi Estuary	ESMR, ESLR	High	3
26	Upper Borth to Newquay [central Cardigan Bay]	THMR, THIU	Medium	1
27	Newquay to Cardigan Island	THMR, THIR	Medium/High	1
28	Teifi Estuary	EHMR, ESLR	High	2
29	Cemaes Head to Trwyn y Bwa	THIR, THMR	Medium/High	4
30	Trwyn y Bwa to Dinas Head [Newport Bay]	THMR	Medium/High	5
31	Dinas Head to Crincoed Point [Fishguard Bay]	THMR, THMU	Medium	3
32	Crincoed Point to Strumble Head	THMR	Medium/High	3
33	Strumble Head to St David's Head	THMR	High	3
34	St David's Head to Ramsey Island	LHMR, THMR	High	5
35	Ramsey Island to Skomer Island [St Brides Bay]	THMR, TSLR	High	4

Source: CCW (2008a, b)
Key: T=Tidal, L=Tidal current – lateral, E=Enclosed estuary or ria, H=Hard rocked coastline, S=Soft coastline, I=High (>100mAOD 250m inland), M=Medium (25-100mAOD 250m inland), L=Low (<25m 250m inland), R=Rural, U=Urban, D=Dunes
Notes: Based on a wind farm development scenario of many parallel turbines (160m to blade tip) at 550m intervals, 13km from the shore. Visibility is based on a landward and seaward buffer of 24km.
Value scores range from; 1=Low value, 5=High value

Forces of Landscape Change

Parts of the Welsh section of Regional Sea 6 are under considerable development pressure, particularly North Wales around principal urban areas (e.g. Bangor). Recreational pressure including access to coastal paths (generating trampling of cliff top vegetation in some places), caravan, campsites, tourist infrastructure, golf courses and increased use of coastal waters for watersports, are all generating pressure on the landscape of England and Wales. Coastal erosion is a problem for much of the coast in Wales and England, and in the future coastal defence may become more of an issue. At Goodwick, there is increased port development and ferry services are to develop in the Fishguard Bay area. Oil and gas activity in the Irish Sea (primarily in the north-eastern part) is likely to continue to provide an industrial offshore element to the seascape in years to come. The Welsh Renewable Energy Route Map indicates the intention to diversify offshore energy production to include wave and tidal energies while increasing offshore wind developments. The combination of these various technologies may generate cumulative impacts and reduce the sensitivity of the seascape to further developments. A number of sizeable onshore wind farms (e.g. Llyn Alaw, Trysglwyn on Anglesey) are already operational and pressure for such developments is likely to continue. Cumulative effects of these with new offshore structures must be considered carefully.

5.6.6.8 Regional Sea 7

Table 5.15 summarises the relative sensitivity and value of seascape character units identified by Scott *et al.* (2005) and the following is a synthesis of the sensitivity analysis of this report.

The coast in Regional Sea 7 from Cape Wrath to the Mull of Kintyre is calculated to have the highest value scores for Scotland (Scott *et al.* 2005) due to a high density of NSAs, which cover the west coast, Inner and Outer Hebrides.

Development would conflict with the coast from Cape Wrath to Loch Torridon where the coast is complex and of high naturalness and remoteness. o the south, turbines would dominate seascapes of contained areas such as the Inner Sound, which is also a highly natural area with qualities of remoteness in places – development would have an incompatible form and character and would detract from distinctive natural forms like those on Trotternish Peninsula.

West Coll, Tiree, Canna and Rum have predominantly large scale, flattish and open seascapes which may reduce their sensitivity to turbine structures, however there are also numerous smaller scale seascapes and limited views of the sea from smaller bays and inlets. Turbines would conflict with key views of Rum which has a dramatic and vertical profile. Wind energy would relate to the feeling of windiness and exposure of these seascapes but may detract from their ‘wild’ aesthetic. Turbines would conflict with the natural qualities of the area and the traditional small scale character of the settlements. Night lighting and interference with sunsets would also create significant impacts and change of character.

From the Sound of Sleat to the Point of Ardnamurchan, the seascape pattern of interlocking mountains, islands and sea is a key characteristic which would be disrupted by development. Turbines would introduce a large scale modification into a highly natural area with some extremely remote hinterland creating a significant change in character. Landmarks views of high peaks and views of Small Isles, Skye and Morar would be compromised.

To the south in the Sound of Mull, Firth of Lorn and Sound of Jura, the enclosed nature of the narrow sounds is incompatible with wind farm development. The strong containment and scale of the islands would be diminished by development. Further west, there are larger scale horizontal seascapes, though development would conflict with the apparent vertical scale of steep mountains rising from the sea around Mull. Development would not relate well to the highly natural and predominantly indented and fragmented coastline particularly around Mull, as well as scale and character of settlement. Large scale and open views around Islay and Jura could accommodate development though it would substantially alter the character of the area, parts of which are only accessible by boat or foot, and are therefore extremely remote. Turbines may detract from the Paps of Jura which are a large scale feature in the landscape.

Table 5.15 – Summary of landscape/seascape assessment for the Scottish coast relevant to Regional Sea 7

#	Area	Seascape character type	Sensitivity	Value
10	Cape Wrath to Loch Torridon	Enclosed Bays, Islands and Headlands cover most of this area with Remote High Cliffs at the northern tip.	High	4
11	Inner Sound/Sound of Raasay	Sounds, Narrows and Islands. Low Rocky Island Coast represents two small sections at the edges of this area.	High	5
12	North East Lewis	Low Rocky Island Coasts	Medium/High	1

#	Area	Seascape character type	Sensitivity	Value
14	The Little Minch	Low Rocky Island Coasts, and Sounds, Narrows and Islands.	High	2
17	Barra	Sounds, Narrows and Islands, Deposition Coasts of Islands and Low Rocky Island Coasts	High	2
18	West Coll and Tiree, Canna and Rum	Deposition Coasts of Islands, Low Rocky Island Coasts and Sounds, Narrow and Islands.	Medium/High	1
19	Sound of Sleat to Ardnamurchan	Sounds, Narrows and Islands.	High	5
20	Sound of Mull/Firth of Lorn/Sound of Jura	Sounds, Narrows and Islands	High	2
21	West Mull/East Tiree and Coll	Low Rocky Island Coasts with small areas of Deposition Coasts of Islands	High	2
22	West Islay	Low Rocky Island Coasts with areas of Deposition Coasts of Islands.	Medium/High	1
23	South Mull/Colonsay/West Jura/Sound of Islay	Low Rocky Island Coasts, Sounds, Narrows and Islands.	High	2
24	West Kintyre/South East Jura and South East Islay	Sounds, Narrows and Islands with a small area of Remote High Cliffs	High	1

Source: Scott et al. (2005)
Notes: Based on a wind farm development scenario of 100 turbines, 150m to blade tip, 8km from the shore in a grid covering 25km^2
Visibility based on 10km landward, 35km seaward buffer.
Value scores range from; 1=Low value, 5=High value

Forces of Landscape Change

Much of the west coast is under increasing pressure from tourism and tourist related developments including holiday/retirement homes and improved access and infrastructure. Such developments may influence the perception of remoteness. Pressure for onshore wind developments is increasing all along the coast, particularly on the Isle of Lewis and Kintyre, and any development that takes place will alter the landscape substantially and may change the perception of some areas as 'wild' and potentially generate cumulative impacts with any offshore development. Other marine renewables including wave may also generate cumulative impacts as an increasing number of built, industrial structures are imposed on this largely rural coast. Aquaculture is likely to increase in years to come.

5.6.6.9 Regional Sea 8

Regional Sea 8 includes the high cliffs of Scotland's northern coast, affording wide open views which would accommodate offshore turbines, though their presence may diminish the appreciation of the scale of the cliffs. Views to Hoy and Orkney would be compromised by developments in the Pentland, though development here is unlikely due to practical considerations. Views from Orkney would likewise be compromised, as turbine height would most conflict with the scale and complexity of the cliffs and stacks on Orkney's west coast. The wide, open views afforded from many locations of the coast of Orkney (and Shetland) may help to prevent the coastal scale and complexity being diminished with developments at distance from the shore. The remote, small-scale and rural character of the west coast of the Outer Hebrides would not easily accommodate the industrial character of wind turbines, and large, visible developments would compete for focus over distant mountain views. The perception of 'wildness' provided by the remote, undeveloped and natural form of most of

Regional Sea 8 would be degraded should offshore developments be visible from the coast at day or night.

Table 5.16 summarises the sensitivity and value analysis for Scottish seascape units identified in Scott *et al.* (2005).

Table 5.16 – Summary of landscape/seascape assessment for the Scottish coast relevant to Regional Sea 8

#	Area	Seascape character type	Sensitivity	Value
32	East Orkney	Deposition Coasts and Islands	Medium/High	1
8	North Caithness & Pentland Firth	Remote High Cliffs and Mainland Rocky Coastline with Open Sea Views to the west, and Deposition Coastline with Open Sea Views to the east	Medium	1
10	Cape Wrath	Kyles and Sea Lochs and Remote High Cliffs	Medium/High	4
13	Butt of Lewis to Carloway	Low rocky Islands and Coasts	Medium	1
15	Carloway to Griminish Point	Low Rocky Island Coasts, Deposition Coasts of Islands, Sounds, Narrows and Islands.	High	4
16	West Uists	Deposition Coasts of Islands	Medium	1
17	Barra	Sounds, Narrows and Islands, Coasts of Islands and Low Rocky Island Coasts	High	2
33	Shetland	Islands, Sounds and Voes with small areas of Remote High Cliffs.	Medium-High	1

Source: Scott et al. (2005)
Notes: Based on a wind farm development scenario of 100 turbines, 150m to blade tip, 8km from the shore in a grid covering 25km^2
Visibility based on 10km landward, 35km seaward buffer.
Value scores range from; 1=Low value, 5=High value

Forces of Landscape Change

The north coast of Scotland is under increasing pressure for onshore wind developments and cumulative effects may arise should offshore structures be intervisible with these, which would in turn increase the sensitivity of this area. Increasing use of the seas around Orkney and Shetland for aquaculture and the Orkney EMEC marine energy testing sites may conflict with other offshore energy developments. On Lewis and the Uists there is increasing pressure for improved roads and onshore wind developments. The erosion of machair sites on the west of the Outer Hebrides is expected to increase as a result of climate change.

5.7 Physical presence and other users

5.7.1 Introduction

The scoping and stakeholder dialogue phases of the SEA emphasised that interactions with other users of the marine area were a prime concern, mainly because of the potential physical footprint of wind farm developments of the scale envisaged. Previous SEAs have considered the potential effects of the physical presence of hydrocarbon developments on other users and concluded that effects were minor and that there were adequate existing assessment/mitigation measures. The assessment that follows addresses major wind farm developments.

The UK Government introduced the Draft Marine Bill on 3 April 2008 and public consultation closed on 26 June 2008. The Marine and Coastal Access Bill had its Second Reading in the House of Lords on 15 December 2008, and started its Committee stages on 12 January 2009. The purpose of the Bill is to simplify and strengthen strategic management of the marine environment by enabling economic, social and environmental impacts and objectives to be considered simultaneously. The Bill seeks to address all users of the marine environment to ensure a sustainable approach to the use of the sea. Two of the principal objectives of the Bill are the establishment of an overarching Marine Management Organisation with responsibility for the marine environment; and development of a strategic marine planning system that will clarify marine objectives and priorities for the future, and direct decision-makers and users towards more efficient, sustainable use and protection of marine resources. DEFRA intend that the first stage of this marine planning system will be the creation of a marine policy statement to create a more integrated approach to marine management and setting both short and longer-term objectives for sustainable use of the marine environment. It is then intended that the second stage will be the creation of a series of marine plans, which will implement the policy statement in specific areas using information about spatial uses and needs in those areas.

In advance of implementation of the Marine Bill and consequent formal marine spatial planning, as part of the Offshore Energy SEA process, an initial high level screening of spatial constraints, issues and data gaps was carried out in 2007 for use in consideration of a potential 3rd Round of leasing for offshore wind energy developments. This project was carried out in two phases: Phase 1 consisted of development of a Geographic Information System (GIS) to map environmental and socio-economic characteristics, sensitivities and constraints (for both wind farm development and operation), and to identify strategic level data gaps. Phase 2 was undertaken to further analyse potential generation capacities from future offshore wind leasing under different constraint scenarios. The geographical scope of Phase 2, was restricted to UK waters of England and Wales. Subsequently the spatial mapping and coverage was extended to include Scottish waters (although wind farms in Scottish territorial waters are not included in this SEA).

The following key spatial issues have been identified in the context of offshore energy developments (for additional background information, see Appendix 3h):

- Navigation – maintenance of free and unconstrained navigation routes is clearly vital to the UK as an island nation, and is a requirement for both territorial waters and the EEZ under the terms of United Nations Convention on the Law of the Sea. Other key issues include the minimisation of any increase to the risk of collision and on vessel passage time through route deviation.

- Fishing activities (including their cultural and economic values) - these are highly variable in space and time; while the vast majority of UK waters are fished to some extent, fishing effort is often focussed in specific areas of prime importance to the industry. Vessel Management System (VMS) data has substantially improved understanding of the spatial and temporal distribution of larger fishing vessels (>15m from 2005); however, the distribution of smaller vessels (which dominate the UK fleet by numbers) is less well understood. Detailed information on smaller vessels is held by Sea Fisheries Committees, although this is restricted to nearshore waters (typically to 6nm offshore), and is not available in a consistent spatial format. Aerial surveillance provides some information on the distribution of vessels of all sizes and nationalities throughout UK waters, although survey effort is highly variable in space and time. The distribution of vessels <15m length beyond 6nm is poorly understood, as is the distribution of non-UK vessels throughout UK waters. Fishing grounds exploited by smaller vessels with a limited home range and/or of prime importance to a local community may be of particular sensitivity to spatial conflict; such areas may exhibit apparently low effort and value relative to the UK as a whole.

- Selection and designation of offshore Natura 2000 sites (and extension of coastal SPAs) is ongoing, and both the spatial location and management implications are not yet defined (i.e. in a spatial context, the feasibility of offshore energy development within a designated site). The European Commission indicated (COM(2008) 768) that it would finalise specific guidance on the application of EU nature conservation legislation in the context of wind farms (a key consideration in potential wind farm siting), although this is not yet available. The location and inter-relationships of potential future protected areas to be established under the Marine Strategy Framework Directive, the Marine Conservation Zones (or Marine Protected Areas in Scotland), the Marine and Coastal Access Bill, and OSPAR Marine Protected Areas are also unclear.

- Other present and potential future uses of the seabed including aggregate extraction, communication cables, oil and gas infrastructure, carbon capture and storage, and other marine renewable energy generation may represent spatial constraints. In some cases, including exploited aggregate and hydrocarbon resources, currently constrained areas may be relaxed in future.

- Visual intrusion – there are various socio-economic drivers, including the importance of coastal tourism, to minimise significant visual impact of offshore developments.

- The extensive spatial extent of MoD practice and exercise areas; and constraints associated with civilian aviation and helicopter-based Search and Rescue (SAR).

The footprint of offshore wind farms is extensive, in that the total area occupied by a development may be very large; but not intensive, in that individual turbines are usually separated by large distances (>1000m in some cases); or exclusive, in that a variety of other marine activities may be possible within the boundaries of an operational development. The SEA has used guidance on predicted spacing of turbines (and therefore generating capacity and density), and array configurations, produced by the British Wind Energy Association (BWEA *pers. comm.*).

The concept of a coastal buffer was introduced in Round 2, with 0-8km and 8-13km used to assess seascape sensitivity. As international context, Belgium and the Netherlands have adopted wind farm zones beyond 12nm from the coast; Denmark has sited developments of limited size up to 20km from the coast; nearly all consented developments in Germany are at 30km or further from the coast (see Section 5.6).

5.7.2 Spatial constraints mapping

As noted above, a phased screening of spatial constraints, issues and data gaps was carried out to support the SEA process. Spatial data (sourced from a number of organisations and agencies in the UK) representing various environmental and socio-economic characteristics, sensitivities and constraints (for both wind farm development and operation) were input to ESRI's ArcGIS 9.2. The different data layers were overlaid enabling spatial relationships between the different features to be visually analysed and mapped, and also allowing the identification of possible strategic level data and information gaps.

This analysis also distinguished between “hard” constraints (which would definitively and consistently exclude offshore wind farm development) and “other” constraints (which would presume against, but not definitively exclude offshore wind farm development). These are shown in Table 5.17.

Table 5.17 – “Hard” and “Other” constraints used in spatial constraint mapping; as identified in Phase 1 Screening

“Hard” constraints	“Other constraints”
Round 1 (R1) and R2 lease areas	Natura 2000 sites: designated, possible, draft, candidate where boundaries known
Licensed dredging areas, application and option areas	MCA ‘siting potential with comprehensive assessment’ areas (draft and unpublished OREI 2 areas)
Oil and gas infrastructure plus 6nm buffer	MoD practice and exercise areas: other areas
IMO vessel routing areas	NATS radar areas
MCA ‘siting not recommended’ areas (draft and unpublished “OREI 1” primary navigation routes)	
MoD practice and exercise areas: danger areas	

Additionally, bathymetry was considered within three categories: 0-20m, 20-25m and 25-60m depth. Bathymetry is a key factor in the development of offshore wind farms, with development in waters >60m depth currently considered uneconomic.

In Phase 2 and subsequently in the analysis summarised below, an assessment was made of indicative generation capacities for different areas in UK waters under a range of constraint and technology scenarios. This was achieved by:

- Using the GIS to calculate the total area potentially available for development under no constraints, with ‘hard’ constraints, ‘other’ constraints and all (combined) constraints.
- Compile information on turbine and wind farm dimensions, capacity and spacing.
- Estimate technology scenarios for future offshore wind development, with an estimate of likely turbine density for each scenario.
- Combine the constraint and technology scenarios to calculate indicative generation capacities for the areas identified as available for development.

The screening studies used information on spatial generation capacity for different turbine size and spacing derived from data on UK wind turbine and wind farm characteristics obtained from environmental statements, turbine manufacturer websites and developer websites. This information has been modified in view of information provided by BWEA (*pers. comm.*). In addition, the MCA “siting not recommended” areas have been modified in light of AIS data, described in Appendix 3h, and extended to the UKCS median line. Representative GIS outputs from the spatial constraints mapping, with an example of constraint relaxation (removal of 6nm exclusion area around existing oil and gas installations, indicating the longer-term effects of installation decommissioning) and the influence of a 12nm coastal buffer, is shown in Figures 5.22-24.

Equivalent total generation capacities have been calculated using a nominal capacity of 2.5MW/km^2 (derived from turbine spacing from BWEA *pers. comm.*, assuming 5MW turbine size). These estimates are broken down by Regional Sea in Table 5.18 and do not make any allowance for reductions in available area as a result of “other” constraints, which may be appreciable.

Figure 5.22 – Percentage of block within 0-60m depth remaining following application of hard constraints, not including 6nm exclusion area around existing oil and gas installations

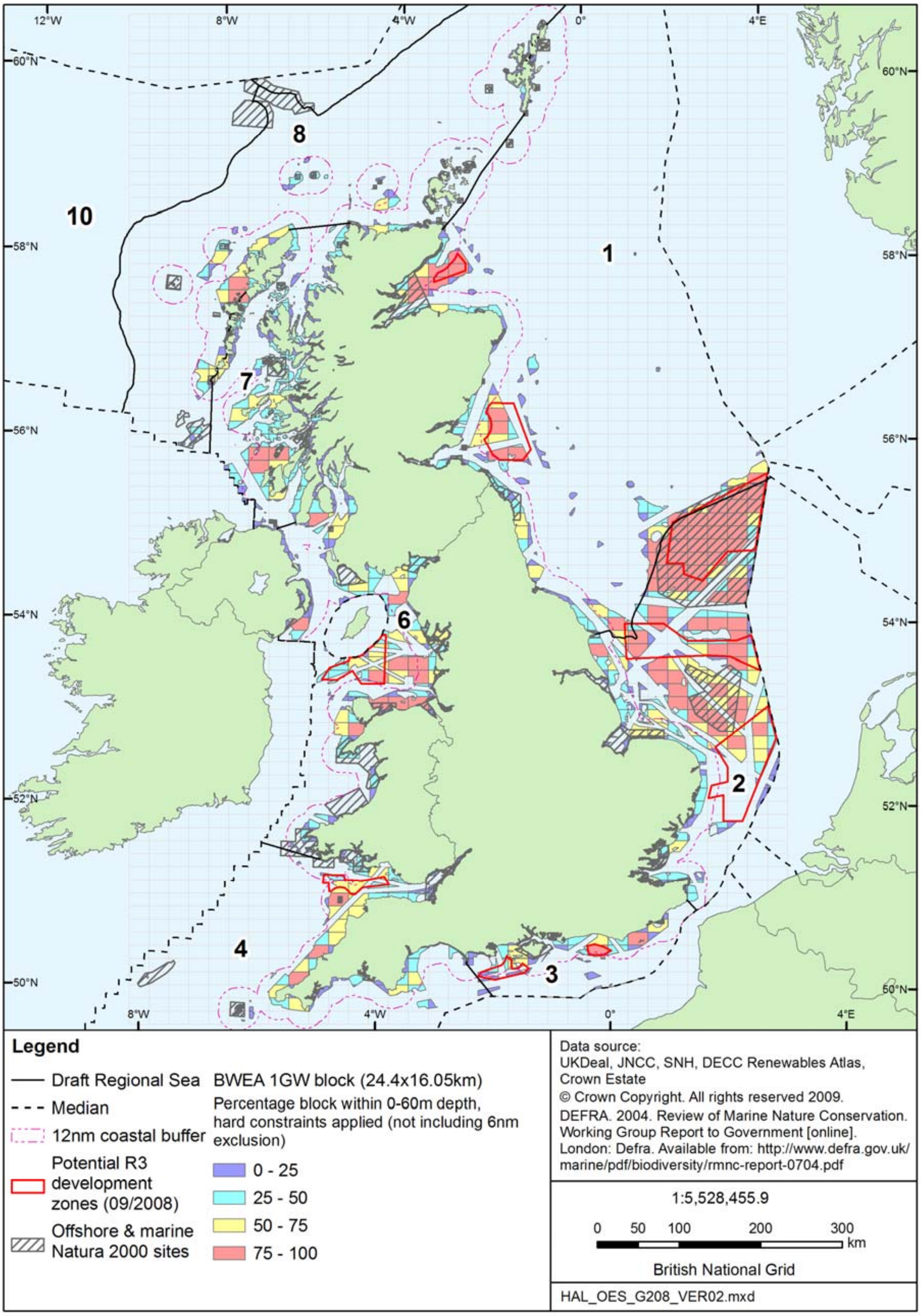


Figure 5.23 – Percentage of block within 0-60m depth remaining following application of hard constraints, including 6nm exclusion around existing oil and gas installations and with a 12nm coastal buffer

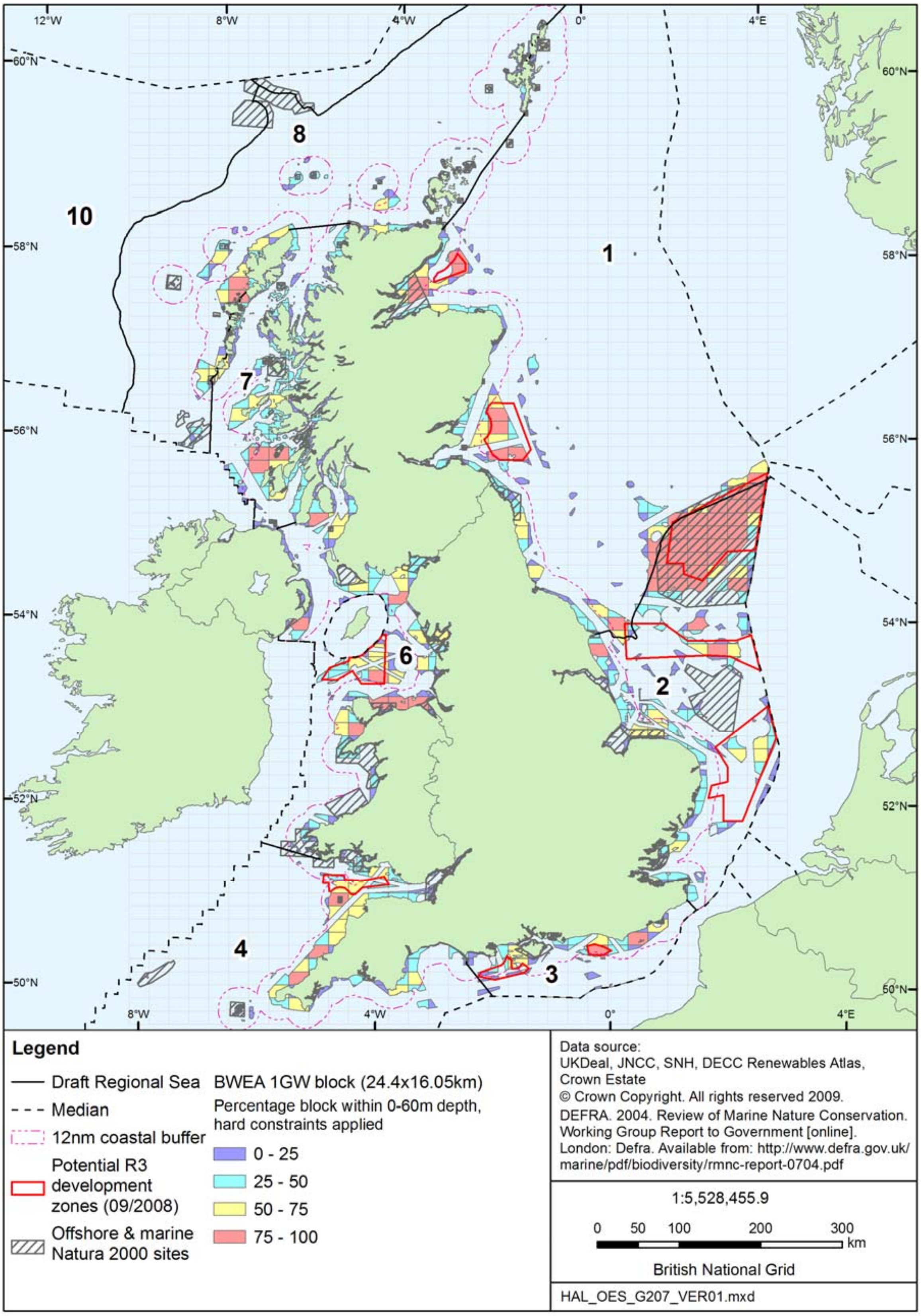


Figure 5.24 – Percentage of block within 0-60m depth remaining following application of hard constraints, including 6nm exclusion areas around existing oil and gas installations and 12nm coastal buffer

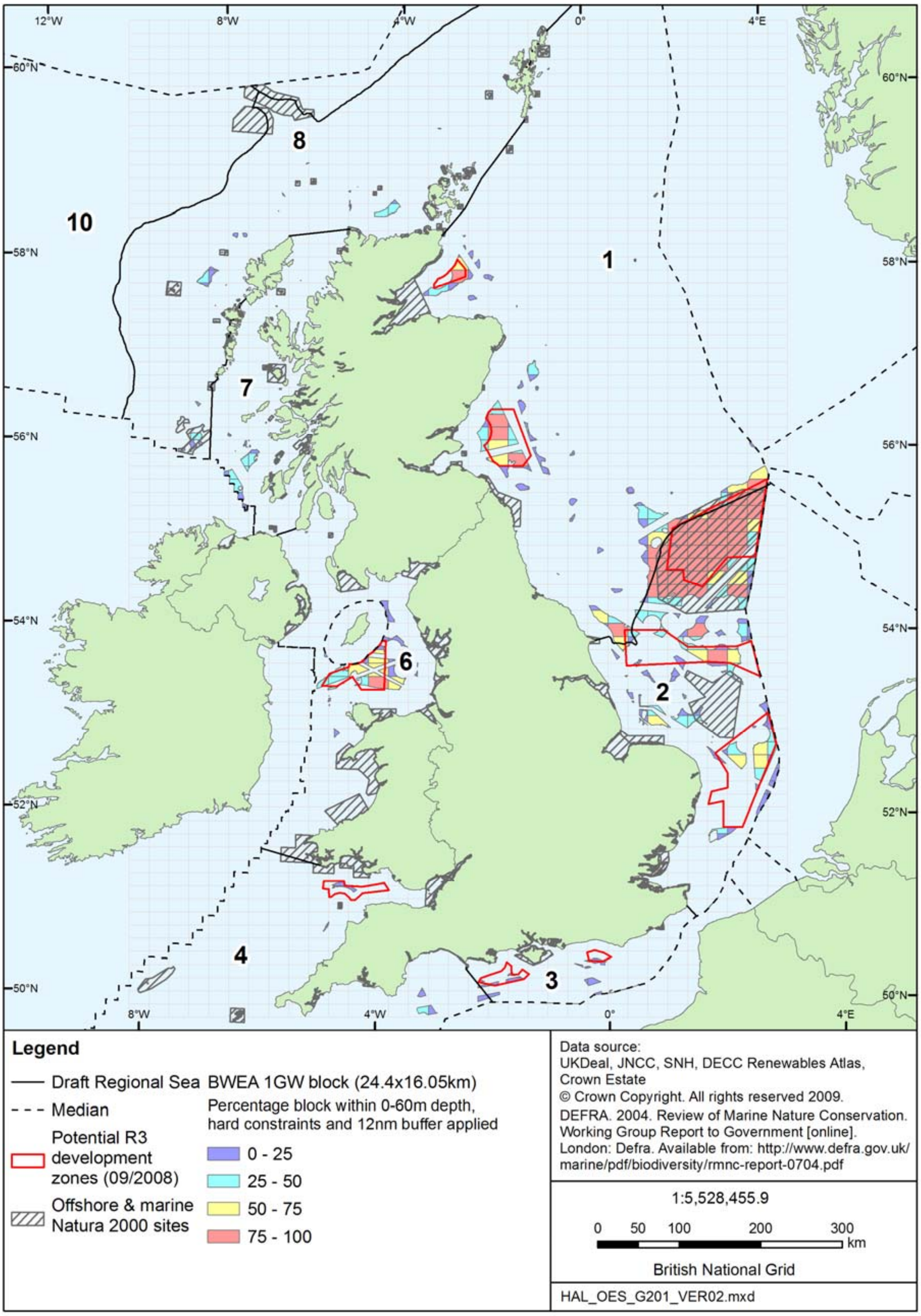


Table 5.18 – Indicative maximum wind power generation (MW) by UK Regional Sea area; with and without 12nm coastal buffer

Regional Sea	No coastal buffer		12nm coastal buffer	
	Area km^2	MW	Area km^2	MW
1. Northern North Sea	15,837	39,591	8,567	21,418
(England)	(7,116)	(17,791)	(4,721)	(11,803)
(Scotland)	(8,720)	(21,801)	(3,846)	(9,616)
2. Southern North Sea	23,752	59,379	18,722	46,805
3. Eastern Channel	3,826	9,565	472	1,181
4. Western Channel & Celtic Sea	8,370	20,925	442	1,106
6. Irish Sea	13,496	33,741	2,293	5,732
(England & Wales)	(8,607)	(21,518)	(2,262)	(5,654)
(Scotland)	(3,740)	(9,351)	(20)	(50)
(Northern Ireland)	(1,149)	(2,872)	(11)	(28)
7. Minches & Western Scotland	11,071	27,678	665	1,663
(Scotland)	(10,921)	(27,303)	(664)	(1,660)
(Northern Ireland)	(150)	(376)	(1)	(3)
8. Scottish Continental Shelf	5,942	14,855	834	2,086
Total	**82,294**	**205,735**	**31,996**	**79,991**
Total (GW)		**206**		**80**

Notes:
The area available includes only waters depths of 60m and less and with what have been judged to be hard constraints removed.
Hard constraints do not include European conservation sites although these may present significant consenting hurdles.
The turbine spacing of 2.5MW/km^2 used, based on BWEA guidance.
These are the total areas available in each Regional Sea and a minimum size needed for a commercial scale wind farm has not been factored in.

The implication of this analysis is that a generation target of 25GW (additional to Rounds 1 & 2 capacity) can be achieved with the implementation of a nominal 12nm coastal buffer and no relaxation of the "hard" constraints identified above (and subject to technical and commercial feasibility). The following points are noted in relation to potential conflicts with "other" constraints, and with other legitimate activities (notably fishing) not included in the spatial analysis:

- Conservation sites – a substantial proportion of the area identified as unconstrained for potential offshore wind farm development is within the draft Dogger Bank SAC; if designated, development would be required to meet Appropriate Assessment criteria (JNCC Draft Conservation Objectives and Advice on Operations note high sensitivity of the sandbank habitat to physical loss and moderate sensitivity to physical disturbance; and that due to consenting process, mitigation and enforcement there is considered to be a low likelihood of oil and gas, aggregates or renewable energy developments causing damage or disturbance to harbour porpoise populations).

- MCA "siting potential with comprehensive assessment" – Maritime and Coastguard Agency note MGN 371 together with BERR (2007b) guidance on applying for safety zones around offshore renewable energy installations provide information on the site-specific considerations which would be applied during the consenting process. This issue is considered in more detail below.

- MoD PEXAs: other areas – with the exception of danger areas identified as "hard constraints", the presence of a PEXA does not preclude other activities. Planning and consultation between the offshore energy industries and the MoD should help to minimise any conflicts of interest where PEXAs exist.

- NATS radar areas – with the exception of the Dogger Bank, a large proportion of the possible development area is identified by NERL as "likely to interfere" with air traffic control radar. Technical measures may alleviate this issue to some extent.

- Fishing – interactions between fishing activities and offshore wind farms are complex, and experience in Round 2 development locations indicates that the effects are dynamic and not always predictable. In summary, stakeholder dialogue with the fishing industry indicated that typical offshore wind farm development would effectively preclude demersal trawling with conventional gears, but not necessarily fixed gear or possibly specialised trawl gears. Exclusion of fishing effort would be likely to have a local beneficial effect on fish stocks, but a negative effect on other fishing grounds through displacement of effort. The implementation of a coastal buffer zone is expected to substantially mitigate conflict with the most sensitive fishing sector (small inshore vessels, which cannot easily relocate and are often of marginal commercial viability). This issue is considered in more detail below.

- Recreational users – conflicts with recreational activities are expected to be substantially mitigated by a coastal buffer zone. The vast majority of recreational vessels (including yachts, diving and angling) would not be excluded from offshore wind farm development areas.

In 2008 the Carbon Trust carried out a study to investigate how offshore wind in the UK could contribute to the UK's target of delivering 15% of its energy consumption from renewable sources by 2020 (Carbon Trust 2008). The study assessed:

- How much offshore wind power capacity would be required to reach the 2020 renewable energy target?
- What would be required to deliver this?
- What should the UK Government, industry and other stakeholders do to achieve this?

The study concluded that the UK would need to build 29GW of offshore wind by 2020 to meet its target.

The Carbon Trust used the spatial constraint criteria and GIS developed for the DECC Offshore Energy SEA to determine the area of seafloor available for offshore wind farm development and to analyse the costs and risks associated with different sites. This was done by segmenting the available seabed (0-60m depth) into 33 combinations of distance from shore, depth and wind speed, calculating the capital expenditure ('capex') per MW of capacity and levelised costs for each segment.

The analysis showed that the most important factor in siting a wind farm is wind speed, followed by depth and then distance. Economically, the most attractive sites are those that are near-shore with shallow water and mid-distance, mid depth sites with higher wind speeds. However, the effect of applying all of the constraints (including for example offshore Natura 2000 sites), would be to restrict development sites for offshore wind farms to the most expensive site types such as north of the Dogger Bank. In order to locate all of the 29GW of capacity on the most economically attractive sites the study suggests that a seaward buffer zone would need to be reduced in some places and some constraints (including those that are currently considered ‘hard’ or ‘fixed’) would need to be relaxed, especially the 6nm exclusion zone around oil and gas installations.

5.7.3 Consideration of a coastal buffer

The waters around the UK coast are of major ecological, economic and cultural importance. Unless appropriately planned and controlled, the possible developments of the scale encompassed by the draft plan/programme could result in adverse effects on coastal features, safety, and present day and foreseeable future uses, including:

- Coastal navigation routes and port access
- Navigation safety e.g. vessel refuges, charted and safe anchorages and scope for manoeuvre/towage of vessels in distress near the coast
- Inshore fisheries
- Aerodrome safety
- Civilian radar interference
- Military radar interference
- Coastal PEXA danger areas
- Recreational and racing yachting
- Coastal tourism (importance and value)
- Visual intrusion (in general and on designated landscapes)
- Sea- and waterbirds (which typically occur in greater densities in coastal waters)
- Natura 2000 sites, either designated or under consideration
- Potential for wet renewable energy generation

The Round 2 SEA recommended a coastal buffer of 8 or 13km based on the sensitivity of seascape units to OWF visual intrusion.

At present, regional spatial strategies for marine areas are lacking. However, the principles of Integrated Coastal Zone Management (ICZM) are integral to relevant proposals in the Marine and Coastal Access Bill of December 2008. The Bill proposals offer the opportunity to link marine management with existing arrangements on land. Marine planning is set to give coastal regulators and communities the chance to have a say in the way the marine environment is managed, and conversely for marine management to give proper consideration to land planning. Similarly, the European Commission (COM(2007) 308 final) has emphasised the importance of the development of ICZM strategies in close co-ordination and co-operation with the Marine Strategy Directive and the related work of regional seas conventions.

The complexity of the decisions regarding major developments near the coast are distilled in the Department of the Environment/Welsh Office Planning Policy Guidance: Coastal Planning (PPG 20 September 1992) which noted the importance of the coast as a national resource and stated that “it is the role of the planning system to reconcile development requirements with the need to protect, conserve and, where appropriate, improve the landscape, environmental quality, wildlife habitats and recreational opportunities of the coast. This is achieved through development plans and planning decisions, which implement policies for the conservation and improvement of the coastal environment, acknowledging the special character of the coast.”

This is amplified by the ODPM Planning Policy Statement 22 National Planning Policies which states that “In sites with nationally recognised designations (Sites of Special Scientific Interest, National Nature Reserves, National Parks, Areas of Outstanding Natural Beauty, Heritage Coasts, Scheduled Monuments, Conservation Areas, Listed Buildings, Registered Historic Battlefields and Registered Parks and Gardens) planning permission for renewable energy projects should only be granted where it can be demonstrated that the objectives of designation of the area will not be compromised by the development, and any significant adverse effects on the qualities for which the area has been designated are clearly outweighed by the environmental, social and economic benefits."

Reflecting the relative sensitivity of multiple receptors in coastal waters, this report concludes that the bulk of this new generation capacity should be sited well away from the coast, generally outside 12 nautical miles (some 22km). The proposed coastal buffer zone is not intended as an exclusion zone, since there may be scope for further offshore wind development within this area, but as mitigation for the potential environmental effects of development which may result from this draft plan/programme. The environmental sensitivity of coastal areas is not uniform, and in certain cases new offshore wind farm projects may be acceptable closer to the coast. Conversely, a coastal buffer in excess of 12nm may be justified for some areas/developments. Detailed site-specific information gathering and stakeholder consultation is required before the acceptability of specific major Round 3 or subsequent wind farm projects close to the coast can be assessed. Marine spatial planning proposals are under consideration in Parliament, which would give coastal regulators and communities further opportunities to have a say in the way the marine environment is managed, in addition to the existing routes for consultation as part of the development consent process.

This consideration applies primarily to OWF because of their large spatial footprint. For hydrocarbon developments, technical measures are potentially available to allow mitigation e.g. through direction drilling from shore as in the development of the offshore extension of the Wytch Farm oilfield into Poole Bay, Dorset.

It is noted that the Carbon Trust (2008) study concludes that there are some economic benefits to siting OWFs away from the immediate vicinity of the coast as a result of improved quality of the wind resource offshore and hence more efficient generation.

5.7.4 Navigational risk assessment

Navigational risk factors associated with large-scale offshore wind farm developments are obvious and well-recognised, and both DECC and the MCA have issued guidelines on the assessment and consenting process. As with oil spill risk assessment for offshore oil and gas developments, the regulatory approach is risk-based, and therefore has elements in common with the regulation of health and safety in an industrial context; for example in the process of assessing risk through a quantitative process (here termed Formal Safety Assessment, FSA) and judging acceptable levels of risk against ALARP (As Low As Reasonably Practicable) criteria.

MCA Marine Guidance Note MGN 371 (M+F) Offshore Renewable Energy Installations (OREIs) - Guidance on UK Navigational Practice, Safety and Emergency Response Issues require that developers… "In …..the preparation of Scoping Reports (SR), Environmental Impact Assessments (EIA) and resulting Environmental Statements (ES) should evaluate all navigational possibilities, which could be reasonably foreseeable, by which the siting, construction, establishment and de-commissioning of an OREI could cause or contribute to an obstruction of, or danger to, navigation or marine emergency response". MGN 371 advises that a traffic survey of the area concerned should be undertaken within 12 months prior to submission of an OREI Environmental Statement. However, if deemed necessary, to cover seasonal variations or perceived future traffic trends, the survey period may be required to be extended to a maximum of 24 months.

The project-specific EIA should also assess potential navigational or communications impacts or difficulties caused to mariners or emergency response services, using the site area and its environs. Those difficulties which could contribute to a marine casualty leading to injury, death or loss of property, either at sea or amongst the population ashore, should be highlighted as well as those affecting emergency response. Consultation with local and national search and rescue authorities should be initiated and consideration given to the types of aircraft, vessels and equipment which might be used in emergencies. This should include the possible use of OREI structures as emergency refuges and any matters that might affect emergency response within or close to the OREI.

MGN 371 also indicates that an ES should consider whether any features of the OREI, including auxiliary platforms outside the main generator site, mooring and anchoring systems, inter-device and export cabling, could pose any type of difficulty or danger to vessels underway, performing normal operations, including fishing, or anchoring. Such dangers would include clearances of wind turbine blades above the sea surface[5], the burial depth of cabling, etc. The ES should also consider whether any feature of the installation could create problems for emergency rescue services, including the use of lifeboats, helicopters and emergency towing vessels (ETVs). All of the above will need to be addressed to the satisfaction of MCA prior to consenting of a development.

In late 2004, the Greater Wash wind farm developers group sought guidance from the MCA on the inter-relationship of wind farms to shipping routes so that they could take early account of the factors involved when planning turbine layout within their allocated water space (lease area). The resulting MCA *Template for assessing distances between wind farm boundaries and shipping routes* fuses together the radar results of the North Hoyle electromagnetic trials with published ship domain theory so as to better interpret the inter-relationship of marine wind farms and shipping routes.

Specific guidelines on navigation risk assessment for OWF developments have been produced by DECC (DTI 2005), *Methodology for Assessing the Marine Navigational Safety Risks of Offshore Wind Farms*. These set out a requirement for assessing risk by Formal Safety Assessment (FSA) using numerical modelling and/or other techniques and tools of assessment acceptable to government and capable of producing results that are also acceptable to government. The FSA is required to: estimate the “Base Case” level of risk based on existing densities and types of traffic and the existing marine environment; and predict the “Future Case” level of risk based on the predicted growth in future densities and types of traffic and reasonably foreseeable future changes in the marine environment. Both Base and Future Cases are to be assessed with and without the OWF development in place; and hazards identified which are caused or changed by the introduction of the wind farm, together with the risk associated with the hazard, the controls put in place and the tolerability of the residual risk. For consenting to proceed, risk must be assessed “Broadly Acceptable” or “Tolerable” on the basis of “As Low As Reasonably Practicable” (ALARP)”, based on criteria set out in the Methodology’s “*Mechanism for Assessing Tolerability of Marine Navigational Safety Risk*”. This considers both the tolerability of individual risks, and of societal concerns.

[5] Recommended minimum safe (air) clearances between sea level conditions at mean high water springs (MHWS) and wind turbine rotors are that they should be suitable for the vessel types identified in the traffic survey but generally not less than 22 metres, unless developers are able to offer proof that no risk exists to any vessel type with air drafts greater than the requested minimum.

On the basis of risk assessment, offshore wind farm developers are required to indicate whether navigation in and/or near the site should be prohibited by specified vessel types, operations and/or sizes; in respect of specific activities; in all, or specified areas or directions; in specified tidal or weather conditions, or simply recommended to be avoided. Relevant information concerning applications for safety zones under SI 2007 No 1948 "*The Electricity (Offshore Generating Stations) (Safety Zones) (Application Procedures and Control of Access) Regulations 2007*" for a particular site during any point in its construction, operation or decommissioning, should be specified in the Environmental Statement accompanying the development application.

Developers are required to provide researched opinion of a generic and, where appropriate, site-specific nature concerning whether proposed structures could produce radar or radio interference such as reflections, blind spots, shadowing, or phase changes; with respect to any frequencies used for marine positioning, navigation or communications, including Automatic Identification Systems (AIS), whether ship-borne, ashore or fitted to any of the proposed structures.

It should also be determined how the overall site would be marked by day and by night taking into account that there may be an ongoing requirement for marking on completion of decommissioning, depending on individual circumstances; and how individual structures and fittings on the perimeter of and within the site, both above and below the sea surface, would be marked. If specific structures are not considered to be sufficiently radar conspicuous from all seaward directions (and for SAR and maritime surveillance aviation purposes), there will be a requirement for passive enhancers (i.e. reflectors) radar beacons (racons) and/or AIS transceivers. Appropriate sound signals may also be required.

All OREI generators and transmission systems should be equipped with control mechanisms that can be operated from the OREI Central Control Room or through a single contact point. Throughout the design process for an OREI, appropriate assessments and methods for safe shutdown should be established and agreed, through consultation with MCA's Navigation Safety Branch, Search and Rescue Branch and other emergency support services.

The DECC (DTI 2005) *Methodology for Assessing the Marine Navigational Safety Risks of Offshore Wind Farms* notes that levels of navigational risk associated with offshore wind farm developments, and their tolerability are likely to be dependent on a number of variables used in the assessment of a wind farm. These will include the size of the water space, its bathymetry and hence the sea room available for manoeuvring, and the variations in the marine operations taking place in the water space. Due to this site specificity, a strategic level FSA approach is not feasible. The anticipated spatial scale of Round 3 leases is relatively large, and any lease area is likely to include areas covering a wide range of shipping traffic densities. In addition, although there is an established methodology for FSA of individual developments, the output from this process does not facilitate an assessment of cumulative risk (i.e. there is no straightforward approach to sum the risk associated with individual developments).

However, in view of high correspondence between draft and unpublished MCA "OREI 1" primary navigation routes and the 2007 AIS data in the SEA analysis; generic indications of risk tolerability given in MCA and DECC guidance; and generic indications of the relative tolerability of wind farm distances from shipping lanes, it is recommended that offshore wind farm leases include a general prohibition on turbine location within a 1nm buffer of a primary navigation route (as mapped for the SEA using 2007 AIS data) . This buffer width is based on the "high" to "medium" risk threshold of the shipping route template; and a larger buffer may be required where additional factors (such as traffic density and tidal set) increase the local risk. Based on a GIS analysis, this measure would exclude approximately 27% of the total area in water depths <60m under consideration for Round 3 leasing (total primary navigation route area in all water depths is equivalent to 15% of the UKCS area).

For small fishing vessels and most non-commercial vessels, including recreational craft, the navigational risk of offshore wind farm developments will be largely mitigated by a coastal buffer zone, which is recommended to address several ecological and spatial conflict concerns. In addition, the recommended air gap of 22m between blade tip and sea surface should prevent any possibility of collision with the turbine rotors.

It is noted that the identification of primary navigation routes is based primarily on AIS data, which currently has limited coverage beyond about 80km (line of sight from antenna height) of the coast; also that the IMO are working to fill data gaps beyond 80km in the near future. A regional data centre will be set up in Lisbon in January 2009 by EU member states and the European Maritime Safety Agency, to co-ordinate AIS data. With these factors in mind, and recognising that maritime traffic distribution can change, it is recommended that the primary navigation route are refined and reviewed periodically, with the results made available to developers.

Subject to the above recommendations, the SEA judgement is that sufficient regulatory control exists, at the consenting and operational stages, to manage navigational safety risk effectively. Outwith the primary navigation route network, there is no clear basis or requirement to spatially constrain offshore wind farm development on grounds of navigational safety.

5.7.5 Fishing interactions

The distribution of fishing effort around the UKCS is described in Appendix A3h.13.4, based on independent analyses of VMS, logbook and aerial surveillance data, consultation with fisheries stakeholders and various published reports. Important fishing grounds for consideration when siting offshore wind farms are listed in Table 5.19. These areas exhibit high densities of fishing effort with high value of landings relative to all UK waters; emphasis is placed on sites with waters <60m depth. Deeper waters areas and those of great local importance (which are more difficult to identify) are described in the text below. The information presented in Table 5.19 should be considered alongside the various maps presented in Appendix A3h, as these better illustrate the locations of the areas described.

Table 5.19 - Important UK fishing grounds for consideration when siting OWFs

Area	Primary gear type(s)
The south coast of the Moray Firth to approximately 12nm offshore, extending southeast to Peterhead (majority >60m water depth).	Primarily mobile gears, with most static effort closer to the coast.
Much of the Firths of Forth and Tay to approximately 12nm and particularly the areas of finer sediment off the coast of approximately Carnoustie to Montrose.	Mobile gears dominant in the Firth of Forth, primarily static gears to the north of Fife Ness.
Inshore waters off the coast of northeast England from approximately Hartlepool to Amble, extending northeast to the Farne Deeps (where water depth >60m). This area is fairly well defined by the extent of seabed sediments consisting of muddy sand.	Primarily mobile gears, with most static effort closer to the coast.
To a lesser extent, inshore waters between Hartlepool and the Humber extending up to approximately 20nm offshore, although greatest effort within 12nm.	Mixed throughout the area, with mobile gears dominant north of Flamborough Head, and static gears dominating to the south.

Area	Primary gear type(s)
Nearshore waters of the Wash and the Thames area.	Mixed, with mobile gears notably dominating within The Wash.
Outer Silver Pit, approximately defined by the extent of seabed sediments consisting of muddy sand.	Mobile.
The southeast coast of England (primarily Sussex) from approximately Dungeness to Portsmouth. Effort is greatest within 12nm, although remains high to the UK/France median line. High densities of non-UK fishing vessels operate throughout the area although decreasingly so closer to the UK coast.	Mixed; static gears dominating close to the coast and limited further offshore, with mobile gears widespread throughout the area and dominant further offshore.
Inshore waters between Portland and the Lizard, with effort generally greatest closer to shore (ca. <6nm) although very high effort extending to approximately 12nm offshore between Sidmouth and Plymouth. Effort remains high beyond 12nm, with considerable densities of non-UK fishing vessels present.	Mixed throughout the area, although static gear effort focussed close to the coast. Static gears dominate between Start Bay and Salcombe.
The Bristol Channel.	Mobile gears offshore, with most static gear effort inshore.
Between the west coast of the Isle of Man and the Northern Ireland coast, extending north to approximately Ballywalter and south into Republic of Ireland waters (considerable proportion >60m water depth).	Primarily mobile, with greatest static effort close to the Northern Ireland coast.
Waters off the east Cumbrian coast extending south and west from approximately to Whitehaven to 12nm offshore.	Mobile.
Inshore waters around the Isle of Arran, with high effort extending throughout much of the area between Kintyre and the Ayrshire coast (where water depth generally >60m).	Mobile.
The Minch, particularly inshore waters between mainland Scotland and the Isle of Skye, between Gairloch and Ullapool, and off the northeast coast of Lewis (considerable proportion >60m water depth).	Mixed throughout the area, although static gears dominating around Skye.
Nearshore waters of Orkney and Shetland, particularly to the northeast of the islands (where majority water depth >60m).	Static gear dominant around Orkney, mixed around Shetland.

Outwith the areas of high effort and value from a UK context listed in Table 5.19, many less intensively fished areas exist which are of great local significance. Such areas are particularly sensitive to spatial conflicts; they are typically fished by small vessels operating within a limited range from port, and may serve communities with livelihoods dependent upon those fishing grounds. At a strategic level, it is not feasible to identify all such grounds; small, inshore vessels operate at almost all ports throughout the UK, although those in remote and rural areas are likely to be most sensitive. At region- and site-specific levels, early consultation with relevant SFCs and fishermen, will facilitate the identification of these locally important areas. In addition to those areas mentioned in Table 5.19, there are many areas of very high fishing effort of considerable value in UK waters exceeding 60m water depth. These include the Fladen Ground, approximately defined by the extent of seabed sediments consisting of muddy sand. Additionally, moderate-high levels of effort are present throughout much of the deeper waters of the northern North Sea and waters north of Scotland, including numerous discrete areas of particularly high effort. Extending from approximately 25km southwest of Pembrokeshire, the Celtic Deep is an area of very high fishing effort, approximately defined by the extent of seabed sediments consisting of muddy sand and sandy mud; the area experiences considerable effort from non-UK vessels.

The distribution of non-UK vessels is mainly in offshore waters, apart from in southern areas, where many foreign fleets (in particular French, Belgian, German and Dutch) hold historical rights to fish within 6nm of the shore and fishing grounds are shared. The areas identified by the SEA spatial constraints analysis (Dogger Bank, scattered areas from Yorkshire to Norfolk, the outer Forth and Moray Firth, and eastern Irish Sea) were relatively lightly fished.

Experience in Round 2 development locations was discussed with representatives of the fishing industry and fisheries management organisations during the SEA stakeholder dialogue. It was noted that extensive inshore fisheries take place throughout most UK waters to approximately 25nm offshore, and that through the activities of Sea Fisheries Committees, the 0-6nm zone is generally quite well understood. The 6-12nm zone, however, is an area of typically high fishing effort but poorly understood - many foreign vessels operate in this area. Offshore wind farms may have cumulative effects on fisheries in these areas through their influence on the locations of other activities such as aggregate extraction, conservation sites etc. Inshore vessels are quite restricted in areas which they may fish by distance from home port, availability of sheltered waters and substrate type.

Stakeholder discussion also took place on fishing activities which may or may not be possible within wind farms. Risk was perceived to increase significantly if fishing within a wind farm; different fishermen have different perceptions of risk, with some willing to take more risks than others - it is was considered inappropriate to define one type of gear as compatible with offshore wind farms and another as incompatible. Mobile gears such as trawls or drift netting were generally not considered possible. However, it was noted that observations have shown vessels to be able to fish specific areas with good accuracy; there could be some scope for fishing mobile gears within offshore wind farms if the layout is suitable. Attention was drawn to observations of fishing activity within the Barrow offshore wind farm; trawling within the wind farm is widely considered hazardous and does not occur; however, potting activities are carried out safely. Catches from pots in the footprint of the wind farm are significant, with different boats now exploiting this area - not vessels which previously trawled the area. Regarding the issue of turbine spacing to minimise fisheries conflict, there was considered to be a trade-off between total wind farm footprint and potential fisheries compatibility. If this is to be achieved, communication between fishermen and developers at an early stage is essential.

Exclusion of fishing (or at least intensive trawling) effort would be likely to have a local beneficial effect on fish stocks, and also on reducing seabed disturbance and associated ecological effects. However, exclusion in some areas is likely to result in negative effects on other fishing grounds through displacement of effort. A “reef effect” has also been noted (for example at Barrow) and is the subject of a RAG commissioned study (Linley *et al.* 2008); although this is unlikely to be significant at a strategic level, in view of the limited spatial area affected by habitat alteration.

At a strategic level, caution is required with regard to the siting of major expansion of offshore wind farms to ensure fishing activities and skills of local cultural importance in an area are not inadvertently lost, through the prevention or significant hindrance of fishing activity for a generation during the lifetime of the windfarms.

5.7.6 Summary of findings

This SEA has been carried out in advance of implementation of the Marine and Coastal Access Bill (and related initiatives) and consequent formal marine spatial planning, and conclusions must therefore be considered as provisional pending development of a more comprehensive strategic marine planning system.

Building on the screening and extensive stakeholder dialogue, the SEA spatial constraints analysis concluded that a generation target of 25GW (additional to Rounds 1 & 2 capacity) can be achieved with the implementation of a nominal 12nm coastal buffer and no relaxation of the "hard" constraints identified above (and subject to technical and commercial feasibility). The above assessment does not support the alternative not to lease or license areas for development (Alternative 1). Constraints mapping has indicated that there are areas of the UKCS in which "hard" constraints currently preclude feasible development (e.g. MoD danger areas, oil and gas platform/infrastructure, existing offshore wind farms), and therefore leasing in these areas will of necessity be spatially restricted. Some hard constraints (e.g. platform 6nm buffers, aggregate extraction zones) are anticipated to be relaxed in the future as infrastructure is decommissioned or resources depleted. Forecasts of the projected timing of oil and gas installation removal are available at https://www.og.berr.gov.uk/upstream/decommissioning/forecast_rem.htm; these are normally updated annually and indicate significant "space" becoming available within a few years. It is concluded that there should be certain spatial restrictions on the areas offered for leasing and licensing and that Alternative 3 is the preferred option.

5.8 Marine discharges

5.8.1 Introduction

As described in previous SEAs, marine discharges from exploration and production activities include produced water, sewage, cooling water, drainage, drilling wastes and surplus WBM, which in turn may contain a range of hydrocarbons in dissolved and suspended droplet from, 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 infrastructure (hydraulic fluids), pipeline testing and commissioning (treated seawater), and support vessels (sewage, cooling and drainage waters). The effects of the majority of these are judged to be negligible and are not considered further here (note, they would be considered in detail in Environmental Statements and chemical risk assessments under existing permitting procedures). The list above equally applies to gas storage activities, although produced water and scale volumes will be minor.

OWF developments have essentially no planned discharges, although there is a potential incidental release of copper and carbon dust from abrasion of the slip-rings of the turbines; this is considered to have negligible environmental effect (Danish Hydraulic Institute 2000).

Discharges from offshore oil and gas facilities have been subject to increasingly stringent regulatory controls over recent decades, and oil concentrations in the major streams (drilling wastes and produced water) have been substantially reduced. However, due mainly to increasing water cut from mature oil reservoirs, and the use of water injection to maintain reservoir pressure, the total volume of produced water discharges on the UKCS has increased and is expected to continue to increase into the near future.

Produced water is derived from reservoir ("fossil") water, through condensation and injection water. The majority of produced water discharge volume to the North Sea and elsewhere is associated with oil production and produced water volumes from gas fields are extremely small in comparison. OSPAR Recommendation 2001/1 for the Management of Produced Water from Offshore Installations includes a presumption against the discharge to sea of produced water from new developments. The assumption that reinjection will be the normal method of produced water disposal (at least 95% by volume) is fundamental to the consideration of potential effects of produced water in the SEA process, although it is also noted that under certain circumstances (e.g. injection pump maintenance) the effluent may be routed to sea. Any produced water discharged will be treated since it is still required to meet legal quality standards in terms of oil in water concentration.

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. Water-based mud cuttings are discharged at, or relatively close to sea surface during “closed drilling” (i.e. when steel casing and a riser is in place), whereas surface hole cuttings will be discharged at seabed during “open-hole” drilling. Use of oil-based mud systems, for example in highly deviated sections or in water reactive shale sections, would require the onshore disposal or reinjection of a proportion of waste material.

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 use of water-based muds.

5.8.2 Evidence base

Produced water

Potential effects of produced water discharges are described in previous SEAs. Most studies of produced water toxicity and dispersion, in the UK and elsewhere (see E&P Forum 1994, OLF 1998, Riddle *et al*. 2001, Berry & Wells 2004) have concluded that the necessary dilution to achieve a No Effect Concentration (NEC) would be reached at <10 to 100m and usually less than 500m from the discharge point. The SEA 6 commissioned study (Kenny *et al*. 2005) reviewed recent studies and data (including analyses of produced water composition from Irish Sea facilities), and reached a similar conclusion. However, under some circumstances (e.g. strong stratification: Washburn *et al*. 1999), a plume concentration sufficient to result in sub-lethal effects may persist for >1000m (Burns *et al*. 1999).

The ICES Biological Effects Monitoring in Pelagic Ecosystems workshop (BECPELAG) analysed samples from caged organisms and passive samplers using a wide range of biomarkers and bioassays for chemical, molecular, cellular and physiological changes. e.g. toxicity bioassays, enzymatic induction (EROD), lysosomal damage, Scope for Growth (SFG), genotoxicity, endocrine disruption effects, metallothionein induction, PAH metabolites, acetylcholinesterase inhibition, bacterial diversity. Although a variety of detectable responses (in caged organisms) around an oil platform were observed and attributed to produced water effects, there was not a gradient of effect and the ecological significance of these responses is unclear.

Drilling discharges

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. 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.

A 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. 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, the toxicity of settled drill cuttings appears to be related primarily to hydrocarbon content, even in WBM discharges; probably because in the past hydrocarbon spotting fluids had been used as a contingency measure (UKOOA 2002, Hartley Anderson 2003).

Dispersion of mud and cuttings is influenced by various factors, including particle size distribution and density, vertical and horizontal turbulence, current flows, and water depth. In deep water, the range of cuttings particle size results in a significant variation in settling velocity, and a consequent gradient in the size distribution of settled cuttings, with coarser material close to the discharge location and finer material very widely dispersed away from the location, generally at undetectable loading.

The past discharge to sea of drill cuttings contaminated with oil based drill mud (OBM) resulted in well documented acute and chronic effects at the seabed (e.g. Davies *et al*. 1989, Olsgard & Gray 1995, Daan & 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. The “legacy” effects of contaminated sediments on the UKCS resulting from OBM discharges have been the subject of joint industry work (UKOOA 2002) and reporting to OSPAR (BERR 2008).

In contrast to historic 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 usually subtle or undetectable, although the presence of drilling material at the seabed close to the drilling location (<500m) is often detectable chemically (e.g. Cranmer 1988, Neff *et al*. 1989, Hyland *et al*. 1994, Daan & Mulder 1996). Considerable data has been gathered from the North Sea and other production areas, indicating that localised physical effects are the dominant mechanism of ecological disturbance where water-based mud and cuttings are discharged.

However, Cranford & 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 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. Barlow and Kingston (2001) report damage to the gills of two species of coastal bivalves where barite was added to experimental system although no controls with other sediment added were tested and the concentrations of material added were very high so it is unclear how or if the results apply to the field situation.

A comprehensive synthesis and annotated bibliography of the composition, environmental fates and biological effect of WBM and cuttings was prepared on behalf of the Petroleum Environmental Research Forum (PERF) and American Petroleum Institute by Neff (2005). The review, covering more than 200 publications and reports, concludes that effects of WBM cuttings piles on bottom living biological communities are caused mainly by burial and low sediment oxygen concentrations caused by organic enrichment. Toxic effects, when they occur, probably are caused by sulphide and ammonia byproducts of organic enrichment

Most studies of ecological effects of drilling wastes have involved soft-sediment species and habitats. 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). These effects were attributed to the physical effects of particulate loading, namely disruption of feeding or respiration, or the burial of settled larvae.

The introduction of non-native species through vessel ballast water discharges has also been considered in previous SEA Environmental Reports. The majority of rigs and vessels likely to be used will already be operating in NW Europe and hence not a potential source of exotic species introductions (although they could facilitate the spread of species). The International Convention for the Control and Management of Ships' Ballast Water and Sediments was adopted in February 2004, but has still to enter into force. Pending ratification, the Helsinki and OSPAR Commissions together with the European Community have issued General Guidance on the Voluntary Interim application of the D1 Ballast Water Exchange Standard as of April 2008 which requests that vessels entering the waters concerned, exchange all their ballast tanks at least 200 nautical miles from the nearest land in water at least 200m deep. In view of these mitigation measures and the limited scale of activity predicted significance effects are not anticipated.

5.8.3 Spatial consideration

The contamination background of the UK marine environment was reviewed in Appendix 3b. In general, the industrial history of the UK has resulted in a widespread legacy of contamination of sediments, particularly in major estuaries and coastal waters. Ongoing sources of contamination are dominated by terrestrial inputs, with a significant contribution of hydrocarbons from offshore produced water discharges; a significant proportion of the total input of persistent substances occurs through atmospheric deposition.

In their assessment of direct, physical anthropogenic pressure on the seabed offshore of the UK, Eastfield *et al*. (2007) considered that field studies have shown that, for the majority of North Sea installations, biological communities are largely unaffected beyond a 500m radius (Kingston *et al*. 1987) and therefore applied buffers of 500m radius to all platforms and wells to provide an estimate of the spatial area affected. The estimated total of 923.6 km^2 physical loss by smothering, in English and Welsh waters, represents 0.4% of the total seabed area. However, this estimate is questionable, since a) the 500m radius of effect is applicable to OBM discharges primarily in the central and northern North Sea (Scottish waters not included in this study); predominantly WBM discharges in English and Welsh waters generally have little or no radius of effect; and b) this estimate excludes the major developed areas of the central North Sea and east Shetland basin. Nevertheless, it is evident that the total UKCS seabed area directly affected by drilling waste discharges is a small (probably <1%) proportion of the total.

5.8.4 Controls and mitigation

Hydrocarbon related activities

OSPAR Recommendation 2001/1 for the Management of Produced Water from Offshore Installations 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. The recommendation also includes a presumption against the discharge to sea of produced water from new developments. The *Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005* updated and largely superseded the *Prevention of Oil Pollution Act, 1971* (POPA). A system of permits for oil discharges has been introduced to replace the POPA exemptions and more wide-ranging powers have been given to inspectors. Operators are required to regularly make reports of actual oil discharge. The regulations are a mechanism to continue implementation on the UKCS of OSPAR Recommendation 2001/1 and make provision for the introduction of the dispersed oil in produced water trading scheme.

A permit is required in advance for the use of chemicals offshore including drilling, well workover, production and pipeline chemicals (*Offshore Chemicals Regulations 2002*). Permit application includes mandatory risk assessment. Any variation in use from permit must have prior approval. Chemical use and discharge must be reported at the end of the activity. Chemicals are ranked by hazard, based on a PEC:PNEC (Predicted Effect Concentration : Predicted No Effect Concentration) approach.

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*).

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, are also feasible for drilling with water-based mud (for example, if particular benthic biotope sensitivities were identified).

Wind farm related activities

Although the depth of boreholes potentially drilled as part of OWF development is significantly shallower than those drilled in connection with hydrocarbon E&P or gas storage, drilling muds may also be used. The use and discharge of these muds and associated cuttings are presently controlled under the FEPA permitting system. All chemicals utilised in the drilling operation must be selected from the List of Notified Chemicals assessed for use by the offshore oil and gas industry under the *Offshore Chemicals Regulations 2002* (this list is derived from the OSPAR list and is available at www.cefas.co.uk). Should any system other than a water-based mud be considered for use in the drilling operation written approval and guidance of disposal of any arisings will be required from the Licensing Authority.

The general FEPA licence conditions are currently under review, including consideration of. whether a separate FEPA licence is necessary when drilling (e.g. during installation of turbine foundations) is proposed.

No additional mitigation measures are currently regarded as necessary for any components of the draft plan/programme.

5.8.5 Summary of findings

5.8.5.1 Offshore wind leasing

With the potential exception of drill muds and cuttings, no significant discharges to the marine environment are predicted to result from the proposed Round 3 leasing.

5.8.5.2 Oil & gas including gas storage

The environmental effects of the major discharges from oil and gas activities have been extensively studied, and are considered to be relatively well understood. The environmental effects of produced water discharges not reinjected are limited primarily by dispersion. Discharges of WBM cuttings in the North Sea and other dispersive environments have been shown to have minimal ecological effects.

5.9 Ancillary development

Although the focus of this SEA is principally marine, the issue of ancillary development onshore is an important strategic consideration.

The importation of gas and onshore gas distribution in the UK are not part of this plan/programme.

Given the scale of hydrocarbon activity and location of existing oil and gas terminals, in general major additional shore based infrastructure is not anticipated as a result of future offshore oil and gas licensing and gas storage and it is envisaged that maximum use would be made by reusing/adapting existing infrastructure.

5.9.1 Grid reinforcement

The National Grid Company carried out a study for the SEA to analyse the impact of connecting 25GW of offshore wind generation in addition to the 8GW already built or planned to the onshore transmission system and to identify and outline where reinforcements to the transmission system would be required. The analysis was carried out against a set of electricity generation and demand scenarios agreed with DECC – the contracted background and the ‘Non-Contractual Scenario’.

To analyse the impact of connecting 25GW of offshore wind generation it was assumed that potential wind farm development sites would be in Regional Sea 1 (2GW), Regional Sea 2 (16GW), Regional Sea 4 (2GW) and Regional Sea 6 (5GW). These locations were based on water depth (areas less than 60m deep) and also areas of sea bed where developers have shown an interest through the Crown Estate’s indicative potential Round 3 areas map (September 2008 version). Although no offshore wind generation was assumed to be located in Regional Sea 3, connection sites were investigated for this region because of developer interest. In the scenario applied, of a total offshore wind generation capacity of 25GW, almost 65% was sited in Regional Sea 2 (southern North Sea) with the area off the north west coast of Wales in Regional Sea 2 also being important. If actual development takes place on a similar pattern, these two areas will require the largest amount of reinforcement of the transmission system. However, this will also depend on other sensitivities that may affect generation and including power generation from new coal, gas and nuclear power stations as well as other marine renewable energy developments.

Based on the generation capacities described above, the requirements for reinforcements can be divided into two categories. Regional Seas with only a few offshore wind farms and relatively small overall capacities of 2GW or less would not require significant reinforcement work apart from extensions to existing substations or the establishment of new substations at the onshore interface point. Regional Seas with the potential for several offshore wind developments and overall capacities greater than 2GW (Regional Sea 6 and Regional Sea 2) would require significant reinforcement to both substations and the wider network including overhead power lines. The areas of potential major onshore reinforcements that have been identified include north west Wales, south east Anglia, Lincolnshire, Yorkshire and Derbyshire.

The main components of the transmission system are substations (connection and/or bussing points) and the overhead lines or underground cables that connect them. Transformers are used to change the generated power between different voltages used on the system. A number of new cables from offshore wind farms are expected to utilise direct current (DC) technology which will require converter stations to interface with the onshore alternating current (AC) system.

Switchgear forms a large spatial component of substations. Air Integrated Switchgear (AIS) are the predominant type in the UK and are made up of 6 to 15 bays each measuring approximately 21m x 40m. Gas Insulated Switchgear (GIS) are more costly than AIS but require less space with each bay measuring approximately 4m x 7m. They are usually only constructed close to the coast (within ~5km). To accommodate offshore wind generation, both types of switchgear would require at least 2 extra bays to be built in existing substations. In addition a typical substation also requires space for supporting equipment, access roads and site facilities.

At the onshore interface (between the offshore and onshore transmission systems) land will be required for the underground cable termination, transformers and reactive compensation equipment. These will most likely be located outside of the substation boundary fence and include buildings for control and communication and access roads within a fenced area. Where offshore wind farms are located at a significant distance from the coast DC connections are likely to be required. It is expected that Voltage Source Converter (VSC) technology is most economically suited to offshore High Voltage Direct Current (HVDC) connections. The land area needed for VSC-HVDC converter termination is more than for an AC connection with a single 1000MVA VSC-HVDC installation occupying 125m x 95m with the converters housed in buildings approximately 24m high. The potential connection solutions used to gauge the onshore impact of offshore wind generation indicate that 2 or 3 of these converters may be installed at one site.

Where an offshore submarine cable from a wind farm arrives onshore there is a need for a transition joint bay where it is joined to the onshore underground cables. There are usually three cables for an AC connection and two for DC. Along the onshore cable routes, cable joint bays will be needed at every 800 to 1000m; these are wider than the normal cable trench. For more than one connection from a wind farm, or where multiple wind farms will connect to the same substation, separate routes will be necessary for each connection.

To connect onshore wind generation to the onshore transmission system, upgraded or new 400kV overhead power lines may be required to accommodate the changes in power flows, especially across congested areas. The most recent towers used to carry the power lines are the L12 design which vary in height (46.5m to 49m) and width (7m to 14.5m) depending upon whether they are a suspension, deviation or terminal tower. The size, height and spacing of the towers is also determined by the type of conductor required, safety, route topography and environmental considerations.

Taking into account the assumptions made and the complexity of the transmission system, the study found that there is sufficient capacity on the onshore system to accommodate up to 10GW of the possible 25GW of offshore wind energy without the need for major reinforcement. Beyond 10GW and with the development of the Southern North Sea offshore wind resource, major reinforcements will be needed, including the requirement for one upgraded and one new substation and four new sections of overhead power lines in the Regional Sea 2 area.

An additional study carried out by National Grid and Econnect for the Crown Estate has investigated the feasibility and costs of installing an east coast subsea transmission cable from Shetland to the south east of England using VSC HVDC technology. The proposed network topology (which is not definitive) would have several connection nodes at various locations on the east coast of Britain where they can accumulate power from new on and offshore developments and provide an interface with strong points on the existing transmission system. This would require new infrastructure on land in the form of upgrades to existing substations or the construction of new substations to accommodate the AC interface switchgear. If HVDC converter stations are located away from the substations then HVAC cables or overhead lines would also be required to connect the converter station to the AC grid. The distance involved would affect the choice of cable voltage used and the number of cables required (between 2 and 5 to transfer 1GW). The offshore transmission network would not be built in a single phase but rather as individual links connecting new generation plants as required and links acting as reinforcement of the onshore grid.

The potential environmental effects of reinforcing the onshore grid transmission system to accommodate new offshore connections are related to the main components of the grid which are the substations and related equipment, buried land cables and overhead power lines. The National Grid Company study on the impact of offshore wind development on the onshore transmission system has identified potential sites and locations where reinforcement work and new onshore grid infrastructure may be required in the future. While some environmental sensitivities at the sites have been taken into account it should be noted that no environmental impact studies have been carried out at this stage because the actual location, size and configuration of the onshore infrastructure is dependent upon the location and size of the future offshore wind farms which are not yet known. More detailed studies of the onshore environmental impacts would be carried out as part of the planning process for any development and would take account of the latest policies, legislation, guidance etc. Policies and site specific considerations can be expected to draw on the findings of the latest Countryside Survey of the natural resources of the UK countryside involving a detailed field survey of habitats, vegetation, freshwater and soils (Carey *et al.* 2008).

In general, each component of the transmission system will have an impact to varying degrees on several different aspects of the environment during construction and operation. These impacts may include but are not limited to:

- visual intrusion in the landscape especially from substation and overhead power lines and towers which may cause visual obstructions and changes to the skyline
- loss damage or disturbance to habitats and species (which may be protected) and
- loss or damage to historical and archaeological features through excavation and construction works and by altering the visual setting of certain features
- changes to current land-use and hydrology by taking extra land for building works (substations) and infrastructure (towers) and by altering run-off patterns and possibly introducing pollutants during construction

The extent and magnitude of these impacts will be dependent upon the scale of the development taking place and their proximity to areas that have been designated for their ecological, cultural and landscape value. Some of the impacts such as the building of new infrastructure will introduce permanent changes to the environment whereas others that occur during construction phases will allow for full or partial recovery of the environment after reinstatement.

5.9.2 Port facilities

As noted in Appendix 3h, the UK Renewables service has recently produced recommendations (UK Renewables 2008) which include the requirement to develop at least 8 ports around the UK by 2014 for wind farm construction in order to meet the UK's 2020 renewable energy target. The principal sites identified as potential offshore wind production ports included Nigg, Tyneside, Seaton, Humber and Isle of Grain, as these locations are sizeable enough and in appropriate locations for continental and projected UK Round 3 offshore wind areas. A greater number of ports around the UK have the potential to assist project construction, but currently lack suitable facilities for services such as turbine assembly and manufacture of towers, blades, key nacelle components and foundations. In addition to those ports listed above, possible construction sites include Arnis, Hunterston, Belfast, Barrow, Mostyn, Milford Haven, Portland, Southampton, Newhaven, Ramsgate, Shearness, Thames Gateway, Harwich, Lowestoft, Great Yarmouth, Hartlepool, Blyth, Methil, Dundee, Montrose, Peterhead and Deephaven.

5.10 Air quality

5.10.1 Introduction

Anthropogenic sources of greenhouses gases are implicated in amplifying the natural greenhouse effect resulting in global warming and potential climate change (IPCC 2007). Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) are termed "direct" greenhouse gases as they have a direct effect on radiative forcing within the atmosphere. Other gases including carbon monoxide (CO), volatile organic compounds (VOC), oxides of nitrogen (NO and NO_2) and sulphur dioxide (SO_2) although not significant direct greenhouse gases, are reactive and impact upon the abundance of the direct greenhouse gases through atmospheric chemistry. The effects of climate change are considered, in the context of offshore energy production on the UKCS, in section 5.11.

Atmospheric acid gases include sulphur dioxide (SO_2) and oxides of nitrogen (NO_X). These gases can be react with water vapour forming acids, to increase 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 surfaces through dry deposition (close to the source) causing similar damage to acid rain (UKTERG 1988). The overall contribution of acid emissions from shipping increased during the 1990s (ICES 2003). Shipping contributes up to 15% of the deposition of these gases in some coastal areas. Deposition is higher around major shipping routes such as the south western approaches and English Channel. The potential effects of emissions of acid gases are considered to be most important at a regional to local 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. Ozone is known to impair lung function and NO_X causes irritation of the airways and can be particularly problematic for asthma sufferers (EPAQS 1996).

The absorption of anthropogenic CO_2 in sea water appears to be causing the gradual acidification of sea water. The potential effects of this acidification such as the dissolution of the shells of plankton and coral skeletons have been raised as a concern (Feely *et al.* 2004)

Gaseous emissions from offshore exploration and production of oil and gas contribute to global atmospheric concentrations of greenhouse gases, regional and local acid gas loads and potentially to local tropospheric ozone and photochemical smog formation.

5.10.2 Evidence base

Offshore wind

Although the operational stage of OWF development has minimal energy requirements (principally maintenance activities), OWF development will result in atmospheric emissions during the construction, commissioning and decommissioning phases of the project, principally through gaseous emissions from power generation of vessels.

The installation sequence of a turbine will vary depending on the type of foundation structure: gravity base will require initial preparation of the seabed, then placement and infill, however the structure can be constructed onshore, thereby reducing offshore operations. Other methods (monopile, multipile and bucket) only require placement and pile drive/suction installation. Therefore time in the field of installation/support vessels may vary depending on turbine structure design.

Turbines are most likely to be taken to site on a barge, and installed from either a jack-up barge or a floating (semi-submersible) vessel/crane, depending on water depth, vessel/crane capability/availability. Positioning of barges/crane vessels will likely be by tugs and other vessels used could include survey vessels, guard vessels and support vessels for equipment/supply transfer and air support for crew changes. During the operational phase of the wind farm, there may also be the requirement for maintenance trips, which will require supply vessels and support.

Table 5.20 – Possible vessels for turbine installation and fuel consumptions

Vessel	Fuel type	Approx. fuel consumption rate (tonnes/day)
Jack-up barge	Diesel	8
Crane barge	Diesel	8[1]
Anchor handlers (can be more than 1 used)	Diesel	18
Standby vessel	Diesel	3
Supply vessel	Diesel	18
Guard boat	Diesel	3
Crew transfer vessel (no. of trips will depend on operation)	Diesel	18[2]
Helicopter (if air support used for crew change)	Helifuel	0.3
Diving barge	Diesel	21[3]
Survey vessel	Diesel	15
Marine mammal mitigation vessel	Diesel	13[4]

Notes: [1] have used fuel usage for jack-up, [2] have used fuel usage for supply vessel, [3] have used fuel usage for diving support vessel, [4] have used fuel usage for inspection vessel

Emissions to atmosphere from individual projects will vary dependent on the number of vessels required and the time these vessels are in the field. These assessments will be done at a project specific level.

There have been a number of Life Cycle Assessments (LCA) documented for both onshore and offshore wind turbines (e.g. Elsam 2004, Vestas 2006, Weinzettel *et al*. 2009, Martinez *et al*. 2009). LCAs have indicated that the life cycle impacts of wind power are lower than those of fossil power plants and that although there is energy input required in the manufacture, construction, installation, decommissioning phases, this is earned back in a relatively short period, i.e. months as opposed to years.

Energy Payback Time (EPT) has been used to assess the relation between the energy consumption for turbine manufacture and the energy production throughout the lifetime (Vestas 2006), and also the operating time needed to produce the same amount of energy as is needed for the whole life cycle of the installation (Weinzettel *et al*. 2009). Vestas (2006) calculated a payback time of 6.8 months for an offshore V90-3.0MW wind turbine; the assumptions in the calculation included location some 14km from shore at a depth of between 6.5 and 13.5m, with a foundation diameter of approximately 4m piled some 25m into the seabed, within a development of 100 turbines, with an operational lifespan of 20 years, requiring 4 maintenance trips per year over its lifespan, connected by a 32kV cable grid with an offshore transformer station. Tryfonidou & Wagner (2004) calculated an EPT for a 5MW wind energy converter for offshore use of *ca*. 4 months, while Weinzettel *et al*. (2009) calculated an energy payback time of *ca*. 5.2 months on a process-based LCA for an offshore floating wind power plant. Using existing data, modelling and assumptions, the LCA on the V90-3.0MW offshore turbine found that 1kWh electricity generated by a turbine, had an impact of 5.23g of CO_2 during the life cycle, compared to 548g per kWh from European average electricity (Vestas 2006).

Oil and gas production

The major sources of emissions to atmosphere from offshore oil and gas exploration and production are internal combustion for power generation by installations, terminals, vessels and aircraft, flaring for pressure relief and gas disposal, flaring from well clean-up and testing, cold venting from storage and loading operations and fugitive emissions. Further information, including quantitative estimates for previous licensing rounds, are given in SEAs 1-7.

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. New developments will generally flare in substantial quantities only for well testing, start-up and emergency 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, will generally have little effect on host platform flaring.

Power requirements for the UK offshore industry are dominated by oil production installations (typically >50MW per platform), with smaller contributions from gas platforms and 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 (see below).

Gas storage

Gas storage has atmospheric emissions associated with it, including power requirement from compression. Types of compression machinery used in gas storage applications will depend on the operating conditions, but can include centrifugal compressor units (usually used for medium and high volumetric rates), driven by gas turbines or electric motors, or reciprocating compressors (usually used for lower flow rates) driven by electric motors or gas engines. The compression of gas for gas storage will generate atmospheric emissions.

There are a small number of onshore gas storage facilities (e.g. Hole House and Hatfield Moor) and one offshore facility currently in operation: the Rough 47/8 Alpha facility (hereafter referred to as Rough). Rough is located approximately 26 miles off the Humber Estuary and is the largest gas storage facility in the UK, capable of supplying in excess of 7.5% of peak day demand. Gas is injected via 30 wells which have been drilled into the reservoir and withdrawn the same way using the internal pressure of the reservoir. Extracted gas undergoes several separation processes offshore before onward subsea transport to the Easington terminal, and after further processing, enters the National Transmission System. Rough has a total storage capacity equivalent to 30 TWh at pressures of over 200bar and gas can be injected into the reservoir at an average of 160 GWh a day, depending on the reservoir pressure.

Atmospheric emissions emanate from a variety of sources at Rough and the Easington Terminal, including the consumption of gas, fuel and diesel, flaring and venting and fugitive and other emissions, with the greatest gas released being CO_2. In 2002, total emissions of CO_2 from Rough amounted to 106,172 tonnes (which accounted for 0.6% of the total CO_2 atmospheric emissions from offshore facilities). This increased to 109,559 tonnes of CO_2 in 2005, but still accounted for *ca*. 0.6% of the total emissions from offshore facilities. CO_2 emissions from Easington Terminal in 2002 amounted 94,786 tonnes (which accounted for just over 2% of the total emissions from onshore facilities) and with the exception of an increase in 2004 (103,883 tonnes, 2.4%), CO_2 emissions decreased to 91,046 tonnes (2%) in 2005. Both the Rough facility and the terminal at Easington account for a very small percentage of the total atmospheric emissions that emanate from offshore and onshore facilities.

Gas compression power requirement can be the major fuel gas user on a facility. From a representative in-house Operator study, assuming plant was online for 365 days per year for 4 years and 349 days per year for 3 years (to allow for planned maintenance) a 20MW compressor would produce 270 t/d of CO_2, while a 40MW compressor would generate 540 t/d CO_2.

As well as emissions from fuel use, emissions can be generated from a blowdown of the compression system, either planned for maintenance purposes or under emergency conditions.

5.10.3 Spatial consideration

Between the two sectors, there is likely to be a reasonably broad distribution of construction activity in all Regional Seas in shelf depths.

There are currently a small number of possible new offshore gas storage developments including the Gateway gas storage project, an offshore underground salt cavern in the East Irish Sea, approximately 24km off the coast at Fylde, north west England. This and the associated infrastructure is expected to be completed by 2011/12. A second is the possible conversion of the Bains gas field in the East Irish Sea into a dedicated seasonal gas storage facility (estimated to be approximately one fifth the size of Rough described above). Pre-development studies will be conducted until early 2009, after which a final decision will be made on the development. If it goes ahead, the facility is expected to have a storage capacity of up to 20 billion cubic feet and come on line for production and injection *ca*. winter 2011/2012. This development would also require a new unmanned platform and additional compression facilities, with the resulting emissions associated with installation (gaseous emissions from installation and support vessels) and operation (fuel use for gas compressors).

5.10.4 Cumulative impact considerations

The Environmental Emissions Monitoring System (EEMS) database was established by UKOOA in 1992 to provide a more efficient way of collecting data on behalf of the industry. Atmospheric data from the EEMS system is produced on an annual basis and can be used to show trends in UK offshore oil and gas activity greenhouse gas emissions. Emissions for the period 1998 to 2005 are summarised in Figure 5.25 (due to the roll out of the new EEMS reporting system, detailed industry reports, with complete data sets, are not yet available for years 2006 or 2007).

Total flaring (excluding terminals) on the UKCS was 1,559,817 tonnes in 2005 (an increase of approximately 12% above 2004 figures (1,372,893)), compared to 1,699,978 tonnes in 1999. As noted above, incremental flaring associated with new developments is not expected to be significant.

The dominant greenhouse gas discharged by the offshore oil and gas industry is CO_2, largely from combustion in turbines. Although short-term trends in CO_2 emissions from exploration and production are variable, the overall trend is one of reduction in discharge with emissions in 2005 showing a 1% reduction over 2004 (see Figure 5.25).

The overall decrease in 2003-2005 emissions may be attributed to a decline in exploration activity (partly offset in subsequent years) and falling production. However it would be expected that CO_2 emissions would increase due to greater power demands associated with operating mature fields, the use of injection as a method of disposal of produced water and drill cuttings and the potential use of reservoirs for gas storage. UK overall emissions of CO_2 fell by 5.6% between 1990 and 2003 to 572.2 million tonnes (Baggott *et al.* 2005) with offshore E&P activities contributing less than 4 % of this total.

Previous SEAs have forecast the atmospheric emissions likely to result from exploration drilling following the last three licence rounds (Table 5.21), and as a proportion of total UKCS emissions from exploration drilling (Table 5.22). It is clear that successive rounds each make a relatively small incremental contribution to total emissions from this sector, and therefore negligible contribution to overall UK emissions.

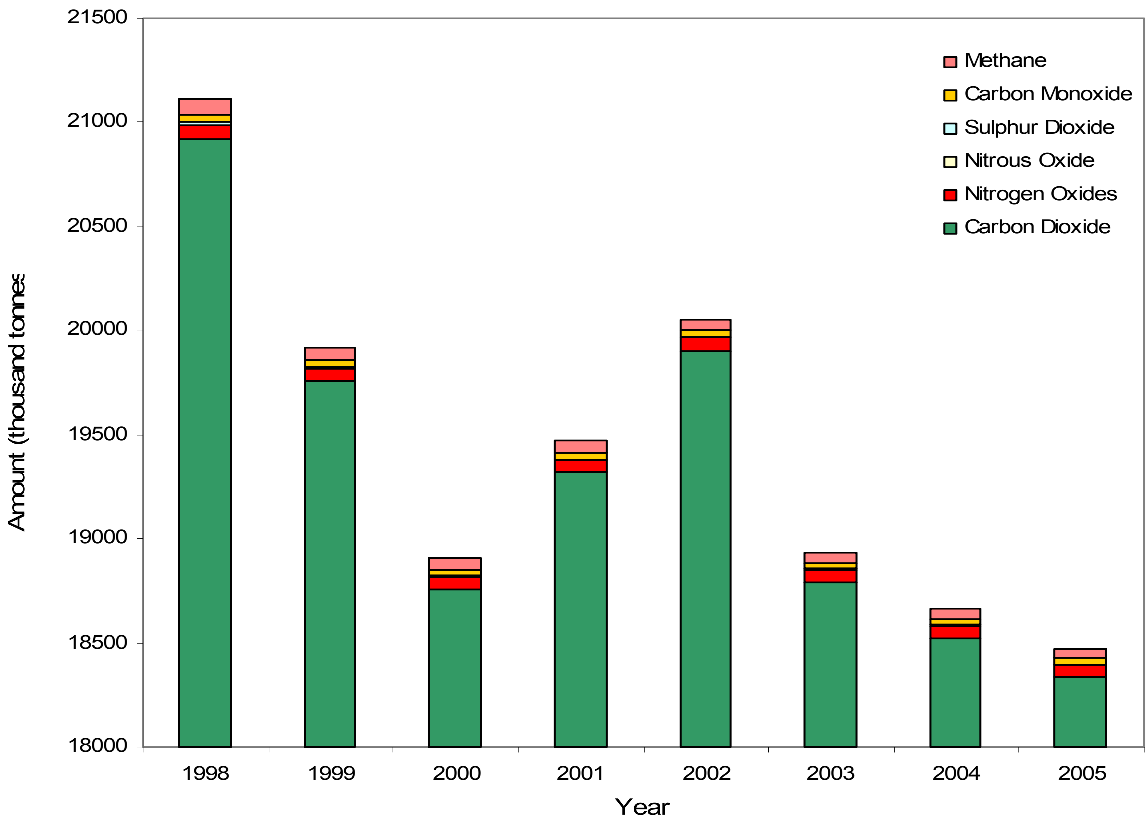
5.10.5 Summary of findings

OWF development will result in atmospheric emissions during the construction, commissioning and decommissioning phases of the project, principally through gaseous emissions from power generation of vessels; Energy Payback Time (EPT) estimates for offshore turbines are of the order of a few months Major sources of emissions to atmosphere from offshore oil and gas exploration and production, and gas storage, are internal combustion for power generation by installations, terminals, vessels and aircraft. Significant combustion emissions from flaring are not expected from potential development in the proposed licence areas, given the availability of existing gas process and export infrastructure.

Potential environmental effects of acid gas and greenhouse emissions are, respectively, regional and global in nature. Given the distance of most prospective areas for oil and gas from the coastline, and the presumption of a coastal buffer for OWF developments, local air quality effects from atmospheric emissions are not expected.

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.

Figure 5.25 – Atmospheric emissions from combined UKCS production and exploration activities



Note: Due to the roll out of the new EEMS reporting system, detailed industry reports, with complete data sets, are not yet available for years 2006 or 2007, therefore data up to 2005 only have been used here. Source: EEMS

Table 5.21 – Indicative atmospheric emissions resulting from SEA forecasts for exploration drilling resulting from previous licence rounds

	CO_2 (tonnes)	NO_x (tonnes)	N_2O (tonnes)	SO_2 (tonnes)	CO (tonnes)	CH_4 (tonnes)	VOC (tonnes)
SEA 7	20,480	86	1	26	6	<1	2
SEA 6	8,192	34.5	0.5	10.3	2.4	<0.1	0.8
SEA 5	40,960	172.8	2.81	51.2	11.77	0.4	3.77

Table 5.22 – Incremental contribution of atmospheric emissions resulting from SEA forecasts for exploration drilling resulting from previous licence rounds, relative to existing emissions from exploration drilling

	CO_2 (%)	NO_x (%)	N_2O (%)	SO_2 (%)	CO (%)	CH_4 (%)	VOC (%)
SEA 7	0.06	0.07	0.08	0.44	0.01	<0.01	<0.01
SEA 6	0.10	0.13	0.10	0.78	0.02	<0.01	<0.01
SEA 5	2.98	1.0	3.7	8.1	0.21	0.01	0.16

5.11 Climatic factors

5.11.1 Background

Scientific understanding of the interconnections of radiative heating with anthropogenically enhanced levels of greenhouse gases and ozone is high (IPCC 2007), with less known about other potentially important factors including aerosols and solar irradiance (for instance see: Blaauw *et al.* 2004). A combination of a commitment to reduce CO_2 emissions and increase the proportion of our energy generated from renewable sources is a positive move towards trying to reduce any anthropogenic influence on climate change and other negative externalities of CO_2 emissions (e.g. ocean acidification), while dealing with finite stocks of hydrocarbons and the security of energy supplies.

In December 2008 the European Parliament and Council of Ministers reached political agreement on legislation to require that by 2020, 20% of the EU's energy consumption must come from renewable sources. The UK's contribution to this will require the share of renewables in the UK's energy consumption to increase from around 1.5% in 2006 to 15% by 2020. In 2008 the Government consulted on a UK Renewable Energy Strategy, which is due to be published in Spring 2009.

The UK government 2007 Energy White Paper, 'Meeting the Energy Challenge', outlined targets and plans relating to CO_2 emissions and energy production to 2050. The legislative aspects of this paper passed into law in the Energy Act 2008, which makes provisions for areas including:

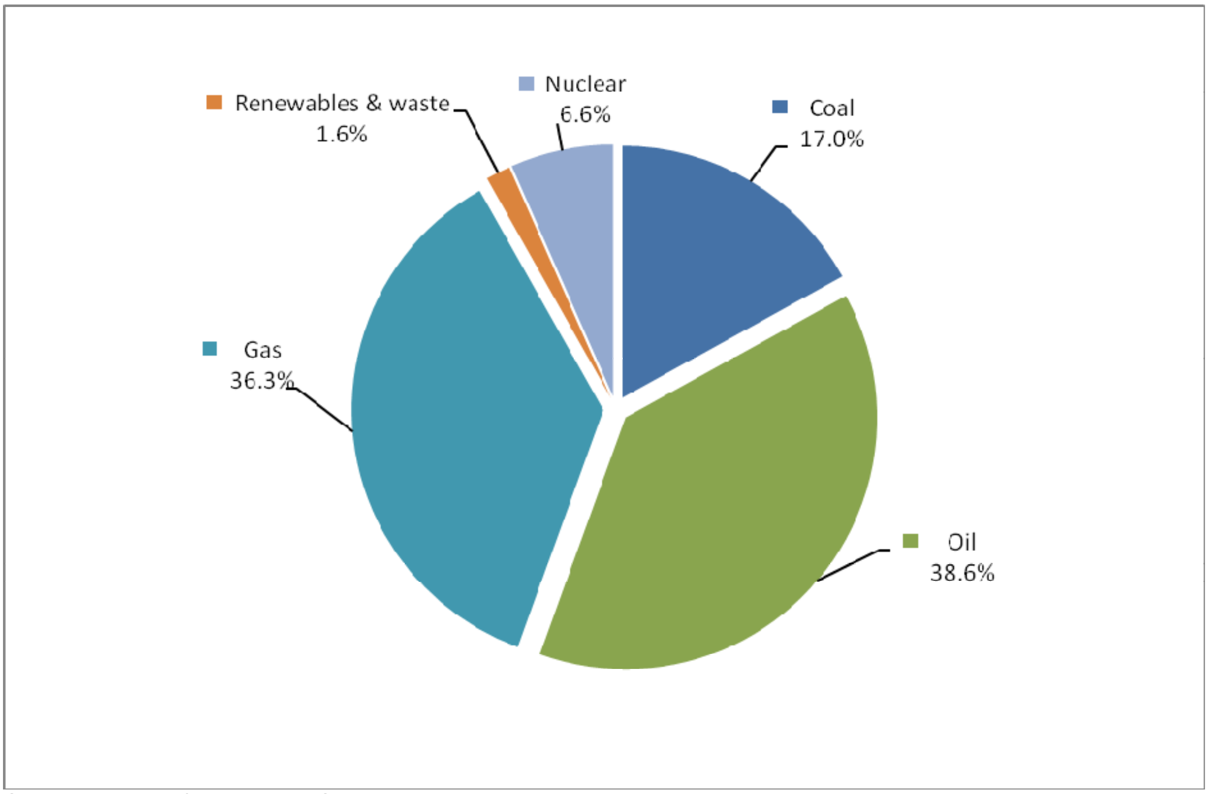
- Gas importation and storage (including Carbon Capture and Storage)
- Electricity from Renewable Sources (strengthens the existing renewables obligation in order to generate enhanced speed of delivery and diversity of supply technologies)
- Decommissioning of Energy Installations
- Improvements to offshore oil and gas licensing
- Miscellaneous energy issues (e.g. provision of smart meters, renewables heat incentives, transmission access powers and costs relating to network connections, gives effect in legislation to earlier administrative transfer of responsibilities for certain aspects of energy regulation, and contains provisions relating to nuclear security)

The proportion of renewables covered by the Renewables Obligation (i.e. biofuels, wave, solar photovoltaic, onshore/offshore wind and small scale and re-furbished hydro) in energy supply has grown from just under 1% in the early 1990s to 9.7% in 2008/09 (2009/10 in Scotland), and is set to grow towards 10.4% by 2010, and 15.4% by 2015. The reform of the Renewables Obligation under the Energy Act 2008 introduces the banding of technologies, whereby the number Renewables Obligation Certificates (ROCs) earned by suppliers per

KWh varies depending on the energy supply technology, which provides incentives to develop and diversify renewables energy production. Currently, fossil fuel energy is the primary source of energy supply in the UK followed by nuclear power (Figure 5.26), the remainder coming from hydro and wind power (RCEP 2000).

The Energy Act will not only help to maintain energy supply reliability, promote competitive markets and ensure affordable heating, but also contribute to the reduction in CO_2 emissions which may be linked to climate change. The Climate Change Act 2008 makes provisions for the reduction of CO_2 emissions through a number of legislative measures. The key target of the Act is the reduction of greenhouse gas emissions by 80% on 1990 levels by 2050 and a specific reduction in CO_2 emissions of 26% by 2020. The Act aims to meet this target through a range of measures, but principally the establishment of a Committee on Climate Change[6], to provide a system of carbon budgeting and trading, to encourage activities that reduce or remove greenhouse gases from the atmosphere and to promote through financial incentive the production of less waste and more recycling.

Figure 5.26 - Share of Net UK Primary Energy Supply in 2007



Source: Digest of UK Energy Statistics (2008)
Note: Figures are the net balance after trade. Excludes traded electricity, petroleum products and manufactured fuels.

The UK is presently the EU's largest energy producer due to energy production and exports of oil and gas from the North Sea (EIA website). In the 1990s, the UK changed from an energy net importer to a net exporter, with government policy designed to maximise production from domestic reserves for as long as possible. To achieve this end, the licensing system was reformed with the introduction of two new licences: i) the 'promote' licence and ii) the 'frontier' licence (IEA website, BERR Oil and Gas website). However, with oil & gas production having peaked during 1999, UK oil & gas production is falling. In the

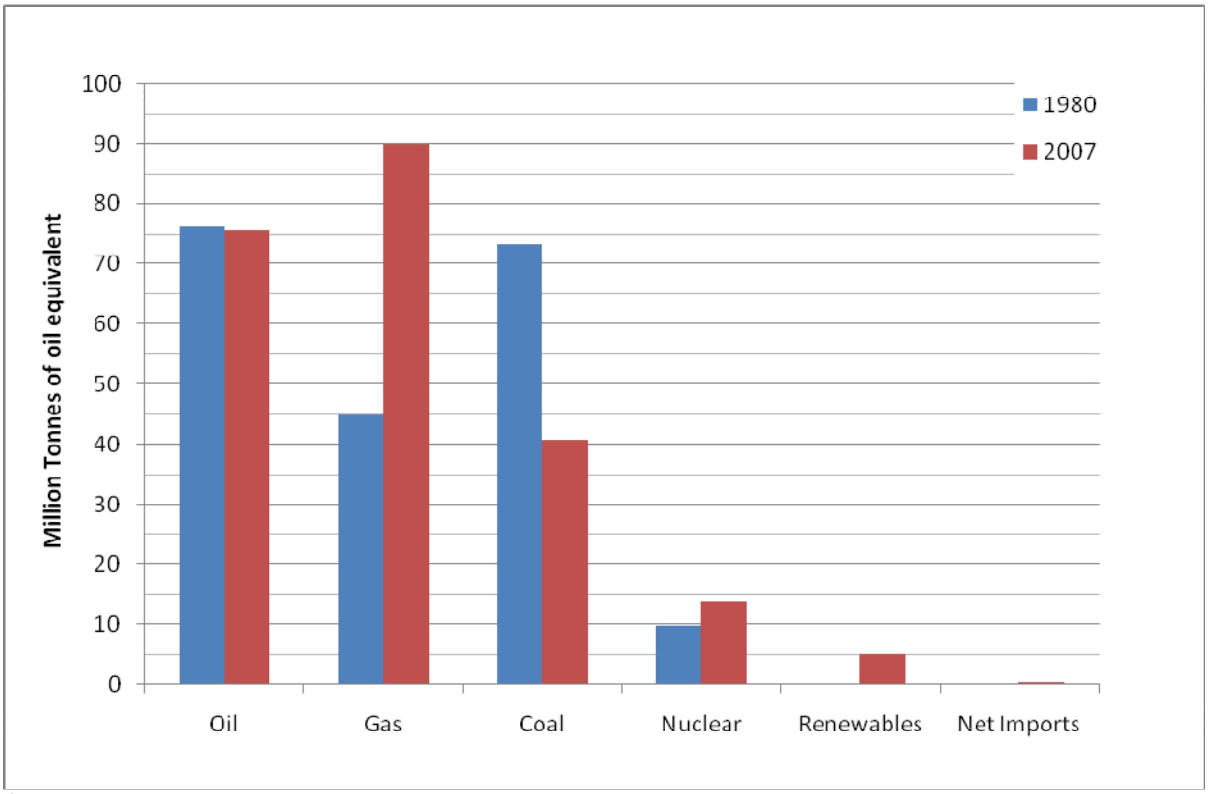
[6] *see: http://www.theccc.org.uk/*

second quarter of 2008, the UK was a net exporter of petroleum products, but a net importer of oil and oil products by 0.9million tonnes (BERR 2008b) – the UK became a net importer of gas in 2004.

5.11.2 Energy Demand and Consumption

Since 1965 demand for energy and subsequent consumption by final users has increased by 16% and 24% respectively – overall energy consumption in the UK for 2001 increased by 15% on 1970 figures and 10% on 1990 figures (BERR 2008d). This increase is linked to the growing output of goods and services associated with economic growth, increasing travel, rising numbers of households and the gradual increase in population. Annual primary energy use in the UK averages about 300GW, with almost 90% coming from fossil fuel (RCEP 2000). Since 1980, consumption of natural gas and primary electricity has risen considerably (Figure 5.27), whilst consumption of oil has remained around the same and coal has fallen (BERR 2008a).

Figure 5.27 - Onshore energy consumption, 1980 and 2007



Source: BERR (2008a)

The supply of renewables energy has substantially increased in recent years from a total of 1.02 million tonnes of oil equivalent in 1990 to 5.17 million tonnes of oil equivalent in 2007. The largest growth in renewables energy production has been in biomass (82% of sources in 2007), though there has been a real increase in all renewables components with the exception of hydro power which has declined by *c.* 2% since 1990, though new schemes such as Glen Doe in Scotland are due to come online in the near future (Figure 5.28). Wind and wave energies have increased substantially up to 2007, nearly accounting for 9% of renewable energy generation, and this is likely to increase as new onshore and offshore wind farms develop, and wave technologies become more prolific.

The final consumers of energy in the UK can be divided into four groups: a) industry, b) domestic sector, c) transport and d) services. The following table shows final energy consumption for the main sectors, indicating that overall energy consumption has stayed stable over the last seven years:

Table 5.23 - Energy Consumption by Sectors (million tonnes of oil equivalent)

	2000	2003	2004	2005	2006	2007
Industry	35.2	33.7	33.0	33.1	32.8	31.7
Domestic sector	46.9	48.2	48.6	47.0	45.7	44.0
Transport	55.6	56.5	58.2	59.2	59.8	59.8
Services	21.5	19.7	20.2	20.0	19.7	19.3
Total final energy consumption	**159.2**	**158.0**	**159.9**	**159.5**	**157.9**	**154.9**

Source: BERR (2008d)

Energy consumption by individual sectors has changed substantially since 1980: there have been rises of 41% for transport, 9% for the domestic sector and 3% for the service sector, whilst consumption by industry has fallen by 34% (BERR 2008d).

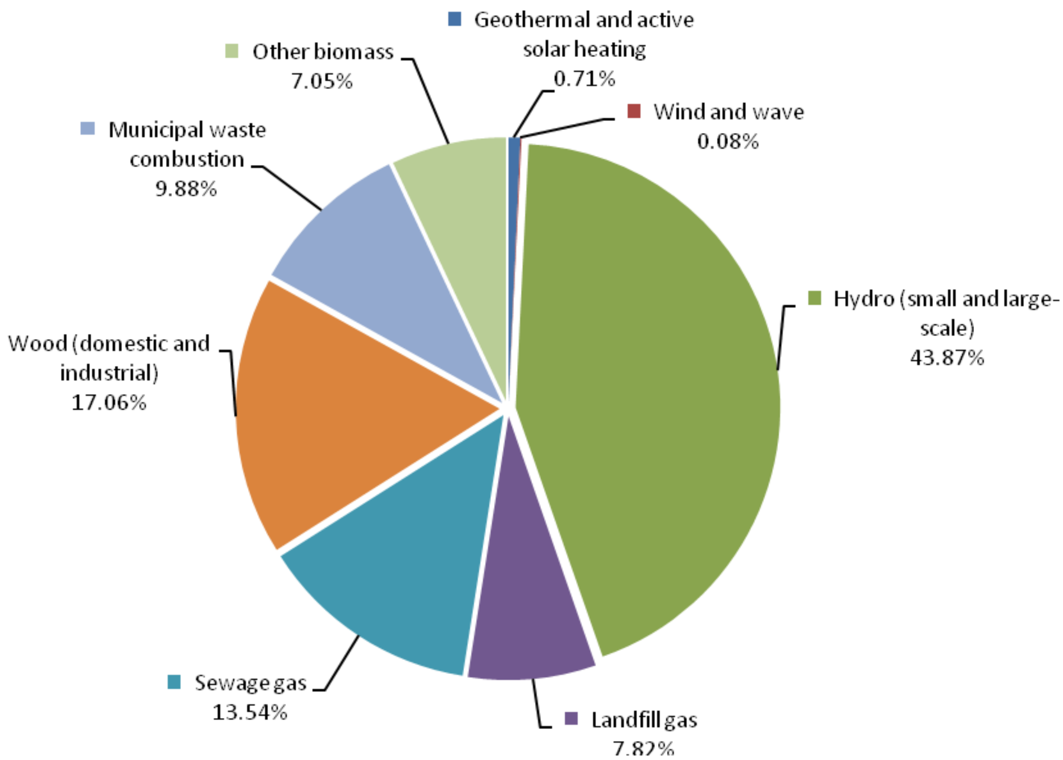
5.11.3 Trends in UK GDP, carbon intensity and energy efficiency

Carbon intensity (the level of greenhouse gas emission per unit of economic output) reflects both a country's level of energy efficiency and its overall economic structure. Over the last 30 years, total UK CO_2 emissions in relation to total economic output have fallen by a factor of two. During 1995 and 2000 carbon intensity of primary energy consumption has fallen significantly due to the 'dash for gas' within the electricity generating sector (and to a lesser extent within industry as a whole), increased use of more efficient generation technology such as combined cycle gas turbines and combined heat and power plants (CHP) as well as better performance by nuclear power stations (House of Commons 1999, Baumert *et al.* 2005, Bishop & Watson 2005). UK industrial emissions fell by 4.4 million tonnes of carbon equivalent (MtC) between 1990 and 2000, accounted for by variations in structure, output and energy efficiency (BERR 2008d).

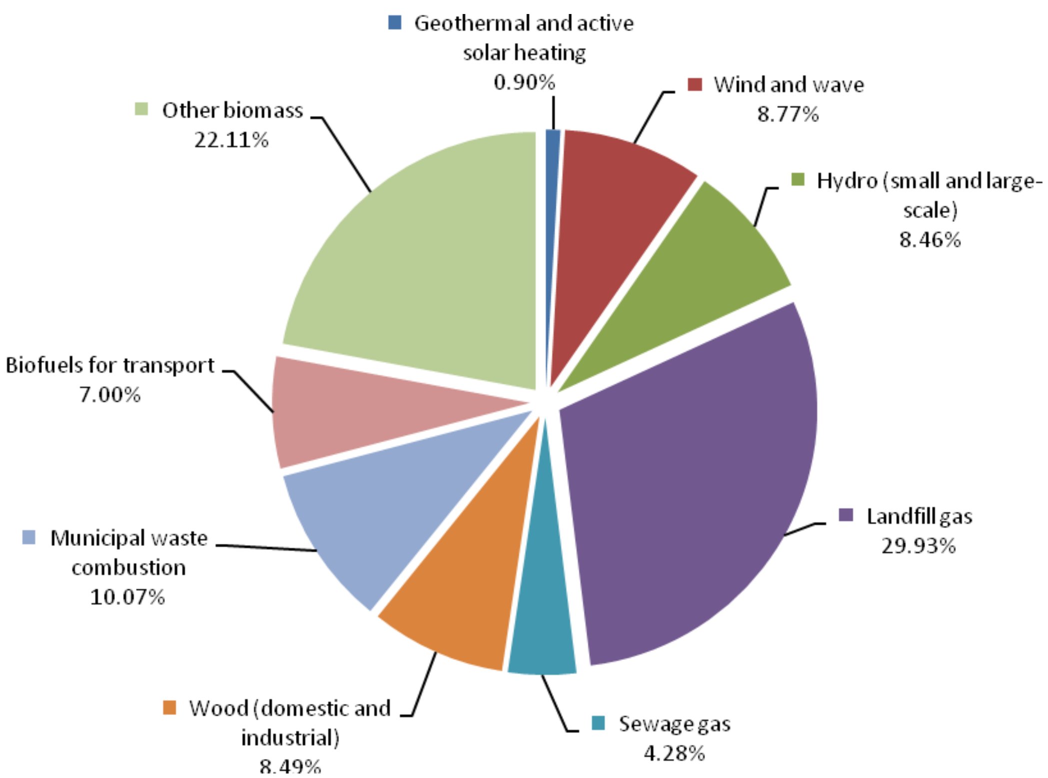
Overall, energy consumption has risen more slowly than economic activity (as measured by gross domestic product), reflecting the tendency of organisations and individuals to find ways of using energy more efficiently (RCEP 2000). This trend is likely to continue due to the Climate Change Levy that came into effect in 2001, encouraging industries to examine more energy efficient production methods – Cumulatively it has saved 16.5 million tonnes of carbon in the period to 2005 and will be contributing savings of more than 3.5 million tonnes of carbon by 2010 (BWEA website). More recently, the Carbon Reduction Commitment (CRC), a new emissions trading scheme, seeks to reduce emissions principally from large, but low-energy use private and public sector organisations. It is thought that alongside the EU Energy Performance of Buildings Directive, measures set out in the CRC should deliver reductions equivalent to 0.5MtC per year to 2015, and 1.2MtC per year to 2020 (DEFRA 2007a).

Figure 5.28 – Renewable energy sources in 1990 (A) and 2007 (B)

A



B



Source: BERR (2008c)

The UK Government has promoted energy efficiency with subsidies, advice and publicity campaigns (Table 5.24). The DEFRA Energy Efficiency (2007) Action Plan outlined potential future measures to improve energy efficiency by 2010. The most recent Energy Efficiency Plan sets out policies put in place by DEFRA to achieve climate and energy policy objectives and to meet the 9% energy saving target by 2016 under the European Union's Energy End-Use Efficiency and Energy Services Directive. It is expected that by 2016, an energy saving of 18% will be made, equivalent to 272.7TWh (DEFRA 2007b).

Table 5.24 – Key UK energy efficiency measures and programmes

Name of Programme/Funding	Summary
Energy Savings Trust (~£100million per year depending on take-up)	An organisation, funded by the Government, providing information on best practice, support networks and manages grant schemes and campaigns across the domestic, transport and public sector
Carbon Trust (~£40million per year)	Supports measures for businesses investing in energy saving technology; funding for R&D of new low-carbon technologies
Warm Front (~£800million for 2008-11)	The governments' main grant-funded programme for tackling fuel poverty. It provides grants for low income households towards different packages of insulation and heating measures

Source: BERR website, DEFRA website

In addition, there are a number of UK initiatives promoting renewable energy sources and technology developments. The Energy Technologies Institute is funded through a 50:50 funded public-private partnership and has a target to generate an investment of £1.1billion for new energy technologies (ETI website), while DEFRA participates in and funds the Carbon Trust[7]. Other programmes are either directed at homeowners, schools and communities, such as the government's Low Carbon Building Programme[8], or renewable energy, such as the Marine Renewable Deployment Fund (a £50million fund supporting the continued development of the marine renewables sector), wind energy[9] or biofuel[10].

5.11.4 Climate change impacts

The IPCC 4th assessment report has a number of principal findings which indicate that it is very likely that since the onset of the industrial revolution, anthropogenic inputs of CO_2 and other greenhouse gases has had a positive radiative effect on global air and sea temperatures, with a projected further increase of 0.2°C increase for the next two decades. Though popularised as 'global warming', the changes in climate which may be experienced in years to come are much more complex than simply increasing temperatures, for instance changes in the frequency and intensity of extremes of heat, cold, droughts, floods, hurricanes, tornadoes and other forms of extreme weather are also likely to occur.

Future climate change may generate alterations which threaten ecological and social systems. For instance the recent IPCC report 'Linking climate change and water resources' (Bates *et al.* 2008) highlights a number of negative effects which may be generated by both flood and drought events. Crop damage, soil degradation, reduced crop yields, ground and

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7 *see: http:// www.carbontrust.co.uk*
8 *see: http://www.lowcarbonbuildings.org.uk*
9 *see: http://www.bwea.com*
10 *see: http://www.supergen-bioenergy.net/?_id=288*

surface water contamination, increased risk of death, injuries and infections and general disruption to infrastructure and loss of property are all likely to increase as a result of flood or drought activity – and this is not to mention the distribution, growth and productivity, and reproduction of plants and animals.

More directly associated with positive radiative forcing is heat related deaths, particularly in Europe and changes in infectious disease vectors (e.g. malaria carrying mosquitoes). Any form of disruption in the food supply due to precipitation events or a change in the growing season is likely to be negative for both local and imported food stocks, despite some advantageous effects of milder temperatures in the mid- to high-latitudes and temperate areas (IPCC 2007). Industries and settlements in coastal locations may be disrupted due to changes in sea-level and coastal erosion and therefore will be more prone to flooding. Increased storminess at sea may also negatively affect offshore operations, with shorter weather windows and increased 'down time'.

Ecosystem

The Working Group II Report (IPCC 2007) in contribution to the IPCC Fourth Assessment Report describes considers impacts, adaptation and vulnerability in relation to climate change. Chapter 4 (Fischlin *et al*. 2007) considers the impacts of climate change on ecosystem properties, goods and services; this includes an assessment of likely wide-scale future impacts across many ecosystems, along with descriptions of observed impacts to date and potential future impacts specific to marine ecosystems. The following text summarises relevant information provided by Fishlin *et al*. (2007) and references therein.

Likely wide-scale future impacts

Some particularly relevant conclusions of Fishlin *et al*. (2007) are provided below, including information on the confidence of such statements:

- During the course of this century the resilience of many ecosystems (their ability to adapt naturally) is likely to be exceeded by an unprecedented combination of change in climate, associated disturbances (e.g., flooding, ocean acidification) and in other global change drivers (especially land-use change, pollution and over-exploitation of resources), if greenhouse gas emissions and other changes continue at or above current rates. Confidence = high.
- Approximately 20 to 30% of plant and animal species assessed so far (in an unbiased sample) are likely to be at increasingly high risk of extinction as global mean temperatures exceed a warming of 2 to 3°C above pre-industrial levels. Confidence = medium.
- Substantial changes in structure and functioning of terrestrial ecosystems are very likely to occur with a global warming of more than 2 to 3°C above pre-industrial levels. Confidence = high.
- Substantial changes in structure and functioning of marine and other aquatic ecosystems are very likely to occur with a mean global warming of more than 2 to 3°C above preindustrial levels and the associated increased atmospheric CO_2 levels. Confidence = high.
- Ecosystems and species are very likely to show a wide range of vulnerabilities to climate change, depending on imminence of exposure to ecosystem-specific, critical thresholds. Confidence = very high.

Observed and potential impacts to marine ecosystems

Climate change can impact marine ecosystems through ocean warming, by increasing thermal stratification and reducing upwelling, sea level rise, through increases in wave height and frequency, loss of sea ice, increased risk of diseases in marine biota, and decreases in the pH and carbonate ion concentration of the surface oceans.

Decreases in upwelling and formation of deep water, and increased stratification of the upper ocean will reduce the input of essential nutrients into the photic zone and reduce productivity. In coastal areas and margins, increased thermal stratification may lead to oxygen deficiency, loss of habitats, biodiversity and distribution of species, and impact whole ecosystems. Changes to precipitation and inputs of nutrients from land may exacerbate hypoxic events.

Changes to planktonic and benthic community composition and productivity have been observed, along with large shifts in pelagic biodiversity and fish community composition. Changes in seasonality or recurrence of hydrographic events or productive periods could be affected by trophic links to many marine populations. Elevated temperatures have increased mortality of winter flounder eggs and larvae, and have led to later spawning migrations. Tuna populations may spread towards presently temperate regions, based on predicted warming of surface water and increasing primary production at mid- and high latitudes.

Marine mammals, birds, cetaceans and pinnipeds, which feed mainly on plankton, fish and squid, are vulnerable to climate change-driven changes in prey distribution, abundance and community composition in response to climatic factors. Changing water temperature also has an indirect effect on the reproduction of cetaceans and pinnipeds, through prey abundance, by either extending the time between individual breeding attempts, or by reducing breeding condition of the mother. Current extreme climatic events provide an indication of potential future effects. For example, the warm-water phase of ENSO is associated with large-scale changes in plankton abundance and associated impacts on food webs, and changes to behaviour, sex ratio, and feeding and diet of marine mammals.

Melting Arctic ice-sheets will reduce ocean salinities, causing species-specific shifts in the distribution and biomass of major constituents of Arctic food webs. Migratory whales that spend the summer in Arctic feeding grounds are likely to experience disruptions in their food sources. Nesting biology of sea turtles, in terms of timing and sex ratio of hatchling, is strongly affected by temperature, while a predicted sea-level rise of 0.5m will eliminate up to 32% of sea-turtle nesting beaches in the Caribbean.

Surface ocean pH has decreased due to absorption of anthropogenic CO_2 emissions and is predicted to continue to decrease. This may impact a wide range of organisms and ecosystems, particularly calcifying benthic organisms and their planktonic larvae.

Cold-water coral ecosystems harbour a distinct and rich ecosystem; they provide habitats and nursery grounds for a variety of species, including commercial fish and numerous new species previously thought to be extinct. These geologically ancient, long-lived, slow-growing and fragile reefs will suffer reduced calcification rates. Cold-water corals depend on extracting food particles sinking from surface waters or carried by ocean currents, they are therefore also vulnerable to changes to ocean currents, primary productivity and flux of food particles.

5.12 Waste

5.12.1 Introduction

The transfer of offshore wastes to shore for treatment and disposal can result in a variety of effects including nuisance, changes in air quality, onshore land use and cumulative effects, with the scale of effect dependent on quantity, effective waste management and eventual disposal method. Large-scale offshore oil and gas production can generate significant quantities of waste (comparable to an equivalent onshore industrial/residential development); however, OWF developments are generally not manned and waste generation will be minimal.

As with onshore industrial waste streams, waste from offshore can be characterised (for management and regulatory purposes) as special waste (e.g. chemicals/paints, oils and sludges), general waste (e.g. scrap metal and segregated recyclables) and other (e.g. radioactive materials).

5.12.2 Evidence base

Offshore Oil and Gas production

In 2007, UKCS offshore oil and gas operations produced around 121,046 tonnes (2006 amount 121,260 tonnes) of waste of which 4,229 tonnes was reused, 21,192 tonnes recycled, 2,082 tonnes used in waste to energy and 71,468 tonnes were landfilled (EEMS 2007).

The return of drill muds and cuttings to shore for treatment and disposal is the major change in offshore waste disposals in recent years. In 2007, 44,313 tonnes of treated cuttings were disposed of to landfill. It is unlikely that major changes to these volumes would result from the proposed licensing and likely scale of drilling. In view of the volumes of material (drilling wastes and general oilfield waste) likely from drilling or operations together with the stringent control of waste disposal activities under IPPC and the Landfill Directive it is considered that any effects on land will be negligible.

Used drill muds and cuttings may be ground and reinjected to rock formations rather than discharged to sea or returned to land. A permit is required for UK interfield transfer of oily cuttings for reinjection. The reinjection of wastes to source is generally regarded as resulting in positive benefits, such as reduced requirement for landfill space. However, the process of reinjection can be energy intensive and thus result in increased atmospheric emissions from an installation.

The target formation(s) for reinjection of such materials is selected on the basis of geological understanding from previous drilling in the area, with performance monitored over time. Any release to sea or to other unintended rock strata is regarded as an accident and considered later in this section. Cuttings cleaning technologies which are capable of reducing oil on cuttings to levels below 1% may have a future positive impact on quantities of cuttings disposed of to land.

Substantial waste generation would be expected at decommissioning of offshore infrastructure (both oil & gas and OWF), although at end of life a high proportion of materials (especially structural steel, copper cabling and other metals) would be expected to be reused or recycled. Regulatory controls over decommissioning are in place and will require a detailed assessment of re-use, recycle and waste disposal prior to end of life.

5.12.3 Cumulative impact considerations

Onshore, during 2006/07, some 22.58 million tonnes of controlled waste (household, commercial and industrial, construction and demolition and agricultural, fisheries and waste) arose in Scotland, with each household in Scotland producing an estimated 1,228kg of waste. An estimated 159 million tonnes of waste was managed in England and Wales. Of this, 65 million tonnes were landfilled, 50 million tonnes were transferred, before final disposal or recovery, 28 million tonnes were treated, 11 million tonnes were handled through metal recycling facilities and 5 million tonnes were incinerated.

At around 0.01% of national waste generation, the contribution from offshore energy production is, and is expected to remain, negligible.

5.12.4 Summary of findings

At a national scale, waste generation from offshore energy activities is negligible. Effective regulatory controls are established which have minimised the generation of hazardous waste materials, and provided waste management procedures comparable with those onshore.

5.13 Accidental events

5.13.1 Introduction

Oil spills are probably the issue of greatest public concern in relation to the offshore oil and gas industry, although the majority of large spills in the UK have resulted from shipping casualties, which although still relatively infrequent, are also more likely to occur in coastal waters where environmental and economic sensitivities are highest. The risks of large oil spills resulting from hydrocarbon exploration and production (E&P) are potentially associated with major incidents on production platforms, export (pipeline and tanker loading sources), with the additional potential for loss of well control and subsequent oil blowout. The historical frequency of such events in the UK and Norwegian continental shelves has been very low (see below). Crude oil spills from E&P are clearly limited to the locations of producing facilities and associated export infrastructure (in the UK, this is predominantly in the central and northern North Sea). Smaller, and historically more frequent, spills may result from transfer and handling of fuel, drilling fluids and lubricating or hydraulic oils.

Other accidental events (with environmental consequences) that could potentially occur on offshore E&P facilities, and associated support vessels, include gas releases and chemical spills. Offshore wind developments generally have a negligible inventory of oils and chemicals, and spill risks are accordingly mostly associated with construction and operational maintenance; or with navigational safety risks to other (not OWF-related) vessel traffic.

Environmental risk is generally considered as the product of probability (or frequency) and consequence. The environmental consequences of oil and chemical spills are associated primarily with seabirds, marine mammals, fisheries and coastal sensitivities; and these sensitivities are considered in the appropriate environment description sections and supporting studies. The sources, frequency, magnitude and potential consequences of hydrocarbons spills are considered below. Much of the information is common to previous SEAs, and is therefore summarised with updates where appropriate.

Specific issues associated with individual UK Regional Seas include the location of sensitive coastlines, such as breeding bird colonies of international conservation importance, the importance of coastal tourism and recreation, and fisheries generally within the area.

It should be noted that the purpose of SEA risk assessment is not to anticipate the detailed risk assessment and contingency planning which would be required in advance of any development, but to evaluate the overall contribution to risk associated with possible offshore energy-related activity.

5.13.2 Summary of effects considerations

Accident scenarios and historic frequency

Previous SEAs have reviewed hydrocarbon spills reported from exploration and production facilities on the UKCS since 1974 under PON1 (formerly under CSON7); annual summaries of which were initially published in the “Brown Book” series, now superseded by on-line data available from the DECC website (https://www.og.berr.gov.uk/information/index.htm). Discharges, spills and emissions data from offshore installations are also reported by OSPAR (e.g. OSPAR 2007).

Well control incidents (i.e. “blowouts” involving uncontrolled flow of fluids from a wellbore or wellhead) have been too infrequent on the UKCS for a meaningful analysis of frequency based on historic UKCS data. The only significant blowouts on the UKCS to date have been from West Vanguard (1985) and Ocean Odyssey (1988), both involving gas. A review of blowout frequencies cited in UKCS Environmental Statements gives occurrence values in the range 1/1000-10,000 well-years. These are generally consistent with derived annual frequencies based on the worldwide database maintained by SINTEF and Scandpower.

E&P in deep water presents a range of different considerations related to engineering design, blowout control, spill fate, and environmental consequences (considered in detail in SEA 7). A 1999 study for the US Minerals Management Service assigned a moderate probability of a deepwater blowout during drilling, completion and workover operations, associated with the wellhead connector, lower marine riser package (LMRP), well flow through the riser, or a broach. Based on industry experience with the very few problems that have been associated with these components, a “catastrophic” rating was assigned to a release through the drill pipe or from a broach, because the drill rig would likely shut down and be abandoned, or move off location. A “severe” ranking was assigned to blowouts originating at the wellhead connector or through the riser; while those associated with the BOP and LMRP were assigned a “minor” ranking. For producing wells, a “catastrophic” consequence was assigned to a deepwater blowout to a broach, and “severe” to blowouts resulting from the wellhead connector or casing hanger seals, while all other components were assigned a low probability. However, it should be noted that all the above scenarios involve multiple system failures and of at least two independent barriers to flow. If the well is in a static condition (i.e., no flow from the reservoir) the primary barrier is usually the hydrostatic pressure exerted by the fluid column (either static or dynamic). The secondary barriers would be the pressure control equipment such as the BOP, the wellhead (innermost casing hanger seal), and the choke/kill line valves. If the well is flowing (i.e. producing oil and/or gas), the primary barrier is that which is closest to the reservoir. This typically includes the packer and associated seal assemblies, the tubing between the packer and the Surface-Controlled Subsurface Safety Valve (SCSSV) and the SCSSV itself. The secondary barriers would then include the tubing above the SCSSV, the master valve of the Christmas tree, the casing and tubing hanger seals and the annulus valves.

The major difference between a blowout during the drilling phase versus the completion or workover phases is the drilling well tendency to "bridge". Bridging is a phenomenon that occurs when severe pressure differentials are imposed at the well/reservoir interface, and the formation around the wellbore collapses and seals the flow path. Completion schemes often include methods to stabilize the reservoir during production in order to reduce the production of solids in the flow stream; therefore a completed well may not have the same tendency to passively bridge off as would a well section being drilled before the steel casing has been cemented in place. The tendency to passively bridge may also be inhibited by the seawater column back pressure which may limit the flow rate and prevent collapse of the well. In these cases, active bridging methods may be used to close the hole. Bridging may have a beneficial effect for spill control by slowing or stopping the flow of oil from the well.

DECC data indicates that the major types of spill from mobile drilling rigs have been organic phase drilling fluids (and base oil), diesel and crude oil. Topsides couplings, valves and tank overflows; 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 (leading to excess oil in produced water). Estimated spill risk from UKCS subsea facilities was equivalent to a risk of 0.003 spills/year for an individual facility, with almost all reported spills less than a tonne (<5bbl) in size.

Historically, major spill events from UKCS production facilities include the 1986 Claymore pipeline leak (estimated 3,000 tonnes), 1988 Piper Alpha explosion (1,000 tonnes), 1996 Captain spill (685 tonnes) and 2000 Hutton TLP spill (450 tonnes). 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 routine inputs from oil-based drilling fluids essentially ceased at the end of 1996, and OPSAR (2000a) noted that reliable estimates on inputs of oil from rivers and land runoff are lacking.

Globally, the total amount of oil spilled annually depends largely on the incidence of catastrophic spills (Etkin 1999), with less than 300,000 tonnes in most years, but exceptional quantities spilled to sea in 1978 (*Amoco Cadiz*), 1979 (Ixtoc 1 blowout and *Atlantic Empress* tanker spill), 1983 (Nowruz blowout and *Castillo de Bellver* tanker spill) and 1991 (Gulf War). Within Regional Sea 6, the *Sea Empress* spill (1996) resulted in significant bird kill and effects on benthic organisms; apparently, however, without major long-term effects. As with the earlier *Braer* spill in Shetland (Regional Sea 1/8 boundary), the timing of the spill was fortuitous in limiting environmental effects and prevailing weather conditions assisted in natural dispersion.

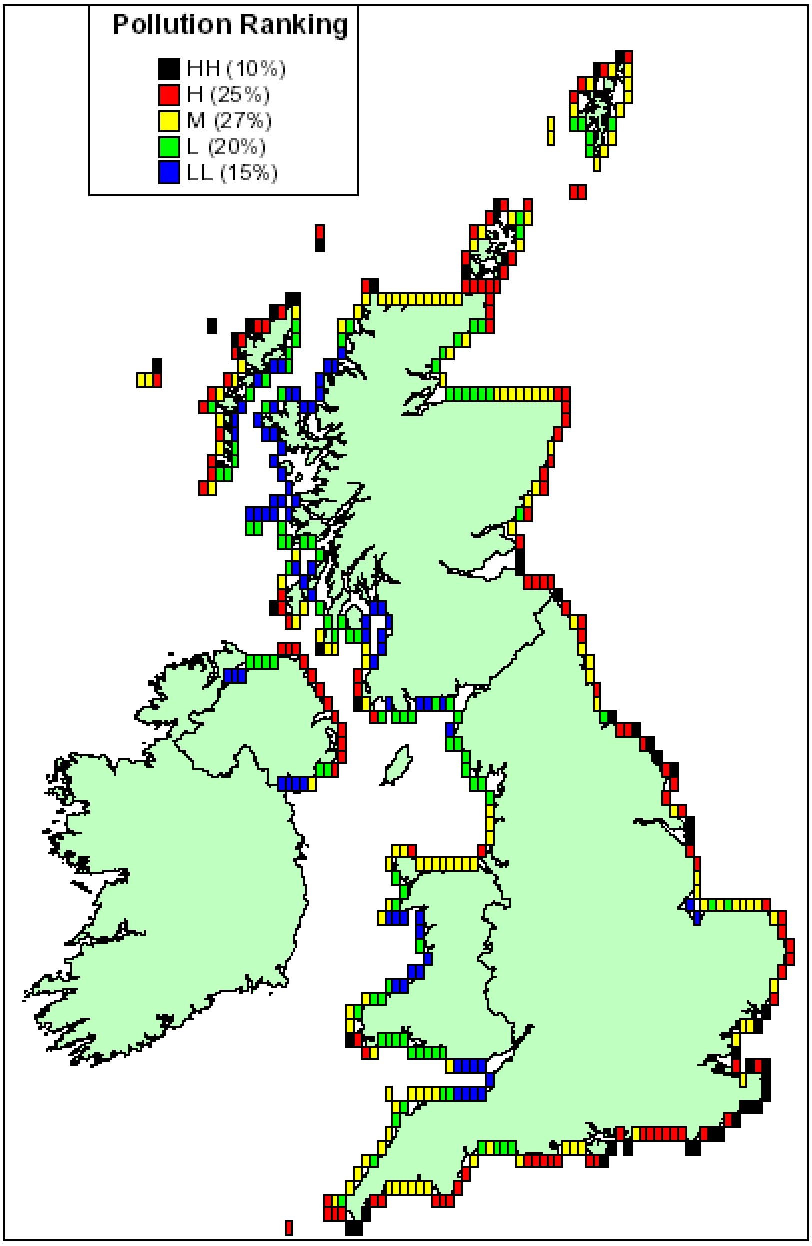
In 2000, the Maritime and Coastguard Agency (MCA) commissioned Safetec UK Ltd (Safetec) to provide data to assist the MCA with regard to decision making on the placement of Emergency Towing Vessels (ETVs) in different locations around the UK Coastline. This involved an assessment of incident frequencies and the likelihood of different types of accidental events in causing pollution which would then impinge on the coastline (Safetec 2000), including both incidents which occur at the coastline (e.g. grounding incidents), as well as incidents that occur at sea but could encroach on the coastline. It should be noted that no intervention in terms of tugs, etc., has been included within the assessment. The risk of oil spills resulting from shipping casualties was considered to be high or very high to the north of Shetland, in the Fair Isle Channel, through the Pentland Firth, down much of the east coasts of Scotland England, through the Dover Strait and along much of the Channel coast, around Land's End, in the Approaches to Milford Haven, through the North Channel, around St Kilda and the Flannans, on the west coast of Lewis and around the Butt of Lewis (Figure 5.29). This assessment facilitated the designation of Marine Environmental High Risk Areas (MEHRAs) and identified the best locations for ETVs in the Northern Isles, the Minches, the South-west approaches and the Dover Straits (which is run on a joint management and finance basis with the French Authorities). The ETVs are on stand-by 24 hours a day, 365 days a year to respond to shipping incidents in their area.

An annual review of reported oil and chemical spills in UK waters – covering both vessels and offshore installations – is made on behalf of the MCA by the Advisory Committee on Protection of the Sea (e.g. ACOPS 2007). These reviews split the UK Pollution Control Zone into 11 areas, and 559 separate discharges from vessels and offshore oil and gas installations were identified in the survey area during 2006, with small increase of 2% over the previous year's total. For the sixth successive year another reduction was apparent in the total number of reported vessel-sourced discharges, which numbered 149 during 2006. Excluding permitted produced water discharges, the reported total of 275 accidental oil discharges attributed to offshore oil & gas installations during 2006 was slightly below the corresponding mean annual total of 280 oil discharges between 2000 and 2006. In contrast, the marked increase in the total number of discharges of substances other than mineral oils reported by offshore oil & gas installations since 2003 follows a change in reporting requirements for discharges of this nature.

The discharges from all sources reported during 2006 comprised 75% mineral oils, 24% chemicals (including oil-based mud and related products) and 1% other substances (including vegetable and animal oils). Crude oils accounted for 22% of all identified types of mineral oil discharges. Bunker, diesel, fuel and gas oils were spilt in varying quantities from vessels or offshore oil and gas installations on 164 occasions. Approximately 80% of all reported discharges were in the open sea, 17% in ports and harbours and 3% in other marine environmental zones.

The PON1 reports indicated that remedial actions were taken by operators following most accidental discharges. The responses included identification of root causes of spills, improvements in operational control procedures, recommendations concerning preventative actions and carrying out any necessary repairs and modifications to faulty or damaged equipment. In addition, several reports referred to operators sealing systems and shutting down operations in order to prevent any further pollution.

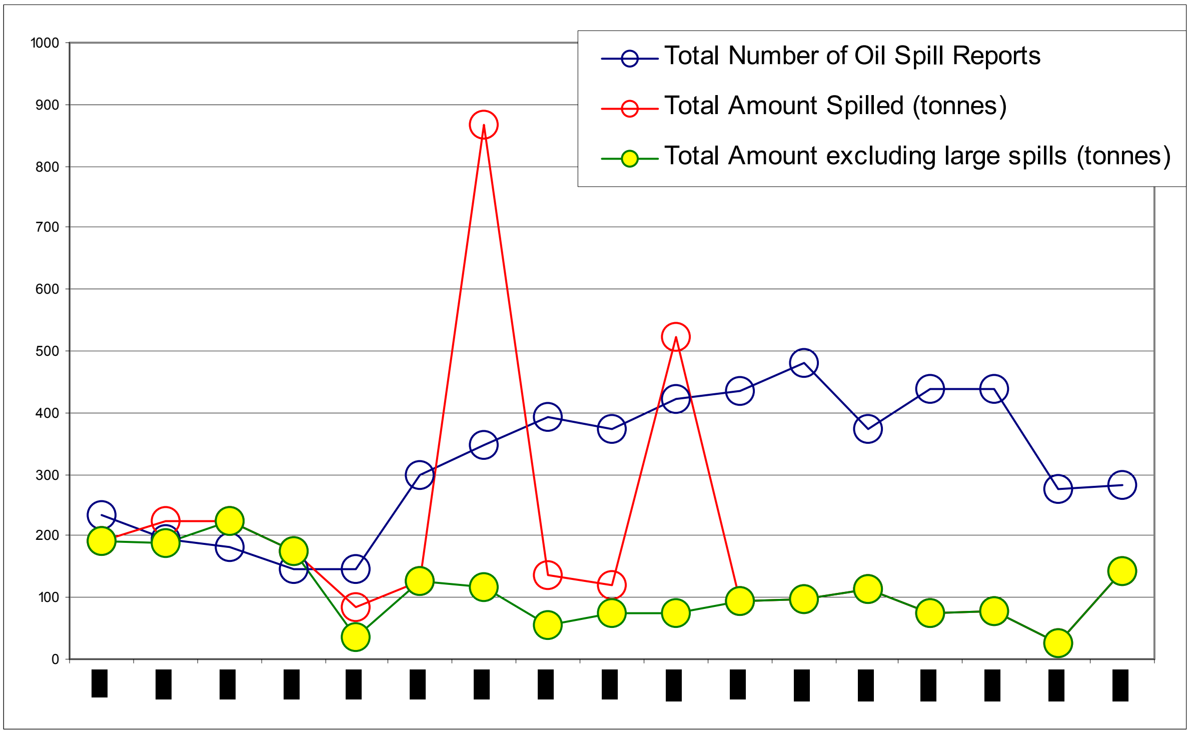
Figure 5.29 – Pollution risk ranking of the UK coastline



Source: Safetec (2000)

Over the preceding decade, DECC data indicates that the reported number of spills has increased (Figure 5.30); consistent with more rigorous reporting of very minor incidents. However, the underlying trend in spill quantity (excluding specifically-identified large spills) suggests that a fairly consistent annual average of around 100 tonnes. In comparison, oil discharged with produced water from the UKCS in 2005 totalled 4'972 tonnes.

Figure 5.30 – Reported oil spills on the UKCS, 1991-2007



*Source: DECC data (*http://www.og.berr.gov.uk/*)*

Oil spill fate & trajectory

The fate of oil spills to the sea surface is relatively well understood. On the sea surface, there are eight main oil weathering processes: spreading, evaporation, dispersion, emulsification, dissolution, oxidation, sedimentation and biodegradation – these are reviewed in SEAs 1, 2 and 3. The rates of individual processes are inter-dependent, and also influenced by hydrocarbon characteristics, temperature and turbulence. In general, oils with a large percentage of light and volatile compounds and low viscosity (such as diesel) will evaporate, disperse and dissolve more rapidly than oil predominantly composed of higher molecular weight compounds (e.g. crude oils). Oil on the sea surface will move due to a combination of tidal currents and wind stress. Generally, the slick front will be wind-driven on a vector equivalent to current velocity plus approximately 3% of wind velocity and 100% of the current.

Surface oil spill trajectory modelling can be carried out using commercial models deterministically (i.e. with defined arbitrary metocean conditions, usually "worst case") or stochastically (i.e. using statistical distributions for wind and current regimes). To support environmental assessments of individual drilling or development projects, modelling is usually carried out for a major crude oil release, corresponding to a blowout, and for smaller diesel or fuel oil releases which are expected to be less persistent.

Oil spill risk assessment and contingency planning

Previous SEAs have reviewed and summarised risk assessment, including stochastic and deterministic modelling, carried out for Oil Spill Contingency Planning (OSCP) in Regional Seas 1/2 (SEA 2, 3, 5); Regional Sea 6 (SEA 6); and Regional Seas 8/9 (SEA 4, 7). "Time to beach", estimated using deterministic modelling, is an important factor in contingency planning, since it relates to the required response time and therefore the geographic availability of response resources.

For SEAs 2 and 3, deterministic calculations were carried out to estimate the time to beach from the most prospective areas within the area (central and southern North Sea), to either the closest landfalls or to adjacent significant coastal sensitivities. 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). The shortest distances to land from the prospective SEA 2/3 locations were around 20km, with a corresponding "Essential Elements" time to beach of ≈10h. The Mid North Sea High and Carboniferous Trend prospective areas in the central North Sea are considerably further offshore, with "Essential Elements" time to beach in excess of 100h, indicating that a diesel or low persistence spill would not beach. For all of the North Sea, 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, but are generally offshore (i.e. away from adjacent UK coastline) with the exception of the southern North Sea in summer, when E/SE winds are most frequently. Estimated "Essential Elements" time to beach at various points in Belgium, the Netherlands and Denmark range from 105 to 180 hours.

SEA 2 noted that the closest landfall to any part of the relevant area, Flamborough Head, holds a kittiwake colony of world stature on the Bempton Cliffs accompanied by internationally important populations of guillemots and razorbills, and is accordingly designated as a Special Protection Area. However, probable hydrocarbon reserves in the Regional Sea 2 are gas, and the risk of a significant spill from E&P sources of persistent oil is low. Foreseeable oil spills advected into this area could be managed using chemical dispersion, subject to the agreement of conservation and fisheries agencies. In Regional Sea 1, the northern area of hydrocarbon prospectivity is within 72km of major seabird breeding colonies on the east coast of Shetland, including those on Unst, Fetlar, Whalsay and the Shetland mainland (beaching possible in 42 hours assuming a constant 30knot wind). 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.

Areas of relatively high prospectivity in Regional Sea 1 are close to the east Caithness shore and east of Orkney, and to a lesser extent north of the "Banff fault zone". These areas are most likely to attract exploration activity and potential production, and spill risks are consequently higher (although low in absolute terms). A persistent oil spill in these areas is likely to move to the northeast driven by the prevailing winds although it could potentially be transported westwards via the Pentland Firth, with consequent risks to north mainland and south Orkney shores. Prospectivity adjacent to the Shetland coast and mainland coastline south of the Moray Firth are lower, and spill risks associated with E&P are correspondingly reduced.

In order to indicate the likely fate and trajectory of oil spills within Regional Sea 6 (the Irish Sea), two representative cases were considered. Stochastic modelling of representative 22 tonne (100bbl) spills from a Liverpool Bay field indicates a relatively high (10-50%) probability of shoreline oiling associated with proximity of these installations to the coast (this modelling does not take account of evaporation and weathering and therefore overestimates beaching probability, BHP Billiton 2001). In view of the very short distances (for example, the Lennox field is about 8km from the coast), deterministic times to beach are very short (worst case <4h). Deterministic trajectory modelling was undertaken for the Dragon appraisal well in the centre of the St George's Channel (block 103/1) using a scenario involving instantaneous loss of the maximum fuel inventory for the proposed rig, indicated, as expected in view of the location's proximity to land (34-39km), relatively short times to beach (12-15h). The modelled proportions of total oil beaching were low, mainly due to the low persistence of diesel. Results of stochastic modelling for the Dragon location indicated a low probability (1-5%) of beaching as a result of the 1177 tonnes instantaneous diesel spill, and negligible probability (<1%) as a result of either a 64 tonne instantaneous kerosene spill (base fluid spill scenario) or 3m^3 instantaneous diesel spill (bunkering spill scenario). In all cases, stochastic probability contours were elliptical, indicating a higher probability of surface oiling to the north-east (associated with prevailing wind and residual current directions) with a higher probability of oiling in the central St George's Channel (i.e. the vicinity of the Celtic Sea Front) than in coastal waters of Pembroke, Cardigan Bay or Carnsore Point. For the smaller spill scenarios, which represent a higher frequency of occurrence, there was therefore considered to be a very small probability (<1%) of surface oil affecting the immediate vicinities of major seabird and seal breeding colonies of the Irish and Welsh coasts. For the larger spill scenario, which has an extremely low probability of occurrence, there is a low probability (1-5%) of local effects at breeding colonies.

A review of trajectory modelling carried out in twelve representative Environmental Statements for exploration wells and developments west and north of Shetland (Regional Seas 8 & 9) was carried out as part of the SEA 4 process. Deterministic estimates of time to beach were reasonably consistent and indicated, unsurprisingly, that time to beach to Orkney, Shetland and the Faroes are broadly comparable with a minimum of 40-50h. Relatively little stochastic modelling has been carried out for west of Shetland locations, with available results indicating probabilities of surface oiling resulting from uncontrolled crude oil blowout scenarios, of 30% along the north-east Shetland coast, but <10% south of St Magnus Bay and <5% for Orkney, the Faroes and mainland Scotland. Diesel spills had an insignificant (<1%) probability of surface oiling of coastlines. The predicted distribution of spill trajectories was dominated by prevailing south-westerly winds, with limited tidal influence.

Deterministic modelling for two locations within the SEA 7 area (west of Lewis), under conditions of sustained 30 knot wind, indicated minimum times to beaching of 34-85h, depending on direction. Minimum times are in the direction of Sula Sgeir. Stochastic modelling indicated a low probability of spill movement to the south.

Ecological effects

The most vulnerable components of the ecosystem to oil spills in offshore and coastal environments are seabirds and marine mammals, due to their close association with the sea surface. These sensitivities are discussed below. Benthic habitats and species may also be sensitive to deposition of oil associated with sedimentation, with mortality of intertidal organisms occurring as a result of direct oiling; while subtidal communities may be affected by dissolved hydrocarbons (e.g. SEEEC 1998). Disruption of intertidal communities over a range of timescales has been observed following many major oil spills; typically with disturbance of the balance between algal populations, grazing species and predators on rocky shores. Effects on sediment communities are typically associated with deoxygenation and organic enrichment. In both cases, the effects of chemical dispersants and attempted physical clean-up may be more severe than those of oil.

Direct mortality of seabirds in the event of oil spill is undoubtedly the most widely perceived risk associated with the proposed licensing and subsequent activities. Spills affecting waters near major colonies during the breeding season could be catastrophic (Tasker 1997). Seabirds are affected by oil pollution in several ways, including oiling of plumage and loss of insulating properties, and ingestion of oil during preening causing liver and kidney damage (Furness & Monaghan 1987). Offshore seabird vulnerability to surface pollution in individual

Regional Seas is summarised in Appendix A3a.6. Vulnerability is seasonal, with a general trend high vulnerability in coastal areas adjacent to colonies during the breeding season. In winter, vulnerability in inshore waters can also be very high in some areas.

Fortunately, there is little experience of major oil spills in the vicinity of seabird colonies in the UK. Census of seabird colonies in south-west Wales following the *Sea Empress* spill concluded that only guillemot and razorbill populations were impacted by the spill (Baines & Earl 1998). The *Sea Empress* spill occurred in February, when seabird numbers at colonies were relatively low, but the density of wintering birds including common scoter was high. Some species, particularly puffins, Manx shearwaters and storm petrels, had not returned to the area to breed and so avoided significant impact. Around 7,000 oiled birds were washed ashore following the spill, although it is likely that the total number of birds killed was several times higher than this (SEEEC 1998). Examination of seabird corpses suggested that most died directly from oil contamination rather than, for example, food chain effects. Over 90% of the oiled birds were of three species – common scoter, guillemot and razorbill. Counts of the breeding populations confirmed the impact on guillemots and razorbills. There were 13% fewer guillemots and 7% fewer razorbills counted at breeding colonies in the area in 1996 compared with 1995, while numbers for both species increased at nearby colonies. The SEEEC (1998) report concluded that by the 1997 breeding season, numbers had recovered significantly.

Oil spill risks to marine mammals have been reviewed by Hammond *et al*. (2008). Direct mortality of seals as a result of contaminant exposure associated with major oil spills has been reported, e.g. following the Exxon Valdez oil spill in Alaska in 1989. Animals exposed to oil over a period of time 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 considered to be 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 and particularly the pupping season. 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.

Intertidal habitats and species are vulnerable to surface oil pollution, and to windblown oil in the case of onshore maritime habitats (e.g. machair). After seabirds and wildfowl, seals and otters are probably the most obvious potential casualties (and the most emotive in terms of press coverage), with vulnerability of intertidal habitats also high, particularly in the event of oiling of sheltered coastlines. The vulnerability of different shore types to oil pollution is largely dependent on substrate and wave exposure, and is reviewed below (after Gundlach & Hayes 1978):

- **Exposed rocky headlands** – wave reflection keeps most of the oil offshore
- **Eroding wave cut platforms** – wave swept. Most oil removed by natural processes within weeks

- **Fine grained sand beaches** – where oil penetrates into sediment, may persist over several months. Penetration can occur due to wave action and tidal movements
- **Coarse grained beaches** – oil may sink and/or be buried rapidly. Under moderate to high energy conditions, oil will be removed naturally from most of the beachface
- **Exposed compacted tidal flats** – oil will not adhere to, nor penetrate into compacted sediments
- **Mixed sand and gravel beaches; shingle beaches** – oil may penetrate rapidly and be buried resulting in persistence over years. Solid asphalt pavement may form under heavy oiling conditions
- **Sheltered rocky coasts** – reduced wave action. Oil may persist for years
- **Sheltered tidal flats** – low wave energy; and high productivity, biomass and possibly bioturbation. Oil may persist for years
- **Salt marshes** – highly productive and vulnerable. Oil may persist for years.

The ecological effects of chemical spills are clearly dependent on the physical properties and toxicity of the chemical involved. Since chemical selection and use on offshore facilities is tightly regulated and the majority of chemicals are in low risk categories, the potential risk is considered to be relatively low (e.g. in contrast to bulk shipping of hazardous chemicals).

Accidental subsea gas releases can result in seabed disturbance and crater formation, although such events are extremely rare. Wright (2006) reports a gas kick during drilling to deepen a depleted production well which resulted in well broach and uncontrolled gas flow for 10 hours; this lead to the formation of a seabed crater some 25m x 15m and 8m deep. Minor gas releases subsea would be expected to result in significant dissolution in the water column, with a proportion of gas released to atmosphere (dependent on various factors including water depth and gas flow rates). Major releases, and all releases direct to atmosphere, will contribute to local air quality effects and to global greenhouse gas concentrations. The relative contribution of all foreseeable releases is minor.

Socio-economic effects

All hydrocarbon spills have the potential to affect fish and shellfish populations by tainting caused by ingestion of hydrocarbon residues in the water column and on the sea bed. If large-scale releases of oil were to reach the sea bed, there is potential for smothering of habitats used by fish either as spawning, feeding or nursery grounds. In addition to direct toxicity of oil and dispersants, oil and certain chemicals have the potential to introduce taint (defined as the ability of a substance to impart a foreign flavour or odour to the flesh of fish and shellfish following prolonged and regular discharges of tainting substances). Possible effects on human consumers of seafood are also an issue of concern in relation to accidental spills and industrial discharges.

Government may issue exclusion orders preventing marketing of seafood from areas considered to be contaminated following a spill or other incident, resulting in economic impacts on local fisheries and associated processing. Historical experience (e.g. the *Braer* spill) indicates that irrespective of actual contamination levels, spills may result in significant loss of public confidence in seafood quality from the perceived affected area, and therefore in sales revenue. Either perceived or actual contamination of target species with hydrocarbons or other chemicals may therefore result in economic damage to the fishing industry (and associated industries).

Impact on the recreational, tourism and amenity appeal in the event of a major oil spill would be influenced both by the severity of oiling and by the extent, duration and tone of media reporting and resulting public perception of the severity of the event. For example, following the *Sea Empress* spill, the local economic impact on tourism was relatively minor (SEEEC 1998). Analysis of the impact on tourism throughout Pembrokeshire suggested a downturn of about £2 million in the commercial service sector in 1996 set against an estimated £160 million contributed by tourists to the economy in 1995. Nevertheless, despite satisfaction with the quality of the environment by those visiting the area, there was evidence from further questionnaires that for one in five who actually considered visiting Pembrokeshire in 1996, the *Sea Empress* spill was significant in leading to rejection.

Major gas releases and chemical spills both have some potential for significant effects in terms of short-term safety issues and longer-term socio-economic effects. As noted above, chemicals used in offshore E&P are generally in low risk categories, and the socio-economic effects are generally similar in nature, but of lower severity, to oil spill. Potential safety issues of gas releases include explosion and (for subsea releases) loss of buoyancy for vessels and floating installation, although recent studies (e.g. May & Monaghan 2003; Beegle-Krause & Lynch 2005) suggest that the latter may not be a significant concern.

Oil spill response preparedness

Spill prevention and mitigation measures are implemented for offshore exploration and production through the *Offshore Petroleum Production and Pipe-lines (Assessment of Environmental Effects) Regulations 1999* and the *Merchant Shipping (Oil Pollution Preparedness, Response and Co-operation) Regulations 1998*. The required measures include spill prevention and containment measures, risk assessment and contingency planning.

Offshore, primary responsibility for oil spill response lies with the relevant Operator, although the Secretary of State’s Representative (SOSREP) may intervene if necessary, under terms laid out by the *Offshore Installations (Emergency Pollution Control) Regulations 2002*. The Maritime and Coastguard Agency (MCA) is responsible for a National Contingency Plan in consultation with other relevant departments, agencies and stakeholders, the latest version of which was issued in August 2006 and is currently (December 2008) under further review. The MCA is the competent U.K. authority that responds to pollution from shipping and offshore installations, although offshore installations have a statutory responsibility for clean-up in their jurisdictions, up to and including a Tier 3 incident (a large spill requiring national assistance and resources). Local authorities (and in Northern Ireland, the Environment Agency) have accepted a non-statutory responsibility for shoreline clean-up.

As noted above, MCA maintains four Emergency Towing Vessels (ETVs) which remain on standby at sea. In addition, the MCA maintains a contractual arrangement for provision of aerial spraying and surveillance, with aircraft based at Coventry and Inverness. Within two days, aircraft can deliver sufficient dispersant to treat a 16,000 tonne spill within 50 miles of the coast anywhere around the UK (National Audit Office 2002). DECC is a partner in this arrangement and undertakes regular aerial surveillance of offshore installations. MCA holds 1,400 tonnes of dispersant stockpiled in 11 locations around the UK, in addition to counter-pollution equipment (booms, adsorbents etc) which can be mobilised within 2-12 hours depending on incident location.

Similar response capabilities, providing a tiered response capability, must be available to Operators prior to commencing drilling or production activities. These provisions are made under various long-term commercial contracts with specialist contractors, supplemented where necessary (e.g. for remote locations) with additional stockpiles. Site-specific Oil Spill Contingency Plans must also be submitted to DECC for approval prior to operations. Additional conditions can be imposed by DECC, through block-specific licence conditions (i.e. “Essential Elements”).

In general, the response policy in the UK for offshore spills is to allow natural dispersion processes to occur, except where chemical dispersion is clearly advantageous (usually to protect birds). This contrasts with a generally more interventionist approach in some other jurisdictions, for example in the US where *in-situ* burning of surface oil is considered as advantageous in some circumstances. The feasibility of containment and recovery in offshore locations is generally considered low in the UK, although various US studies have considered the feasibility of ship-based and sub-surface collection systems, specifically engineered to enable operations in the vicinity of a blowout, or to collect oil directly from a blowing wellhead. In general, these feasibility studies have not lead to full-scale deployment. In the UK, the MCA ETVs have very limited capability for surface oil recovery, and there is currently no capacity for large-scale containment and recovery in the offshore UKCS (or in adjacent national waters, including Norway and Ireland).

5.13.3 Conclusions & data gaps

The environmental risks of accidental spill events associated with proposed activities following a further oil & gas licensing round are qualitatively similar to those of previous and ongoing activities in the North Sea, Irish Sea and west of Shetland, and mitigation in the form of risk assessment and contingency arrangements is well established. Offshore wind farm developments are not considered to represent a significant source of accidental spills, where navigational safety risks have been fully considered.

E&P project specific risk is highly associated with reservoir fluid type (e.g. heavy oil compared with condensate or gas), distance from sensitive coastal habitats and locations, and prevailing winds and currents. The areas of enhanced risk are therefore west Shetland (Regional Sea 8) and to a lesser extent the northern North Sea (Regional Sea 1). Project specific risk of major incidents in Regional Seas 2, 3, 4 and 6 are moderated by prospective fluid type (condensate or gas).

Subsea drilling equipment has evolved over the years into reliable systems with multiple redundancy. The subsea drilling pressure control system comprises several inter-related components including the wellhead assembly, BOP stack, choke & kill line system and riser. There have been very few drilling incidents resulting in loss of well control, and historic improvements in spill prevention and mitigation have stabilised the volume of oil spilled from E&P operations on the UKCS at a relatively low level, primarily through identification of root causes of spills and improvements in operational control procedures.

The risk context to the activities resulting from proposed licensing and leasing includes other hydrocarbon discharges; and spills associated with shipping. In general, the UKCS area has few hydrocarbon discharges and a low incidence of accidental spills. However, in a national context, areas of high or very high risk of oil spills resulting from shipping casualties (MEHRAs) have been identified by MCA and, in part, mitigated by measures including the provision of Emergency Towing Vessels.

In some cases, there is strong seasonality in specific species' sensitivities – in particular in relation to bird populations and breeding/moulting seals. Existing regulatory controls emphasise the risk management and contingency planning aspects of environmental management, including the timing of operations; and additional controls at an SEA level are not considered to be necessary.

Oil spill response planning and capability, by the MCA, the oil industry and local authorities is generally consistent and as effective as practicable. It is clear that prevailing weather conditions will rarely facilitate offshore containment and recovery of surface oil (also that the emphasis should be on prevention rather than cure).

5.14 Consideration of potential for cumulative impacts

As noted above, the SEA Directive (footnote to Annex I) and the *Environmental Assessment of Plans and Programmes Regulations 2004* require *inter alia* that secondary, cumulative and synergistic effects should be considered. Stakeholder consultation has emphasised the importance of cumulative effects within the overall process. The approach adopted for assessment of cumulative effects within the DECC SEA process has developed over successive SEAs, reflecting experience, consultation responses and guidance from a range of sources within the UK, EU and internationally, including guidance to the SEA Directive e.g. ODPM (2005). A range of approaches, techniques and guidelines for assessing cumulative impacts of offshore wind farms were reviewed in April 2007 in a discussion paper for the Offshore Renewable Energy Environmental Forum (Hartley Anderson 2007); and there are a number of ongoing initiatives, both sectoral and generic, which are relevant.

Much of the published guidance and discussion of Cumulative Impact Assessment (CIA) relates to process (with extensive use of flow diagrams) – how and when to incorporate CIA into SEA, EIA and planning; the need for an integrated and precautionary approach; identification of the need for CIA screening, baseline and trend definition for valued resources; reporting and consultation. There is also wide recognition of the difficulties of CIA in terms of identifying pathways of change and contribution of actions to the environment, and a large literature speculating on causal mechanisms which could, potentially, result in cumulative effects. There is a corresponding deficit of empirical data which actually demonstrate and quantify cumulative effects (relevant to offshore energy); and in the absence of this, little practical experience or guidance on how to assess the significance of specific effect mechanisms on specific receptors, particularly at a strategic level. There are some case studies, although not directly applicable (for geographic reasons) to this SEA; for example in the US, the development of cumulative effects assessment received considerable attention through the Committee on the Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope (2003). The committee report gave an example of retrospective analysis of cumulative impacts of oil and gas activities on Alaska's North Slope (including social and cultural effects), and also made an assessment of likely future impacts.

Following the Round 2 OWF leasing, developers of potential sites in the Greater Wash commissioned an initial scoping assessment of potential cumulative (and in-combination) effects in this area (Wash Developers 2004). This was aimed at improving consistency and collaborative opportunities for data gathering; and identified potential cumulative effects under the receptor headings navigation and shipping, commercial fisheries, natural fishery resource, ornithology, cetaceans and marine mammals, landscape and visual character and socio-economic effects. A number of receptors/issues, including marine benthos, noise and vibration, marine archaeology, water and sediment quality and tourism and recreation were "scoped out", that is, excluded from further consideration in that context.

Other recent initiatives in the UK include the COWRIE project *Developing Guidance on Ornithological Cumulative Impact Assessment for Offshore Wind Farm Developers*, currently in draft. This guidance follows an earlier workshop (Norman *et al*. 2007) and is intended to recommend methodologies robust enough to meet statutory requirements and practicable for developers within the time frames and resources normally available for environmental impact assessment. In practical terms, the guidance describes generic approaches to CIA (in a marine ornithological context) and identifies some of the key parameters for use with analytical tools (e.g. avoidance rates for collision risk modelling, although these are not quantified). Of the key mechanisms of effect discussed, cumulative collision mortality, cumulative disturbance, cumulative barrier effects and indirect effects; the first is most amenable to quantitative assessment and preparation of a specific guidance note on collision risk calculations for offshore projects, incorporating acceptable avoidance rates is recommended. The extent to which disturbance and barrier effects (due to visual intrusion or physical disturbance) accumulate is likely to be non-linear, and an informative assessment of the cumulative impacts of disturbance (which may require detailed study of energy-budgets of birds within the area, and their variability over time) are likely to be costly and time-consuming, but the only way in which cumulative disturbance impacts can be quantified. The draft report recommends that such an assessment is made only if the cumulative impacts of disturbance are likely to be significant. Where disturbance impacts are minimal, subjective treatment of the issue is adequate.

At a UK-level, several workshops have been held where a variety of stakeholders have discussed the issues surrounding cumulative effects assessment. For example, the outcomes of a 2003 stakeholder workshop on the implementation of marine spatial planning and cumulative effects assessment are reported in Gilliland *et al*. (2004). This concluded that the fundamental components of cumulative effects assessment are spatial, and that there is a need for improved, more targeted guidance on cumulative effects assessment in the marine environment; and recommended that urgent practical steps should be taken to collate and make widely accessible marine data from a range of sources. The offshore SEA programme, and this SEA in particular (since it has a UKCS-wide focus), have contributed towards the latter requirement.

In general, the assessment approach used in this SEA has been cumulative in the sense that although individual (usually operational) sources of effect have been identified, the mechanism and significance of effect has been considered in a generic way (e.g. all sources of visual disturbance; pulse noise from seismic and pile-driving sources; physical disturbance of seabed habitats), and in the context of other anthropogenic activities (notably fishing). Much of the approach described is aimed at CIA of specific projects or development areas (for example, the definition of functional areas/reference population) and it is unclear how this could be extended to a strategic (UK) level.

5.14.1 Definitions

Secondary, cumulative and synergistic effects are not defined by the SEA Directive, and a range of definitions have been used. ODPM (2005) notes that the terms are, to some extent, not mutually exclusive and that often the term cumulative effects is taken to include secondary and synergistic effects. An additional term, incremental effects, has been used by previous DECC oil & gas SEAs to distinguish those effects resulting from activities which may be carried out under the proposed licensing; together with activities carried out under previous licensing. This definition is extended below to include activities (oil, gas, gas storage and OWF) which may be carried out under the proposed licensing and leasing.

Secondary effects comprise indirect effects which do not occur as a direct result of the proposed activities, but as a result of a more complex causal pathway (which may not be predictable).

Incremental effects have been considered within the SEA process as effects from licensing E&P activities (including gas storage), and leasing OWF development; which have the potential to act additively with those from other licensed/leased activity.

Cumulative effects are considered in a broader context, to be potential effects of E&P activities which act additively or in combination with those of other human activities (past, present and future); in an offshore SEA context notably fishing, shipping (including crude oil transport) and military activities, including exercises (principally in relation to noise).

Synergistic effects – synergy occurs where the joint effect of two or more processes is greater than the sum of individual effects – in this context, synergistic effects may result from physiological interactions (for example, through inhibition of immune response systems) or through the interaction of different physiological and ecological processes (for example through a combination of contaminant toxicity and habitat disturbance).

In contrast to OWF development, to some extent, all potential sources of effect (i.e. disturbance, emissions and discharges) resulting from oil and gas activity within an area with a long (40 year) history of exploration activity are cumulative, insofar as they are incremental to previously existing sources (although the net trend of overall source level may be a reduction, due to improved environmental management and/or declining production levels).

Therefore, effects are considered secondary, incremental, cumulative or synergistic only if:

- the physical or contamination "footprint" of a predicted project overlaps with that of adjacent activities; or
- the effects of multiple sources clearly act on a single receptor or resource (for example a fish stock or seabird population); or
- if transient effects are produced sequentially.

Although the sequential effect concept is considered by the SEA mainly in the context of acoustic or other physical disturbance, a different use of the term sequential effect has been developed primarily in the context of sequential visual impact (e.g. for onshore wind farms, from the point of view of a moving observer: SNH 2005).

The SEA Directive (Annex II) also requires, as a criterion for determining the likely significance of effects, consideration of environmental problems relevant to the plan or programme. On the assumption that environmental "problems" are a result of some anthropogenic effect, the potential interactions between potential activities following the proposed licensing/leasing and recognised environmental problems in the SEA area are considered in this section of the SEA document.

Those potentially significant effects considered to be cumulative are assessed below.

Underwater noise

Incremental effects on marine mammals resulting from the proposed licensing/leasing are considered likely. Consideration of activity levels concentrated in Regional Seas 1, 2 and 6; with additional oil and gas activity likely in Regional Seas 8/9 and OWF activity in Regional Seas 3 and 4; and propagation ranges for noise concluded that it is likely that multiple sources (including simultaneous surveys and pile-driving) will occur at the same time, and that both activities may extend throughout much of the year, and be audible to marine mammals over much of the coastal Regional Seas. However, it seems improbable (given the spatial ranges discussed above) that injurious or strong behavioural levels of effect will coincide and also improbable that significant effects, as regulated under the Habitat Regulations and Offshore Marine Regulations, will occur; with the possible exception of effects on coastal populations of bottlenose dolphins, which would be controlled through the Appropriate Assessment process.

The assessment concluded that in view of the probable increase in pulse noise generation associated with the proposed combination of oil and gas licensing and offshore wind leasing, and concerns over cumulative effects (as yet not clearly understood), operational criteria should be established to limit the cumulative pulse noise "dose" (resulting from seismic survey and offshore pile-driving) to which key areas of marine mammal sensitivity are subjected.

Cumulative acoustic effects on other receptors are not considered to be probable.

Cumulative acoustic effects are more likely to result from continuous operational noise, than from pulse noise, although it is possible that seismic, pile-driving and military sonar noise may be qualitatively comparable and under exceptional circumstances may interact.

Synergistic effects – such as the potential for energetic costs of behavioural displacement, added to reduced foraging efficiency due to (e.g.) competition for prey stocks with commercial fishing – can be speculated but without evidential basis. Similarly, indirect effects of underwater noise – which would primarily be through prey species interactions, or displacement of competing species or individuals – have not been demonstrated or even suggested by field data.

Incremental Simultaneous and sequential seismic surveys and pile-driving

Cumulative Seismic survey and pile-driving noise and broadband impulse noise, for example military sonars, and continuous mobile sources e.g. shipping

Synergistic None known

Secondary None known

Physical damage to features and biotopes

Potential sources of physical disturbance to the seabed, and damage to biotopes, associated with oil and gas activities were identified as anchoring of semi-submersible rigs, wellhead placement and recovery, production platform jacket installation and piling, subsea template and manifold installation and piling, pipeline, flowline and umbilical installation and trenching and decommissioning of infrastructure. Given the forecast scale of exploration and production, it is likely that there would be considerable spatial separation between disturbance "footprints" and a low probability of incremental overlap of affected areas. 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 (e.g. anchoring), less than five years. Incremental effects are therefore not considered significant.

Existing control and mitigation measures are provided through the *Offshore Petroleum Production and Pipe-lines (Assessment of Environmental Effects) Regulations, 1999* or (in the vicinity of an SAC) from *The Offshore Petroleum Activities (Conservation of Habitats) Regulations, 2001*. The required consenting procedure for specific projects ensures that biotopes of particular conservation or ecological value are identified and afforded appropriate protection.

Scour is a significant issue in relation to wind farm foundations, with potential demonstrated at some sites (e.g. Scroby Sands) for incremental overlap of the spatial footprint of adjacent foundations. Scour can be largely mitigated (at cost and with associated ecological effects) using various forms of physical protection. Benthic monitoring at constructed Round 1 OWF sites in the UK indicates that in general, community disturbance outside the immediate area around piles has been minimal, and difficult to distinguish from natural variability and the beneficial effects of exclusion of fishing activity.

Effects of seabed disturbance resulting from proposed activities will be cumulative to those of other activities, notably demersal fishing. In a UKCS context, the contribution of all other sources of disturbance are minor in comparison to the direct physical effects of fishing, and it can be argued that the positive effect of fisheries exclusion offsets any negative effects of exploration and production and OWF development. On balance, however, the spatial extents of both positive and negative effects are probably negligible for most seabed habitats.

Incremental Physical footprint incremental to existing offshore activity – minor increment from oil and gas; higher from OWF

Cumulative Cumulative effects dominated by trawling. In these areas the disturbance effect of oil and gas and OWF development is likely to be offset by fishing exclusion.

Synergistic None known

Secondary None known

Physical presence

The spatial interactions of OWF developments with other users are considered in Section 5.8. The physical presence of offshore infrastructure (with associated safety exclusion zones) required for exploration and production in shallow waters can have significant direct effects on other users of the affected areas (notably the fishing industry). The predicted incremental effect of exploration and development following proposed licensing is not significant.

Physical presence of offshore infrastructure and support activities may also potentially cause behavioural responses in fish, birds and marine mammals. Previous SEAs have considered the majority of such interactions resulting from interactions with offshore oil and gas infrastructure (whether positive or negative) to be insignificant; in part because the number of surface facilities is relatively small (of the order of a few hundred) and because the majority are at a substantial distance offshore, in relatively deep water. This assessment is considered to remain valid for the potential consequences of a further round of oil and gas licensing, including for gas storage. However, the larger numbers of individual surface structures in OWF developments, the presence of rotating turbine blades and considerations of their location and spatial distribution (e.g. in relation to coastal breeding or wintering locations for waterbirds), indicate a higher potential for physical presence effects.

In addition to Round 1 & 2 wind leasing developments and the 25GW envisaged to result from Round 3, the Crown Estate has invited companies to apply for exclusive development rights for offshore wind generation in Scottish territorial waters. 23 site applications were received by October 2008 and the allocation of awards is due in January 2009. Though the scale of development and location of individual sites is not currently known, there is obviously the potential for these developments to generate cumulative effects with possible developments resulting from future offshore wind farm leasing (and other coastal and offshore activities). Similarly, potential OWF developments in the waters of adjacent Crown dependencies (such as the Isle of Man) or states would contribute to overall cumulative impacts.

Overall, the assessment concludes that the available evidence from existing OWF developments – principally the extensive monitoring studies conducted at Horns Rev and Nysted, and monitoring at UK OWFs – suggests that displacement, barrier effects and collisions are all unlikely to be significant to bird populations at a strategic or a local level. Some important uncertainties remain in relation to bird distribution (and temporal variability), the statistical power of monitoring methods and the sensitivity of this conclusion to modelling assumptions (notably avoidance frequency in modelling of collision risk; and several important factors in modelling of population dynamics). The COWRIE project (draft) Developing Guidance on Ornithological Cumulative Impact Assessment for Offshore Wind Farm Developers, noted above, makes various recommendations in relation to data acquisition and assessment of cumulative effects on birds, principally in relation to assessment at a local or regional scale.

Displacement and barrier effects on birds could, theoretically be cumulative with disturbance effects resulting from other activities, or even synergistic (most probably through nutritional or energetic mechanisms). Empirical data relevant to these concerns is currently lacking.

Incremental Small increment from oil and gas to existing exclusion zones and obstructions, visual intrusion and disturbance; potentially significant increment from Round 3 OWF. Displacement, barrier effects and collision risk to birds potentially significant at a local or regional level; considered unlikely to be significant to bird populations at a strategic level.

Cumulative Exclusion and snagging risks are cumulative to those resulting from natural obstructions, shipwrecks and other debris. Extent of cumulative effect associated with oil and gas licensing round is negligible. Potential cumulative displacement, barrier effects on birds.

Synergistic No conclusive data

Secondary No conclusive data

Marine discharges

Total produced water discharge from UKCS oil production was 240 million tonnes in 2005, with an average oil in water content of 20.47mg/kg (DECC website). In comparison with this, the potential discharge from new developments following the proposed round will be negligible since it is expected that the bulk of produced water will be reinjected rather than discharged. Through OSPAR, the UK is committed to a presumption against discharge from new developments.

Environmental effects of produced water discharges are limited primarily by dispersion, to below No Observed Effect Concentrations (NOECs). Synergistic interactions are possible between individual components, particularly PAHs, specific process chemicals (especially those which are surface-active, including demulsifiers), and other organic components. However, given the anticipation that the bulk of produced water from new field developments will be reinjected rather than discharged, and that such discharges as are made will be treated to required quality standards, the scope for incremental, cumulative or synergistic effects is remote.

Previous discharges of WBM cuttings in the UKCS have been shown to disperse rapidly and to have minimal ecological effects. Dispersion of further discharges of mud and cuttings could lead to localised accumulation in areas where reduced current allows the particles to settle on the seabed. However, in view of the scale of the SEA area, the water depths and currents, and probability of reinjection drill cuttings from any major field development, this is considered unlikely to be detectable and to have negligible incremental or cumulative ecological effect.

OWF developments have essentially no planned discharges, although there is a potential incidental release of copper and carbon dust from abrasion of the slip-rings of the turbines; this is considered to have negligible environmental effect

Incremental Produced water – incremental contribution of produced water is dependent on the extent of reinjection but noting the presumption against new produced water discharges, the scale of discharge and effects will be negligible. WBM drilling discharges generally disperse widely and significant accumulations do not occur. It is therefore possible that discharge footprints will overlap, although the ecological effects will be undetectable. Potential “sinks” may occur in areas of sediment accumulation although this is considered unlikely to be detectable.

Cumulative Principal cumulative sources of major contaminants, including hydrocarbons and metals, are shipping (including wrecks) and atmospheric inputs. Cumulative sources of particulate contaminants include aeolian dust and sediment disturbance from trawling, although these are negligible in the context of natural suspended particulate loads.

Synergistic Synergistic effects of chemical contaminants in produced water and drilling discharges are conceivable, although substantive data is almost entirely lacking and it is considered unlikely that significant synergistic effects would result from chemicals used in exploration and production operations.

Secondary None known

Atmospheric emissions

Atmospheric emissions from offshore oil and gas exploration and production activities may contribute to reduction of local air quality. Greenhouse and acid gas emissions effectively contribute to a mixed regional or global “pool” and can therefore be considered cumulative.

The implications of the ultimate use of oil and gas production from UKCS for greenhouse gas emissions and on UK commitments under the Kyoto Protocol, were not considered here since these are subjects for different high level policies, fora and initiatives including UK energy policy, security of supply considerations, emissions trading etc.

Flaring from existing UKCS facilities has been substantially reduced relative to past levels, largely through continuing development of export infrastructure and markets, together with gas cycling and reinjection technologies. In addition, offshore oil industry emissions are subject to an Emissions Trading Scheme. New developments will generally flare in substantial quantities only for emergency pressure relief, with “zero routine flaring” now considered a realistic design target for new developments. Other than start-up flaring, subsea tie-back developments will generally have little effect on host installation flaring.

Incremental Incremental emissions resulting from internal combustion for power generation by installations, terminals, vessels and aircraft, flaring for pressure relief and gas disposal, and fugitive emissions during tanker loading.

Cumulative Greenhouse and acid gas emissions effectively contribute to a mixed regional or global "pool" and are therefore considered to be cumulative. On a global scale, cumulative contributions of emissions resulting from predicted activities and developments will be negligible in comparison to the influence of onshore sources.

Synergistic None known

Wastes to land

In view of the relatively small number of wells predicted, and recent establishment of a licensing mechanism to allow interfield cuttings reinjection, it is considered unlikely that major incremental or cumulative landfill requirement will result from proposed licensing/leasing.

Incremental Incremental return of general oilfield wastes insignificant; incremental return of drilling wastes also unlikely to represent a significant contribution to onshore waste disposal requirements.

Cumulative Not quantified

Synergistic None known

Secondary None known

Accidental events

Accidental events (with environmental consequences) that could potentially occur on offshore E&P facilities, and associated support vessels, include oil and chemical spills and gas releases. Offshore wind developments generally have a negligible inventory of oils and chemicals, and spill risks are accordingly mostly associated with construction and operational maintenance; or with navigational safety risks to other (not OWF-related) vessel traffic.

Although the consequences of a major oil spill could be severe, in both ecological and economic terms, the incremental risk associated with the predicted level of activity is moderate or low. In a study of accidental oil spills and maritime casualties carried out on behalf of the MCA to inform the placement of emergency towing vessels, Safetec (2000) ranked pollution risk[11] as high or very high to the north of Shetland, in the Fair Isle Channel, through the Pentland Firth, down much of the east coasts of Scotland England, through the Dover Strait and along much of the Channel coast, around Land's End, in the Approaches to Milford Haven, through the North Channel, around St Kilda and the Flannans, on the west coast of Lewis and around the Butt of Lewis. In relative terms, predicted activity following a further licence round would not have a significant influence on this assessment and the cumulative risk is therefore not significantly influenced by the proposed activities.

Regulatory mechanisms already in place require Operators to develop effective oil spill mitigation measures, covering organisational aspects and the provision of physical and human resources which will minimise incremental risks. Times to beach, under worst case trajectory modelling conditions, are relatively short in some areas and effective contingency

[11] The risk assessment methodology considered frequency, but not sensitivity or consequence

planning and local resources are therefore necessary to allow the deployment of response measures where appropriate.

In terms of cumulative risk, there is little doubt that due to scale and consequence, the major risk of significant oil spills is associated with tanker transport of crude oil and refined products. While some control and response measures have been implemented, for example following the Donaldson inquiry into the *Braer* incident, the residual risk remains relatively high (in comparison to other oil spill sources including E&P).

Other cumulative sources of anthropogenic hydrocarbon input to the UKCS (including those from outside the area) include rivers and land run-off, coastal sewage discharges, dredge spoil, operational shipping discharges and atmospheric deposition. Although cumulative hydrocarbon inputs are often summed for comparative purposes, it is important to note that the environmental effects and fate of individual oil types and sources may be very different. Simple comparison of cumulative inputs may therefore be misleading in terms of effects assessment. In size and frequency terms the majority of oil spills most likely to result from E&P operations will make an insignificant contribution to overall regional inputs.

As context, it may be noted that overall, although the acute effects of oil spills can be severe at a local scale, the cumulative effects of around a century of oil spills from shipping – and thirty years of oil and gas development – do not appear to have resulted in wide-scale or chronic ecological effects. It is therefore concluded that the limited incremental effects of predicted activity, assuming that effective risk management practices continue to be implemented, will be minimal.

Incremental Hydrocarbons from oil spills will be incremental to (minor) offshore exploration and operational discharges; however, it is considered very unlikely that oil spill footprints will overlap given the spill frequency associated with predicted activities.

Cumulative There are a range of cumulative sources of hydrocarbons to the area. Depending on magnitude, accidental spills represent a minor to major contribution to overall regional inputs of oil.

Synergistic None known

5.15 Potential for transboundary impacts

Assessment summary

The Offshore Energy SEA includes all UK waters, therefore transboundary effects are possible with all neighbouring states whose waters abut the UK. These are France, Belgium, the Netherlands, Germany, Denmark, Norway, the Faroes and the Republic of Ireland. Since activities from this draft plan/programme may occur in UK waters and including adjacent to the majority of median lines, the sources of potentially significant environmental effects with the additional potential for transboundary effects include:

- Underwater noise
- Marine discharges
- Atmospheric emissions
- Impact mortality on migrating birds and bats
- Accidental events – oil spills

All of the five aspects above may be able to be detected physically or chemically in the waters of neighbouring states.

The scale and consequences of environmental effects in adjacent state territories due to activities resulting from adoption of the draft plan/programme will be less than those in UK waters and are considered unlikely to be significant.

5.16 Alternatives

The plan/programme alternatives were described in Section 2.5 and include

1. Not to offer any areas for leasing/licensing
2. To proceed with a leasing and licensing programme
3. To restrict the areas offered for leasing and licensing temporally or spatially

Based on the preceding consideration of effects, the potential effects of the plan/programme alternatives in relation to the SEA topics is summarised below.

The assessment summary uses the key below:

(dark green)	Potential positive impact on topic
(light green)	Potential minor positive impact on topic
(blue)	Neutral impact on topic
(yellow)	Potential minor negative impact on topic
(orange)	Potential negative impact on topic

Alternative 1, not to lease or license areas for development since as a result there would allow no contribution to the UK wider energy and climate change policy objectives. Unconstrained development (Alternative 2) poses the risk of significant environmental effects on ecological and other receptors, including European conservation sites. The conclusion of the SEA is that Alternative 3 to the draft plan/programme is the preferred option, with the area offered restricted spatially.

Sources of potentially significant effect	Alt 1	Alt 2	Alt 3	Narrative
SEA Topic Biodiversity, habitats, flora and fauna				
Physical damage to biotopes from infrastructure construction, vessel/rig anchoring etc				"Footprint" effects associated with both OWF and oil & gas; negligible incremental effect from gas storage in developed reservoirs.
Potential behavioural and physiological effects on marine mammals, birds and fish associated with seismic surveys, construction noise				Geophysical surveys principally associated with oil & gas exploration and development; some seismic potentially required for gas storage. Potential effects associated with both OWF (pile-driving during construction) and oil & gas; source levels high therefore significant propagation; negligible incremental effect from gas storage in developed reservoirs
Potential behavioural and physiological effects on marine mammals, birds and fish associated with operational noise				Negligible operation noise from OWF; source levels from oil & gas production and gas storage (e.g. gas compression) relatively low therefore local effects only
Potential for non-native species introductions in ballast water discharges				Possibility of effects mitigated by adherence to recent ballast water guidance
Behavioural disturbance to fish, birds and marine mammals etc from physical presence of infrastructure and support activities				Potential effects associated with both OWF and oil & gas; negligible incremental effect from gas storage in developed reservoirs
Collision risks to birds and other species				Principally associated with OWF; mortality rate variable depending on location but unlikely to be significant at a strategic level with locational mitigation
Barriers to movement of birds (e.g. foraging, migration)				Principally associated with OWF; significance of effect variable depending on location but unlikely to be significant at a strategic level
Changes in food availability resulting from habitat change				Effects associated with both OWF and oil & gas; but considered insignificant at strategic level
Potential for effects on flora and fauna of produced water and drilling discharges				Associated principally with oil & gas exploration and development; produced water discharges unlikely for new developments; drilling discharges limited to WBM

Sources of potentially significant effect	Alt 1	Alt 2	Alt 3	Narrative
EMF effects on fish				Principally associated with OWF; current evidence does not indicate significant effects but unlikely to be significant at a strategic level
Major oil spill risks and associated damage to species, habitats and ecosystem function				Low risk of occurrence of major spills. Offshore wind farm and gas storage developments are not considered to represent a significant source of accidental spills, where navigational safety risks have been fully considered. Overall risk associated with oil exploration and development considered low.
SEA Topic Geology and sediments				
Physical effects of anchoring and infrastructure construction (including pipelines and cables) on seabed sediments and geomorphological features (including scour)				Potential effects associated with both OWF and oil & gas; negligible incremental effect from gas storage in developed reservoirs
Sediment modification and contamination by particulate discharges from drilling etc.				Associated principally with oil & gas exploration and development; limited drilling possible for gas storage in developed reservoirs and some OWF foundations
Effects of reinjection of produced water and cuttings				Associated principally with oil & gas exploration and development and gas storage
Onshore disposal of returned wastes – requirement for landfill				Associated principally with oil & gas exploration and development and gas storage; limited waste production from OWF developments/operation
Post-decommissioning (legacy) effects – cuttings piles and footings				Significant cuttings piles from new developments unlikely (since control of OBM discharges); footings from new oil & gas and OWF developments likely to be removed below seabed level
Risk of sediment contamination from oil spills				Low risk of occurrence of major spills. Offshore wind farm and gas storage developments are not considered to represent a significant source of accidental spills, where navigational safety risks have been fully considered. Overall risk associated with oil exploration and development considered low.
SEA Topic Landscape/seascape				
Potential visual impacts of development including seascape effects including change to character				Visual effects associated with all offshore surface installations; significance highly dependent on location

Sources of potentially significant effect	Alt 1	Alt 2	Alt 3	Narrative
SEA Topic Water environment				
Contamination by soluble and dispersed discharges				Associated principally with oil & gas exploration and development; produced water discharges unlikely for new developments; significant effects of soluble and dispersed components of WBM unlikely
Risk of contamination of the water column by dissolved and dispersed hydrocarbons from oil spills				Low risk of occurrence of major spills. Offshore wind farm and gas storage developments are not considered to represent a significant source of accidental spills, where navigational safety risks have been fully considered. Overall risk associated with oil exploration and development considered low.
SEA Topic Air quality				
Local air quality effects resulting from exhaust emissions, flaring and venting				Combustion emissions from power generation primarily from oil & gas production, and gas storage; vessel emissions from the various elements of the draft plan/programme
Air quality effects of a major gas release or volatile oil spill				Low risk of occurrence of major spills. Offshore wind farm and gas storage developments are not considered to represent a significant source of accidental spills, where navigational safety risks have been fully considered. Overall risk associated with oil exploration and development considered low.
SEA Topic Climatic factors				
Contributions to greenhouse gas emissions positive/negative				Incremental contribution of oil & gas and gas storage neutral (replacement of reserves) or negligible; OWF development would contribute to significant reduction in emissions
SEA Topic Population Human health				
Positive socio-economic effects of potential activities, in terms of security of supply, employment, expenditure and tax revenue (outline assessment)				Positive effects associated with all proposed activities; but large-scale OWF and other developments would have major benefit
Positive socio-economic effects of reducing climate change (outline assessment)				Associated with OWF; climate change effects are potentially major on global scale

Sources of potentially significant effect	Alt 1	Alt 2	Alt 3	Narrative
Potential for effects on human health associated with effects on: – local air quality resulting from atmospheric emissions – discharges of naturally occurring radioactive material in produced water – potential food chain effects of major oil spills				Negligible negative effects at strategic level Renewable energy contribution should result in positive impact
SEA Topic Other users of the sea, infrastructure, material assets & natural resources				
Interactions with fishing activities (exclusion, displacement, seismic, gear interactions, "sanctuary effects")				Potentially significant effects (at strategic level) from OWF developments due to spatial scale; location-specific
Other interactions with shipping, military, potential other marine renewables and other human uses of the offshore environment				Potentially significant effects (at strategic level) from OWF developments due to spatial scale; location-specific
Socio-economic consequences of oil spills				Associated principally with oil & gas exploration and development and gas storage; low risk of significant effect
SEA Topic Potential effects to known or postulated archaeological heritage				
Contribution to identification of archaeological heritage				Surveys associated with oil & gas and OWF have the potential to make positive contribution to identification and interpretation of archaeological remains
Physical damage to archaeological heritage from infrastructure construction, vessel/rig anchoring etc				Risk of damage associated with footprint of oil & gas and OWF mitigated through preparatory survey work

6 RECOMMENDATIONS AND MONITORING

6.1 Recommendations

The SEA considered the alternatives to the draft plan/programme and the potential environmental implications of the resultant activities in the context of the objectives of the draft plan/programme, the SEA objectives, the existing regulatory and other control mechanisms, the wider policy and environmental protection objectives, the current state of the environment and its likely evolution over time, and existing environmental problems. The conclusion of the SEA is that alternative 3 to the draft plan/programme is the preferred option, with the area offered restricted spatially through the exclusion of certain areas. It is concluded that there are no overriding environmental considerations to prevent the achievement of the offshore oil and gas, gas storage and wind elements of the plan/programme, albeit with a number of mitigation measures to prevent, reduce and offset significant adverse impacts on the environment and other users of the sea.

Substantial progress has been made in implementing the recommendations from previous UK Offshore Energy SEAs (see listing on SEA website) which, together with a wide range of other initiatives have served to improve understanding of receptors and effects (e.g. through Research Advisory Group on Marine Renewable Energy, COWRIE, Oil and Gas UK, Oil and Gas Producers, conservation agency Natura 2000 programmes etc).

The following recommendations are made from the current Offshore Energy SEA process, for amplification and detail see the assessments in Section 5. Many recommendations apply equally to the different elements of the draft plan/programme since there is remarkable commonality in the potential sources of effect from the industrial activities; where a recommendation is sector specific this is indicated.

1. In areas with high renewable energy generation potential DECC should ensure decisions on renewable energy leasing and licensing for oil & gas (including natural gas storage) are coordinated to minimise potential sterilisation of areas for other industries. This recommendation extends to maintaining options for potential future geological storage of captured carbon dioxide.

2. The draft plan/programme for an additional 25GW of offshore wind farm (OWF) generation capacity will require wind farm development on a massive scale. In advance of a formal marine spatial planning system being in place for the UK, the leasing and consenting of OWFs must ensure the minimisation of disruption, economic loss and safety risks to other users of the sea and the UK as a whole. In particular, there should be a presumption against OWF developments which:

    a. impinge on major commercial navigation routes, significantly increase collision risk or cause appreciably longer transit times
    b. occupy recognised important fishing grounds in coastal or offshore areas (where this would prevent or significantly impede previous activities)
    c. interfere with civilian aviation including radar systems
    d. could potentially jeopardise national security for example through interference with radar systems or significant reductions in training areas
    e. result in significant detriment to tourism, recreation and quality of life

3. Until there is a firmer base of information available to inform adaptive management, in respect of ecological receptors a precautionary approach to siting is recommended since the offshore wind industry is relatively young, with appreciable technological

development expected in for example, turbine size, rotation speed, spacing and potentially rotational axis. This precautionary approach dictates that unless suitable evidence indicates otherwise, avoidance (for the present) of areas known to be of key importance to waterbird and marine mammal populations, including breeding colonies, foraging areas and other areas essential to the survival of populations

4. Reflecting the relative sensitivity of multiple receptors in coastal waters, this report recommends that the bulk of this new generation capacity should be sited well away from the coast, generally outside 12 nautical miles (some 22km). The proposed coastal buffer zone is not intended as an exclusion zone, since there may be scope for further offshore wind development within this area, but as mitigation for the potential environmental effects of development which may result from this draft plan/programme. The environmental sensitivity of coastal areas is not uniform, and in certain cases new offshore wind farm projects may be acceptable closer to the coast. Conversely, a coastal buffer in excess of 12nm may be justified for some areas/developments. Detailed site-specific information gathering and stakeholder consultation is required before the acceptability of specific major Round 3 or subsequent wind farm projects close to the coast can be assessed. Marine spatial planning proposals are under consideration in Parliament, which would give coastal regulators and communities further opportunities to have a say in the way the marine environment is managed, in addition to the existing routes for consultation as part of the development consent process.

5. To minimise habitat change and to ensure areas developed as a result of the current draft plan/programme are left fit for previous or other uses after decommissioning, the volumes of rock used in cable armouring, foundation scour protection and pipeline protection must be minimised and there should be active promotion of alternative protection methods through the consenting process.

6. For areas (zones and blocks) which contain good examples of habitats/species on the Habitats Directive Annexes, developers should be made aware that a precautionary approach will be taken and some areas with relevant interests may either not be leased/licensed until adequate information is available, or be subject to strict controls on potential activities in the field. Similarly, developers should note that DECC will continue to conduct Appropriate Assessments/screenings to consider the potential of proposed leasing/licensing and subsequent activities to affect site integrity.

7. The effects of noise on marine mammals particularly from piling and seismic survey remain an issue of debate. A range of mitigation measures are available and their adoption is normally required through consenting. However, there is a need for cross-industry coordination of what noisy activities are planned, where and when, to facilitate the assessment of cumulative effects and implementation of temporal/spatial mitigation actions. The approach would require a mechanism to facilitate the exchange of information, for example through a web-based forum hosted by DECC, JNCC or the future MMO.

8. Although there has recently been significant survey effort in coastal waters, the lack of modern data on waterbirds in offshore areas is noted. Developers need to be aware that access to adequate data on waterbird distribution and abundance is a prerequisite to effective environmental management of activities for example in timing of operations and oil spill contingency planning.

9. There remain a number of subject areas for which the information base is limited and will need to be enhanced to support future marine spatial planning as well as project specific consenting. These information gaps include aspects of the natural world and human uses, with regional context and long-term trend data notably lacking. These gaps include:
    - Seabed topography and texture. For some areas there is excellent data for example from multibeam mapping undertaken variously including by the MCA, BGS and the SEA programme, but the UK lacks a coordinated programme to marshal such data, to identify priority gaps and to find ways to fill them
    - Recent information on the distribution of fish eggs and larvae, and variability in space and time
    - Detail of bird migration patterns, and variability in space and time including flight heights in different weather conditions
    - An understanding of the marine areas routinely used by breeding birds for foraging, in particular those adjacent to SPAs
    - Ecology of most marine mammal species and in particular important areas for breeding, foraging and resting
    - Finer scale distribution of fishing effort, gears and catches for smaller vessels (<15m)
    - Precision on the offshore distribution of navigation (AIS data coverage typically only extends 80km from shore)
    - Effects on fishing activity in and immediately adjacent to constructed wind farms

10. In areas of cold water coral reefs and other vulnerable habitats and species, physically damaging activities such as rig anchoring and discharges of drilling wastes (from hydrocarbon or renewable energy related activities) should be subject to detailed assessment prior to activity consenting so that appropriate mitigation can be identified and agreed which may include no anchoring and zero discharge.

11. For the area to the west of the Hebrides (covered in SEA 7) it is recommended that blocks west of 14 degrees west should continue to be withheld from oil and gas licensing for the present. This recommendation also applies to the deepest parts of the Southwest Approaches. This is in view of the paucity of information on many potentially vulnerable components of the marine environment, and other considerations. Once further information becomes available, the possible licensing/leasing in these areas can be revisited.

12. Potential applicants for licences in the 26th and subsequent oil and gas licensing rounds should be reminded that the expectation for facilities design will be for zero discharge of oil in produced water.

13. The Department has a central role in UK energy and climate change response policies; in recognition of the national and international focus on climate change and curbing fossil fuel emissions, DECC should seek and give consideration at both the oil and gas licensing and project consenting stages to CO_2 emission reduction proposals e.g. capture and storage (rather than venting) of CO_2 from gas treatment offshore.

14. Efforts are (or will be) underway to identify offshore Marine Conservation Zones/Marine Protected Areas e.g. under the Marine Strategy Framework Directive, OSPAR and the *Marine and Coastal Access Bill*. Where the objectives of the conservation sites and renewable energy development are coincident, preference

should be given to locating wind farms in such areas to reduce the potential spatial conflict with other users.

15. Similarly, as part of the Natura 2000 initiative, further offshore SACs and extensions to SPAs are being identified. Such sites are not intended to be strict no-go areas for other activities and a number have been mooted in areas with significant potential for offshore wind farm development. Wind farm developers should be aware that SAC/SPA designation may necessitate, subject to the conclusions of any appropriate assessment, suitable mitigation measures so as to avoid adverse effects on a designated site or species.

16. Gas storage projects need an EIA under the requirements of the EIA Directive. However, it is unclear at present under which UK regulations EIA for such projects would be undertaken, and early resolution is desirable in light of the drivers for increased UK gas storage capacity.

17. The Offshore Vulnerability Index (OVI) to surface pollutants developed by the JNCC should be reviewed in the light of results from recent aerial and boat based bird survey data, and updated if necessary. Consideration should also be given to whether the development of UK-specific individual waterbird species sensitivity indices and mapping of a Wind Farm Sensitivity Index (WSI) in UK waters would be useful in support of site selection and consenting.

18. The existing initiatives to develop waterbird Population Viability Analysis for sensitive species should be progressed, including, if necessary, research to improve the accuracy of inputs to the models.

19. The potential for capacity extensions to existing Round 2 wind farm leases requires careful site specific evaluation since significant new information on sensitivities and uses of these areas is now available (see also recommendation 2 above). As a general rule it is recommended that any such site extensions are to the seaward rather than the landward side. Round 1 sites are closer to the coast and it is anticipated that the majority would not be extended; any application for this would also require detailed site specific evaluation.

20. Siting and consenting processes for offshore wind farms must remain flexible to allow for technological innovation, including in mitigation measures.

21. The information collected by offshore renewables and oil industry site surveys and studies is valuable in increasing the understanding of UK waters. The initiatives such as the UKDEAL, Cowrie and UKBenthos databases to ensure that such information is archived for potential future use should be continued and actively promoted during the consenting processes. Similarly, there should be encouragement for the analysis of this information to a credible standard and its wider dissemination.

22. It is recommended that in certain key areas of marine mammal sensitivity, operational criteria are established to limit the cumulative pulse noise "dose" (resulting from seismic survey and offshore pile-driving) to which these areas are subjected. This could be implemented within the existing regulatory framework for activity consenting, but will require a mechanism to facilitate the exchange of information, for example through a web-based forum hosted by DECC, JNCC or the MMO when established, with suitable links to all parts of the UK.

23. To assist developers and the achievement of conservation objectives, DECC and others in Government should encourage the adoption of consistent guidance across the UK on the implementation Habitats Directive requirements, for example disturbance of European Protected Species (Annex IV species).

6.2 Monitoring

The SEA Regulations require the Responsible Authority for the draft plan/programme to:

> *"….monitor the significant environmental effects of the implementation of each plan or programme with the purpose of identifying unforeseen adverse effects at an early stage and being able to undertake appropriate remedial action."*

In so doing, the Regulations allow for the responsible authority's monitoring arrangements to comprise or include arrangements established otherwise than for the express purpose of complying with the Regulations e.g. monitoring conducted for other regulatory purposes.

The types of relevant monitoring already undertaken or proposed for this SEA fall into four types:

- Emissions monitoring
- Effects monitoring
- SEA objectives monitoring

Each of these is summarised below.

Emissions monitoring

As required by the various environmental permits and other environmental legislative requirements (see Appendix 5), operators must monitor and report the quantities of solid, liquid and atmospheric emissions, discharges and wastes generated. For wind farms this is currently through the FEPA licensing regime with performance data made publicly available; for the oil industry via the Environmental Emissions Monitoring Scheme and all oil or chemical spills via Petroleum Operations Notice Number 1 (PON 1). As well as monitoring compliance with individual permit conditions the data provides a benchmark which allows performance trends to be monitored over time, and projected increases from a new DECC draft plan/programme to be placed into context. The DECC Offshore Environmental Inspectorate is responsible for ensuring that operators comply with environmental legislative requirements and all offshore hydrocarbon installations are inspected.

Effects monitoring

There has been extensive monitoring of the effects of UK offshore oil and gas activities dating back to 1975, and several regional surveys have been undertaken in recent years under the auspices of DECC/OGUK Monitoring Committee, FRS, CEFAS and the National Marine Monitoring Programme. Similarly, there are extensive monitoring programmes undertaken in connection with UK offshore wind farm development and operation, through FEPA and other permit conditions. There is also a large body of monitoring work on the effects of oil industry operations and a rapidly growing one for offshore wind farms, from other North Sea states and beyond. Studies include operational effects monitoring at field or regional scales, themed research projects and academic studies. This existing monitoring activity is reviewed as part of the DECC SEA process and to date has been found adequate to understand the evolution of baseline conditions in respect of sediment contamination and biological effects across the SEA areas.

SEA objectives monitoring

The draft Offshore Energy SEA objectives and indicators were considered during scoping and at the assessment workshop and the stakeholder meetings (see Appendix 2). The agreed objectives and indicators are given in Section 3.4. The SEA indicators will be monitored by the DECC and the SEA team to track SEA performance over time.

Where unforeseen adverse effects are identified the DECC will seek to establish the cause in consultation with the Consultation Bodies/Authorities and other stakeholders. Remedial action will be developed and agreed with relevant parties and implemented as appropriate.

Information on the overall status of the UK seas and trends over time are variously collated for national, European and international initiatives. For example it is anticipated that the UK Charting Progress 2 Report will be published in 2010 as required under the Marine Strategy Framework Directive, and OSPAR Contracting Parties are currently preparing the next Quality Status Report also for 2010. Data from the monitoring of the effects of the implementation of this draft plan/programme would be included in these reports and those prepared as required under the Marine Strategy Framework Directive. In respect of atmospheric emissions, the Committee on Climate Change was set up under the *Climate Change Act 2008* to support the strategic aims of DECC and the devolved administrations and to independently assess how the UK can optimally achieve its emissions reductions goals for 2020 and 2050. The Committee will advise Government on the level of carbon budgets and will submit annual reports to Parliament on the UK's progress towards targets and budgets to which the Government must respond.

7 NEXT STEPS

The Offshore Energy SEA Environmental Report and supporting documents are available for review and public comment for a period of 12 weeks from the date of publication in January 2009. The documents are being made available from the SEA website (www.offshore-sea.org.uk) or on CD or printed copy. Comments[12] and feedback should be marked "Offshore Energy SEA Consultation" and may be made via the website or by letter or e-mail addressed to:

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The Department of Energy and Climate Change
4th Floor Atholl House
86-88 Guild Street
Aberdeen AB11 6AR
Fax: 01224 254019
E-mail: sea.2009@berr.gsi.gov.uk

On completion of the public consultation phase a Post Consultation Report will be prepared and placed on the offshore SEA website collating the comments, DECC responses to them and any technical clarifications required.

The Department will consider comments received from the public consultation in their decision making regarding the draft plan/programme.

On adoption of the plan/programme a Statement will be published detailing:

a) how environmental considerations have been integrated into the plan/programme
b) how the Environmental Report has been taken into account
c) how opinions expressed by the consultation bodies and public consultees on the relevant documents have been taken into account
d) how the results of any consultations entered into with other Member States have been taken into account (if required)
e) the reasons for choosing the plan/programme as adopted, in the light of the other reasonable alternatives dealt with; and
f) the measures that are to be taken to monitor for potential significant environmental effects of the implementation of the plan/programme.

[12] **Confidentiality:** Your comments may be made public by DECC in relation to this consultation exercise. If you do not want your name or all or part of your response made public, please state this clearly in the response. Any confidentiality disclaimer that may be generated by your organisation's IT system or included as a general statement in your fax cover sheet will be taken to apply only to information in your response for which confidentiality has been requested. However, please also note that DECC may disclose information it holds pursuant to a statutory, legal or parliamentary obligation, including without limitation, requirements for disclosure under the Freedom of Information Act 2000 and/or the Environmental Information Regulations 2004. In considering any request for disclosure of such information under the Freedom of Information Act 2000 or the Environmental Information Regulations 2004, DECC will consider and make use of relevant exemptions or exceptions where they properly apply and, where relevant, will consider whether the public interest in withholding the information outweighs the public interest in disclosing the information. It is DECC's normal practice to consult and consider the views of third parties where necessary although decisions on disclosure are ultimately taken by DECC. However, any decision by DECC against the release of information can be appealed to the Information Commissioner and ultimately the Information Tribunal. We will handle any personal data you provide appropriately in accordance with the Data Protection Act 1998 and the Freedom of Information Act 2000.

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GLOSSARY AND ABBREVIATIONS

Term	**Definition**
µg	Microgram(s)
µPa	Micropascal(s) (unit of pressure)
AA	Appropriate Assessment
Abiotic	Refers to nonliving objects, substances or processes e.g. climate
Abyssal	Relating to the great depths of the ocean, typically in water depths of 2000-6000m
Accretion	An increase resulting from depositional processes
Actinaria	Sea anemones
Aeolian	Wind-borne source
AFEN	Atlantic Frontier Environmental Network
AGLV	Areas of Great Landscape Value
Amnesic Shellfish Poisoning	An illness caused by consumption of shellfish (principally bivalves such as clams, mussels, oysters, snails and scallops) contaminated by poisonous concentrations of toxins produced by dinoflagellate algae. See also Paralytic Shellfish Poisoning and Diarrhetic Shellfish Poisoning
Amphipods	Small crustaceans e.g. “sandhoppers”
Anadromous	Migrating from marine environments to freshwater rivers to breed
Anemone	Flower-like marine Cnidarians with a flexible cylindrical body and tentacles surrounding a central mouth
Annex I	Under the Habitats Directive, a list of habitats considered to be most in need of conservation at a European level
Annex II	Under the Habitats Directive, a list of species considered to be most in need of conservation at a European level (excluding birds)
Annex IV	Under the Habitats Directive, a list of ‘animal and plant species of Community interest in need of strict protection’, of which the deliberate capture, killing or disturbance of such species is banned, as is their keeping, sale or exchange
Anthropogenic	Relating to/caused by humans
AOB	Apparently Occupied Burrows (birds)
AON	Apparently Occupied Nests (birds)
AONB	Area of Outstanding Natural Beauty
AOS	Apparently Occupied Sites (birds)
AoSP	Area of Special Protection
AOT	Apparently Occupied Territories (birds)
AQMA	Air Quality Management Areas
Aquaculture	The cultivation of aquatic plants and animals for food or other purposes
Archipelago	A group of many islands in a large body of water
ARU	Automated recording unit
Ascidians	Minute sedentary marine invertebrate having a saclike body with siphons through which water enters and leaves
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (United Nations). Now (as of 2008) the Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas
ASP	See Amnesic Shellfish Poisoning
ASSI	Area of Special Scientific Interest
Auks	Diving seabirds of the family Alcidae, characterised by a chunky body, short wings and webbed feet e.g. razorbills, guillemots, puffins
Autotrophic	An organism capable of synthesizing its own food from inorganic substances, using light or chemical energy e.g. green plants, algae, certain bacteria
Bacterioplankton	The bacterial component of plankton

Term	Definition
Ballast water/sediments	Water (and suspended sediments) put into a vessel to enhance stability
BAP	Biodiversity Action Plans
Barchan dunes	Type of sand dune found in areas of limited sediment supply with peak currents in excess of $0.4ms^{-1}$
BAT	Best available techniques
Bathymetry	The measurement of the depth of bodies of water
Beam trawling	A bottom trawl that is kept open laterally by a rigid beam
BECPELAG	ICES study “Biological Effects of Contaminants in Pelagic Ecosystems”
Bedform	Seabed features (e.g. sandwaves, ripples) resulting from the movement of sediment, from seabed erosion or deposition
Benthic	Relating to organisms living in or on the seabed
Benthos	Organisms living in or on the seabed
BEP	Best Environmental Practice
Bioaccumulation	The accumulation of a substance, such as a toxic chemical, in various tissues of a living organism
Biodiversity	The variety of life in all its forms, levels and combinations. Includes ecosystem diversity, species diversity, and genetic diversity
Biogenetic Reserve	An area of conservation which includes species for the purposes of genetic preservation
Biogenic	Produced by the action of living organisms
Biogeographic	Relating to the geographical area characterised by distinctive flora and fauna
Biomass	Living material; e.g. the total mass of a species or of all living organisms present in a habitat; usually excluding shell mass
Biosphere reserve	Non-statutory protected area representing significant examples of biomes protected for their conservation purposes (UNESCO)
Biota	The total flora and fauna of a given area
Biotopes	The smallest unit of habitat where all environmental conditions and all types of organisms found within it are the same throughout
Bioturbation	Physical disturbance of sediment or soil by organisms, especially by burrowing or boring
Birds Directive	Council Directive 79/409/EEC on the conservation of wild birds
Bivalves	Marine or freshwater molluscs having a soft body with plate-like gills enclosed within two shells hinged together
Block	See *Licence Block*
Bloom	Rapid increase in concentration of phytoplankton, often dominated by one species; may be seasonal (spring bloom); natural or anthropogenic
Blowout	An uncontrolled flow of fluids from rock into a well, sometimes catastrophically to the surface. May consist of salt water, oil, gas or a mixture of these
BODC	British Oceanographic Data Centre
boe/day	Barrels of oil equivalent per day
Boreal	Relating to the north, particularly forest areas of the northern North Temperate Zone
BP	BP is years before present (the present being standardised to 1950)
Brachiopods	Marine invertebrates of the phylum Brachiopoda with bivalve dorsal and ventral shells, similar in appearance to bivalve molluscs e.g. lamp shells
Brackish	Slightly salty
Bryozoans	Small aquatic animals of the phylum Bryozoa that reproduce by budding and form moss-like or branching colonies permanently attached to stones or seaweed
BTO	British Trust for Ornithology
By-catch	Species caught which are not the targeted species of the fishery; may be retained or discarded

Term	**Definition**
Byssus	A tough, thread-like structure by which mussels attach themselves to the substratum
Candidate Special Area of Conservation	Conservation site submitted to the EC for designation by national government, but not yet formally adopted
Carboniferous	a major division of the geologic timescale extending from approximately 360-300Ma
Carse	A low flat, peat or marsh covered plain, normally estuarine
CCW	Countryside Council for Wales
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
Cephalopods	Marine molluscs including squid, octopus and cuttlefish
Cetaceans	Aquatic mammals including whales, dolphins and porpoises
CFCs	Chlorofluorocarbons
Chemosynthetic	Synthesis of carbohydrate from carbon dioxide and water using energy obtained from the chemical oxidation of simple inorganic compounds
Chlorophyll	Photosynthetic pigment found in most plants, algae and cyanobacteria. Sea surface chlorophyll concentration is often used as an index of phytoplankton abundance/primary productivity
CITES	Convention on International Trade in Endangered Species
Clupeids	Fish of the family Clupeidae including herring, sprat and anchovy
CMA	Centre for Maritime Archaeology
CMS	Convention on the Conservation of Migratory Species of Wild Animals (also known as the Bonn Convention - 1979)
Cnidaria	A diverse phylum of relatively simple aquatic organisms containing specialised stinging cells e.g. jellyfish, anemones, corals
Coastal lagoon	Small, shallow basin which has very low (or negligible) freshwater input
Coccolithophorids	Exclusively marine phytoplankton characterised by calcium carbonate plates
Coelenterates	Invertebrate animals of the phylum Cnidaria including the jellyfishes, hydras, sea anemones, and corals
Community	A group of animals or plants living or growing together in the same area
Continuous Plankton Recorder	A plankton sampling instrument designed to be towed from merchant ships on their normal sailings, with plankton collected on a moving band of filter material (Continuous Plankton Recorder)
Contourite	A marine sediment deposited by fast flowing ocean-bottom currents along contours.
Copepods	Small crustaceans, usually planktonic
CPA	Coast Protection Act
CPR	See *Continuous Plankton Recorder*
Creels	Basket-like fish traps placed on the seabed, usually to target crustaceans
Cretaceous	A major divisions of the geologic timescale, extending from approximately 146-65.5Ma
Crinoid	Echinoderms of the class Crinoidea including feather stars and sea lilies
Crustaceans	Arthropods (mostly aquatic) usually having a segmented body and chitinous exoskeleton e.g. crabs, lobsters, copepods
cSAC	See *Candidate Special Area of Conservation*
Ctenophores	Any of various marine animals of the phylum Ctenophora, having transparent, gelatinous bodies bearing eight rows of comb-like cilia used for swimming
dB	Decibel(s)
Decalcified fixed dunes	Mature stages of sand dune succession
Decapods	Crustaceans characterised by ten legs, such as lobsters, crabs, shrimps and prawns
Defra	Department for Environment, Food and Rural Affairs

Term	**Definition**
Delphinids	Dolphins and porpoises
Demersal	Living at or near the bottom of the sea
DEPCON	Deposit Consent (included in Pipeline Works Authorisation)
Development well	Well drilled in order to produce hydrocarbons from a proven field
Diadromous	Migratory between fresh and salt waters (fish)
Diamicton	Thick unconsolidated muddy and gravelly unsorted sediments
Diarrhetic Shellfish Poisoning	An illness caused by consumption of shellfish (principally bivalves such as clams, mussels, oysters, snails and scallops) contaminated by poisonous concentrations of toxins produced by dinoflagellate algae. See also Paralytic Shellfish Poisoning and Amnesic Shellfish Poisoning
Diapir	An intrusion caused by buoyancy and pressure differentials, especially in non–igneous materials, examples being salt domes and mud diapers
Diatoms	Microscopic algae, with cell walls of silica consisting of two interlocking symmetrical valves
Dinoflagellates	Minute single-celled organisms, primarily marine plankton, with one or more whip-like organelles (flagella) generally used for locomotion. Approximately half are photosynthetic, and some species may produce toxins
Draft Special Area of Conservation	Conservation site which has been formally advised to UK government as suitable for selection as a SAC, but has not been formally approved by government as sites for public consultation.
Drifters	Oceanographic instruments released into the water column to obtain information on currents
Drill cuttings	Rock chips produced as a result of drilling
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
dSAC	See *Draft Special Area of Conservation*
DSFB	District Salmon Fishery Boards
DSP	See Diarrhetic Shellfish Poisoning
DTI	Department of Trade and Industry
Dune slacks	Low-lying areas within dune systems that are seasonally flooded and where nutrient levels are low
E&P	Exploration and Production
EAC	Ecotoxicological assessment criteria
EC	European Community
Echinoderms	Radially symmetrical marine invertebrates e.g. starfish, sea urchins
Echiurans	Non-segmented worms, usually burrowing
Ecosystem	An ecological community together with its environment, functioning as a unit
Eddy	A current of water or air, moving contrary to the direction of the main current, especially in a circular motion
EHS	Environment and Heritage Service (Northern Ireland)
EIA	See *Environmental Impact Assessment*
Elasmobranchs	Any of numerous fishes of the class Chondrichthyes, characterised by a cartilaginous skeleton and including the sharks, rays, and skates
EN	English Nature now Natural England
ENAW	Eastern North Atlantic Water
Endocrine disruption	Disruption of the hormonal systems of organisms
Environmental Impact Assessment	Systematic assessment of the environmental effects a proposed project may have on its surrounding environment

Term	Definition
Environmental Statement	Formal document presenting the findings of an EIA for a proposed project. Issued for public consultation in accordance with The Offshore Petroleum Production and Pipe-lines (Assessment of Environmental Effects) Regulations, 1999
Epifauna	Benthic organisms that live upon the surface of seabed sediments or soils
ES	See *Environmental Statement*
ESA	Environmentally Sensitive Area
ESAS	European Seabirds at Sea
ESCR	Earth Science Conservation Review
Espoo Convention	The Convention on Environmental Impact Assessment in a Transboundary Context (1991)
Estuarine	Of, relating to, or found in an estuary
Estuary	The wide part of a river where it nears the sea; normally where fresh and salt water mix
Eulittoral	The intertidal band, in-between the low and high water line
EUNIS	European Nature Information System; includes data on species, habitats and sites; see http://eunis.eea.europa.eu/introduction.jsp
Euphausiids	Commonly known as krill, they are shrimp-like, small marine crustaceans forming an important component of zooplankton
Eutrophic	Rich in dissolved nutrients, photosynthetically productive and often deficient in oxygen during warm weather
Evaporites	Natural salt or mineral deposit formed from by evaporation of water
Exploration well	Well drilled to determine whether hydrocarbons are present in a particular area
Fault	A fracture in the continuity of a rock formation caused by a shifting or dislodging of the earth's crust, in which adjacent surfaces are displaced relative to one another and parallel to the plane of fracture
FEPA	Food and Environment Protection Act
Fetch	The un-interrupted distance over which wind acts to produce waves
Fjard	Similar to a fjord but tend to be wider and narrower, often with larger numbers of low lying islands.
Fjord	A long, narrow, deep inlet of the sea between steep slopes
Fluvial	Produced by the action of a river or stream
Fog	When describing marine weather, visibility less than 1 mile
Formation	An assemblage of rocks or strata
Fronts	The interface between water masses of different characteristics, usually temperature and/or salinity
FRS	Fisheries Research Services
Fugitive emissions	Very small chronic escape of gas and liquids from equipment and pipework
Ga	Billion years ago
Gadoid	Fish of the cod family
Gastropods	Univalve molluscs, usually with a coiled or spiralled shell e.g. snails, periwinkles, whelks
GCR	Geological Conservation Review site
Geomorphology	The study of the underlying form, and weathering processes, of rocks and land surfaces
Gillnet	Nets that hang vertically in the water, either in a fixed position (e.g. surface or seabed) or drifting, that trap fish by their gill covers
Glacigenic	Relating to glacial activity
Gravity survey	A survey technique used to measure the gravitational pull of the Earth over an area, to determine the density of the underlying rocks, helping to locate rock formations that might contain trapped oil

Term	**Definition**
Grey dunes	Mature dunes, normally vegetated and inland
Grilse	A young Atlantic salmon on its first return from the sea to fresh or brackish waters
Gyre	A circulatory ocean current
Ha	Hectare(s)
HAB	Harmful algal bloom
Habitats Directive	Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora, see *Habitats and Species Directive*
Haline	Salty or regarding salt content
Heritage Coast	Sections of coast that are of exceptionally fine scenic quality, substantially undeveloped and containing features of special significance and interest
Heterotrophic	Unable to synthesize food and is dependent on complex organic substances for nutrition
Hexactinellid sponges	Sponges with a skeleton made of four- and/or six-pointed silaceous spicules, often referred to as glass sponges
HMSO	Her Majesty's Stationery Office
Holocene	Geological period since latest glaciation; from about 10,000 years ago to present
Holoplankton	Planktonic organisms that spend all developmental stages within the plankton.
Holothurians	Sea cucumbers
Hydrocarbon	Compounds containing only the elements carbon and hydrogen, (such as oil and natural gas)
Hydrodynamic	Of, relating to, or operated by the force of liquid in motion
Hydrography	In this context, the study of sea water masses, currents and tides
Hydroid	Any of numerous characteristically colonial hydrozoan coelenterates having a polyp rather than a medusoid form as the dominant stage of the life cycle
Hypoxia	Deficiency in the amount of oxygen
Hz	Hertz (unit of frequency)
IACMST	Inter-Agency Committee on Marine Science and Technology
IBA	Important Bird Area
Iceberg ploughmarks	Ridge/trough features on the seabed created by icebergs
ICES	International Council for the Exploration of the Sea
ICZM	Integrated Coastal Zone Management
Igneous	Rocks formed when molten rock cools and solidifies
IMO	International Maritime Organisation
Imposex	When male sex characteristics, such as the development of male sex organs i.e. penis and/or vas deferens, are stimulated to form on normal female gastropods
Infauna	Aquatic organisms (usually animals, but sometimes algae) living within sediments or soil
Interglacial	Geological interval of warmer global average temperature separating colder periods (glacials)
Internal waves	Within the sea, these are waves generated on the interface between two fluids of different densities
INTERREG	European Commission community initiative that aims to stimulate interregional co-operation in the EU.
Intertidal	The coastal zone between high water mark and low water mark
Invasive species	A species that is non-native to the ecosystem and whose introduction causes or is likely to cause economic or environmental harm or harm to human health
Invertebrate	Animals without backbones
IOPP	International Oil Pollution Prevention

Term	Definition
IPCC	International Panel on Climate Change
IPPC	Integrated Pollution Prevention and Control
Irish Sea Pilot	A pilot project set up in 2002 following the UK Government Review of Marine Nature Conservation to test the potential for an ecosystem approach to managing the marine environment at a regional sea scale
Isopod	Any of numerous crustaceans of the order Isopoda, characterised by a flattened body bearing seven pairs of legs and including the sow bugs and gribbles
IUCN	The World Conservation Union
JESS	Joint Energy Security of Supply Working Group
JMCs	Joint Maritime Courses
JNCC	Joint Nature Conservation Committee
Jurassic	A major unit of the geologic timescale, extending from approximately 200-146 Ma
Ka	Thousand years ago
Kelp	Any of often very large brown seaweeds of the order Laminariales
Km	Kilometre(s)
Lagoon	Stretch of salt water separated from the sea by for example, a low sandbank
Lamprey	Primitive elongated fishes characterised by a jawless sucking mouth with rasping teeth
LBAP	Local Biodiversity Action Plans
Lewisian gneiss	Metamorphic rocks which have been modified by heat and pressure several times. Up to approximately 3,000 million years old
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. A Block is approximately 200-250 square kilometres
Licensing round	An allocation of licences made to oil companies
Limpet	Gastropods, usually marine, with low conical shells
LIMPET	Worlds first commercial wave power station located on the shoreline of Islay
Littoral	The edge of the sea, but particularly the intertidal zone
LNG	Liquefied Natural Gas
LNR	Local Nature Reserve
Loliginid	Squids of the family Loliginidae, mostly neritic and ranging in size from approximately 3-100cm mantle length
Lough	A lake, or bay/inlet of the sea (Ireland)
Ma	Million years ago
Machair	A distinctive sand dune formation, comprising a fertile low-lying raised beach. Found only in western Ireland and the north and west of Scotland
Maerl beds	Calcified red seaweeds which grow as unattached nodules on the seabed, and can form extensive beds. Slow-growing, but over long periods its dead calcareous skeleton can accumulate into deep deposits
Marine Environment High Risk Area	Area of high environmental sensitivity at risk from shipping
Marine spatial planning	A means of bringing together separate sectoral policies with the aim of allocating and managing sea space to minimise conflicts between existing users and between users and the environment
MARPOL	The 1973/1978 International Convention for the prevention of pollution from ships
MASH	OSPAR working group on Marine Protected Areas and Species Habitats
MCA	Maritime and Coastguard Agency
MCA	Marine Consultation Area
MCS	Marine Conservation Society

Term	**Definition**
MDAC	Methane derived authigenic carbonate
Medusae	A type of jellyfish
Megafauna	Large animals
Megaplankton	Very large zooplankton between 20 and 200cm in size e.g. large jellyfish
Megaturbidite	A thick, extensive deposit from an exceptionally large mass flow
MEHRA	see *Marine Environment High Risk Area*
Meiofauna	Small benthic animals
Meroplankton	Plankton that spend only part of their life cycle in the water column before settling to the bottom
MESH	Mapping European Seabed Habitats
Mesolithic	The middle Stone Age, marked by the appearance of small stone tools and weapons and by changes in the nature of settlements
Mesoscale	Of intermediate scale
Mesozoic	The era of geologic time that includes the Triassic, Jurassic, and Cretaceous periods
Meteorology	The study of the processes and phenomena of the atmosphere, especially as a means of forecasting the weather
Metocean	Relating to meteorology and oceanography
Middens	A mound or deposit containing shells, animal bones, and other refuse that indicates the site of a human settlement
Miocene	epoch of geologic time extending from approximately 23.0-5.3Ma
MNCR	Marine Nature Conservation Review
MNR	Marine Nature Reserve
MOD	Ministry of Defence
Molluscs	Invertebrates (mainly marine) typically having a soft unsegmented body, a mantle, and a protective calcareous shell. They also include cephalopods e.g. squid, octopus, cuttlefish
Moraines	Rock debris transported by glaciers or ice sheets
Morphological	Concerned solely with shape
Moulting	The routine of shedding old feathers (birds) or hairs (mammals)
MPA	Marine Protected Area
MSPP	Marine Spatial Planning Pilot
Mudstones	Dark clay rock
MW	Megawatt
NAC	See *North Atlantic Current*
NAEI	National Atmospheric Emissions Inventory
Nanoplankton	Planktonic organisms 2-20μm in diameter
NAO	See *North Atlantic Oscillation Index*
NAS Scotland	Nautical Archaeological Society Scotland
National Monuments Record	The national repository for archaeological and historic data
Natura 2000 Network	A network of sites, Special Areas of Conservation and Special Protection Areas, of conservation value designated under the EU Habitats and Birds Directives respectively
NCR	Nature Conservation Review sites
NEAFC	North East Atlantic Fisheries Commission
Necropsy	Examination of a body to determine or confirm the cause of death
Nematode	Roundworms (free-living or parasitic in plants and animals)
Nemertea	Soft unsegmented marine worms

Term	**Definition**
Neolithic	A period in the development of human technology that is traditionally the last part of the Stone Age, characterised by the use of crops and domesticated animals
Nepheloid layers	Particle-rich layer above the ocean floor
Nephrops	Abbreviation of *Nephrops norvegicus*, commonly known as Norway lobster, Dublin Bay prawn or langoustine. A small orange-pink lobster found in the north-east Atlantic and Mediterranean Sea. The tail is frequently eaten, often under the name "scampi"
Neritic	Relating to the ocean waters between low tide and a depth of approximately 200m
NGO	Non-Government Organisation
NMMP	National Marine Monitoring Programme
NMR	See *National Monuments Record*
NNR	National Nature Reserve
Non-statutory	Having no basis in statute or in law
NORM	Naturally Occurring Radioactive Material
North Atlantic Current	A powerful warm ocean current that continues the Gulf Stream north west before splitting in two west of Ireland. One branch (the Canary Current) goes south while the other continues north along the coast of north western Europe
North Atlantic Oscillation Index	An index based on the pressure difference between the Azores high and the Icelandic low pressure areas
NPOA	National Plans for Action
NPPG	National Planning Policy Guidelines
NSA	National Scenic Area
Nursery	A subset of all habitats where juveniles of a species occur
Oceanography	The scientific study of the ocean and its phenomena
Octocoral	Corals with eight tentacles on each polyp. There are many different forms, which may be soft, leathery, or even those producing hard skeletons
Odontocetes	Toothed cetaceans
Oligotrophic	Lacking in plant nutrients and having a large amount of dissolved oxygen throughout
Ommastrephid squid	Short-finned squid
OPF	Organic-Phase Drilling Fluids
Ophiuroids	Brittle stars, Echinoderms of the class Ophiuroidea
OPRC	The International Convention on Oil Pollution Preparedness, Response and Cooperation (1990)
OSPAR	Oslo and Paris Commission – for the protection of the marine environment of the North East Atlantic (1992)
Otter trawling	A demersal trawl that is held open laterally by otter boards or 'doors'
OVI	Offshore Vulnerability Index
OWF	Offshore wind farm
PAH	Polycyclic aromatic hydrocarbon
Palaeogene	Geologic period extending from approximately 65-23Ma
Palaeolithic	The 'old' Stone Age (being the period of the emergence of primitive man) about 2.5 million to 3 million years ago until about 12,000 B.C.
Paralytic Shellfish Poisoning	An illness caused by consumption of shellfish (principally bivalves such as clams, mussels, oysters, snails and scallops) contaminated by poisonous concentrations of toxins produced by algae (diatoms and dinoflagellates). See also Amnesic Shellfish Poisoning and Diarrhetic Shellfish Poisoning
Parasitic cones	Small satellite cones of igneous rock around a volcano where lava has been forced through lines of weakness at the side of a volcano
PCB	Polychlorinated biphenyl

Term	Definition
PEC:PNEC	Predicted Effect Concentration: Predicted No-Effect Concentration
Pelagic	Relating to a distribution within (or above) the water column of the sea, generally away from the coast and seabed
Pennatulid	Sea pen: colonial marine cnidarians
Peri-glacial	Characteristic of a region adjoining a glacier or ice sheet
Permian	Geologic period extending from approximately 299-251Ma
Petrels	Tube-nosed, pelagic seabirds in the order Procellariiformes
Petrogenic	Derived from mineral hydrocarbons
PEXA	Practice and Exercise Area
Phalaropes	Any of several small wading birds of the family Phalaropodidae
Photic zone	The upper layers of bodies of water into which sunlight penetrates sufficiently to influence the growth of plants and animals
Physiographic	The study of the natural features of the earth's surface, especially in its current aspects, including land formation, climate, currents, and distribution of flora and fauna (also called physical geography)
Phytodetritus	Detritus originating from photosynthetic organisms, typically phytoplankton, in the upper layers of the water column which then falls towards the seabed. Also known as 'marine snow'
Phytoplankton	Free floating microscopic plants (algae); including diatoms and dinoflagellates
Picoplankton	Tiny plankton between 0.2 and 2µm in size, mostly bacteria
PILOT programme	PILOT is the successor to the Oil and Gas Industry Task Force (OGITF)
Pingo	Dome-shaped mound found in permafrost areas
Pinnipeds	Marine mammals including seals, sea lions and walruses
Plankton	Free-floating microscopic organisms
Pleistocene	Epoch on the geologic timescale from approximately 1.81-0.01Ma
Pliocene	Epoch on the geologic timescale from approximately 5.3-1.8Ma
PM_{10}	Particulate matter of less than 10 micrometres in diameter
$PM_{2.5}$	Particulate matter of less than 2.5 micrometres in diameter
PMSU	Prime Minister's Strategy Unit
Pockmarks	Depressions or craters in the seabed, typically in 0.5-20m in depth and 1-1000m in diameter in the North Sea, generally believed to be formed by the expulsion of fluid (gas or water) through seabed sediments
Polychaetes	Annelid worms, chiefly marine
Polychlorinated biphenyls	Persistent, toxic organic compounds once widely used in industry
PON	Petroleum Operations Notice
Possible Special Area of Conservation	Conservation site which has been formally advised to UK Government, but not yet submitted to the EC.
Progradation	General term for a coastline which is advancing into the sea
Protozoan	Single-celled organisms with a nucleus
pSAC	See *Possible Special Area of Conservation*
PSP	See *Paralytic Shellfish Poisoning*
Pteropods	Small marine gastropod molluscs of the subclass Opisthobranchia with wing-like lobes on the feet
Purse seines	A deep curtain of netting that is shot in a circle to form an enclosing cylinder around shoals of pelagic fish
Pycnocline	Water column layer separating mixed surface and bottom layers during thermal stratification
Quadrant	Subdivision of sea area for purposes of awarding licences for hydrocarbon exploration and exploitation. A whole quadrant contains thirty blocks, and is approximately 7,500km^2
Quaternary	Geologic time period extending from approximately 1.8Ma to the present

Term	**Definition**
Radionuclide	Natural or artificial radioactive isotope
RAF	Royal Air Force
Ramsar sites	Areas designated by the UK under the Ramsar Convention (Convention on Wetlands of International Importance especially as waterfowl habitat)
Raptors	Birds of prey, characterised by a hooked beak, sharp talons and good eyesight
RCAHMS	Royal Commission on the Ancient and Historical Monuments of Scotland.
Red Data Book	Documents the current status of globally threatened biodiversity
Richter local magnitude	A logarithmic scale which assigns a single number to quantify the size of an earthquake based on measurements of seismic waves
Riverine	Relating to or resembling a river
RLD	Regional Landscape Designation
RMNC	Review of Marine Nature Conservation
Roche moutonée	Small bare outcrop of rock shaped by glacial erosion
Ro-ro	Roll on-roll off
ROV	Remotely Operated Vehicle
ROW	Receiver of Wreck
RSPB	Royal Society for the Protection of Birds
RSPB	Royal Society for the Protection of Birds
SAC	See Special Area of Conservation
SAHFOS	Sir Alister Hardy Foundation for Ocean Science
Salicornia	Glassworts: salt-tolerant plants growing on beaches, saltmarshes or mangroves
Salmonids	Fishes of the family Salmonidae which includes salmon and trout
Salps	Any of various free-swimming tunicates
Saltmarsh	Low coastal grassland normally overflowed by the tide
Sarn	Relict glacial outwash features composed of ridges of boulder to pebble-size rocky material
SCANS	Small Cetacean Abundance in the North Sea
SCC	See *Scottish Coastal Current*
SCI	See *Site of Community Importance*
Scottish Coastal Current	A northward flowing current, derived from North Atlantic and Irish and Clyde Sea waters, running along the west coast of Scotland through the Minch and to the west of the Outer Hebrides
SCR	Seabird Colony Register
SEA	See *Strategic Environmental Assessment*
Sea urchin	Spiny, hard-shelled animal that lives on the rocky seafloor or burrows into soft sediments
Seamount	Permanently submerged mountains rising from the seafloor, typically formed from extinct volcanoes
SEC	See s*helf edge current*
SEERAD	Scottish Executive Environment and Rural Affairs Department
Seismic survey	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
SEPA	Scottish Environment Protection Agency
Sessile	Permanently attached or fixed; not free-moving
SFG	Scope For Growth

Term	Definition
Shelf break	Region of bathymetric change between the gently inclined continental shelf to the much steeper depth gradient of the continental slope
Shelf edge current	A poleward flowing current following the shelf edge to the north west of Ireland and west of Scotland
Shellfish	General term for commercially fished Molluscs and Crustaceans
Shingle	Beach material which is intermediate in size between sand and cobbles
Shorebirds	Any of various birds, such as the sandpiper and plover, that frequent the shores of coastal or inland waters
Shoreline Management Plan	A document that sets out a strategy for coastal defence for a specified length of coast, taking account of natural coastal processes and human and environmental influences and needs
Significant wave height	Average height (trough to crest) of the largest one third of waves for a given period of time
Silt	A sedimentary material consisting of very fine particles intermediate in size between sand and clay
SINTEF database	The SINTEF Offshore Blowout Database is a comprehensive event database for blowout risk assessment
Site of Community Importance	Conservation site that has been adopted by the EC but not yet formally designated by the government of a country
Skerries	Small rocky islands, usually too small for habituation, and may be submerged at high tide
Smolts	A young salmon at the stage intermediate between the parr and the grilse, when it becomes covered with silvery scales and first migrates from fresh water to the sea
SMRU	Sea Mammal Research Unit
SNH	Scottish Natural Heritage
SOMAP	Sound of Mull Archaeological Project
Sonar	A system using transmitted and reflected underwater sound waves to detect and locate submerged objects or measure the distance to the floor of a body of water
SOPEP	Shipboard Oil Pollution Emergency Plan
SOSREP	Secretary of State Representative
SOTEAG	Shetland Oil Terminal Environmental Advisory Group
SPA	See *Special Protection Area*
Spawning	The release of eggs of aquatic animals such as bivalve molluscs, fish and amphibians
Special Area of Conservation	Areas designated as European Sites (Natura 2000) under the Habitats and Species Directive
Special Protection Area	Areas designated as European Sites (Natura 2000) under the Birds Directive
Spicules	Calcareous or siliceous skeletal structures that occur in most sponges, providing structural support, as well as deterrence against predators
Sponges	Chiefly marine invertebrate animals of the phylum Porifera, characteristically having a porous skeleton and often forming irregularly shaped colonies attached to an underwater surface
SSSI	Site of Special Scientific interest
SST	Sea Surface Temperature
Stac	See Stack
Stack	A residual rock pinnacle which marks coastal cliff retreat and/or the landward advance of a rock platform
Statutory	Prescribed, authorised or punishable under a statute

Term	Definition
Storm surge	A positive or negative storm surge occurs respectively with a rise or fall of water against the shore, positive sometimes produced by strong winds blowing onshore, negative surge sometimes produced by strong winds blowing offshore. Currents produced can predominate over tidal streams and local wind-driven currents
Strand	General description of a wide intertidal area usually composed of sand
Strategic Environmental Assessment	An appraisal process through which environmental protection and sustainable development is considered in advance of 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
Sublittoral	Below intertidal, permanently submerged by seawater
Sweep	Addition of a batch of additive to a drilling fluid; typically of a viscous additive to clear the hole of cuttings
SWT	Scottish Wildlife Trust
TAC	Total allowable catch
Taxa	Taxonomic category or group
TBT	Tributyltin
Telemetry	The science and technology of automatic measurement and transmission of data by wire, radio, or other means from remote sources, to receiving stations for recording and analysis
Thermal stratification	Layering of the water column due to temperature gradients between different depths
Thermocline	Layer within the water column where temperature changes rapidly with depth
Tombolo	A sand or gravel bar connecting an island with another land mass
Topography	Surface features of an area
Trawling	Actively pulling a net through the water behind a vessel. Pelagic trawling does not make contact with the seabed; demersal trawling involves the use of a weighted line (footrope) which makes contact with the seabed
Triassic	Geologic period extending from approximately 251-200Ma
Trophic	Relating to the nutrition/feeding habits of organisms
Trophic level	The position occupied by an organism in a food chain or a food web
Tubificids	A type of annelid worm
Tunicates	Chordate marine animals with a cylindrical or globular body enclosed in a tough outer covering e.g. sea squirts
UK	United Kingdom
UKCS	United Kingdom Continental Shelf
UKOOA	United Kingdom Offshore Operators Association
UKOPP	United Kingdom Oil Pollution Prevention
UNESCO	United Nations Organisation for Education, Science, Culture and Communications
Vitellogenesis	Formation of the yolk of an egg
Waders	Any of many long-legged birds that wade in water in search of food (includes oystercatcher, whimbrel, snipe, avocets, stilts, plovers, sandpipers, godwits, curlews, snipe and phalarope)
Waterbirds	Group of birds which include divers and grebes, bitterns and herons, rails, crakes and coots, wildfowl and waders
Waterfowl	Collective term for all swimming waterbirds including grebes, coots and all wildfowl
WBM	Water Based Mud
WeBS	Wetland Bird Survey

Term	Definition
WFD	Water Framework Directive (Directive 2000/60/EC)
Whelk	Predatory marine gastropod mollusc of the family Buccinidae.
White dunes	Embryonic small dunes on the upper beach
WHO	World Health Organisation
WHS	World Heritage Site
Wildfowl	Collective term for all ducks, shelducks, geese and swans
WNAW	Western North Atlantic Water
Wrasse	Fishes of the family Labridae
Xenophyophores	Large, single celled organisms of up to 10cm diameter, usually epifaunal benthic deposit feeders
Zoanthid	A soft coral
Zooplankton	Free floating animals (often microscopic)

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