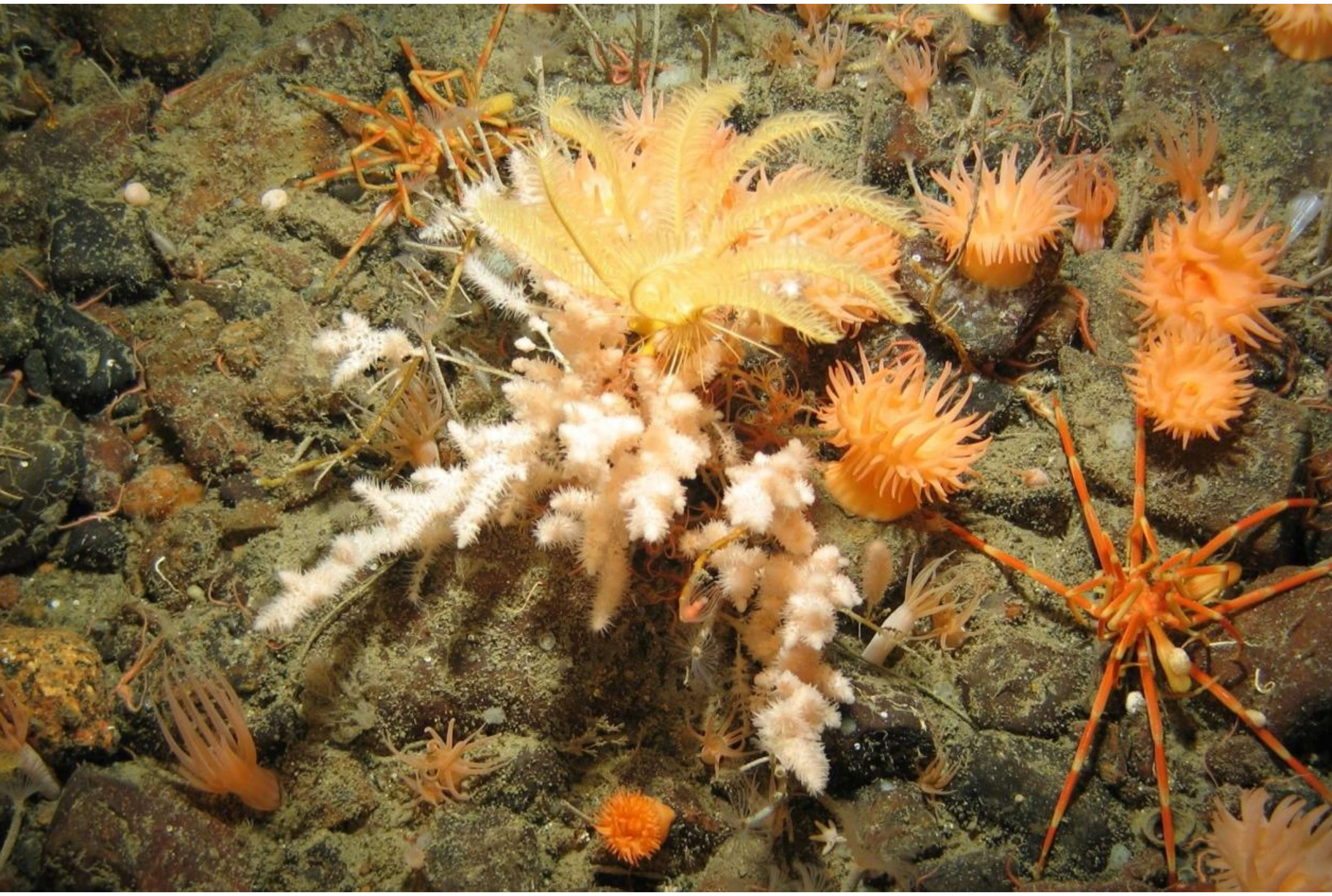
Department of Energy & Climate Change

UK Offshore Energy Strategic Environmental Assessment



OESEA3 Environmental Report

Future Leasing/Licensing for Offshore Renewable Energy, Offshore Oil & Gas, Hydrocarbon Gas and Carbon Dioxide Storage and Associated Infrastructure

March 2016

Any enquiries regarding this publication should be sent to us at oep@decc.gsi.gov.uk

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Non-Technical Summary

Introduction

This Environmental Report has been prepared as part of the United Kingdom Department of Energy and Climate Change (DECC) Offshore Energy Strategic Environmental Assessment (OESEA) programme and is hereafter referred to as OESEA3. The SEA process aims to help inform licensing and leasing decisions by considering the environmental implications of the proposed plan/programme and the potential activities which could result from their implementation.

Previous SEAs undertaken as part of this programme included the OESEA in January 2009 and OESEA2 in February 2011, which built on a series of previous regional scale SEAs undertaken by DECC and its forerunner departments since 1999. OESEA considered the environmental implications of a draft plan/programme to enable: further seaward rounds of oil and gas licensing, including gas storage in UK waters; and further rounds of offshore wind farm leasing in the UK Renewable Energy Zone (now Exclusive Economic Zone)[1] and the territorial waters of England and Wales to a depth of 60m. The OESEA2 Environmental Report considered the implications of a draft plan/programme for further licensing/leasing for offshore energy including oil and gas, gas storage including carbon capture and storage (CCS) and marine renewables (wind, wave and tidal technologies).

The indicative time horizon (i.e. period of currency) for OESEA2 was 5 years from publication. During this period, as with previous SEAs, DECC has maintained an active SEA research programme; identifying information gaps (some of which were outlined in the recommendations of previous SEA Environmental Reports), commissioning new research where appropriate, and promoting its wider dissemination through a series of research seminars. This has also involved continued engagement with the SEA Steering Group (includes membership from industry, Government, statutory advisors and environmental organisations including NGOs) and review of the information base for the SEA. OESEA3 is intended to:

- Consider the environmental implications of DECC’s draft plan/programme to enable further licensing/leasing for offshore energy (oil and gas, hydrocarbon gas storage, carbon dioxide storage and marine renewables including wind, wave, tidal stream and tidal range). This includes consideration of the implications of alternatives to the plan/programme and consideration of potential 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 OESEA3 Environmental Report, including its conclusions and recommendations.

[1] this part of the plan/programme did not include the territorial waters of Scotland and Northern Ireland.

What is the draft plan/programme?

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.

Enhanced levels of atmospheric greenhouse gases (principally carbon dioxide, CO_2) derived from manmade sources (e.g. from combustion of fossil fuels in heating and energy production) have been linked to global climate change, with associated wide ranging environmental changes having been projected, including: increased atmospheric temperatures, rising sea-levels, potentially more frequent extreme weather events and ocean acidification, with associated socio-economic and environmental effects. The evidence relating to global climate change has been summarised in the latest Intergovernmental Panel on Climate Change (IPCC) assessment report. The UK Government is committed to the reduction of greenhouse gas emissions by 80% on 1990 levels by 2050, with interim targets of 34% by 2020, 50% by 2025, and 57% by 2032[2] implemented in the *Climate Change Act 2008*. Most recently, the UK was involved in the Paris Agreement, which was adopted by parties to the United Nations Framework Convention on Climate Change in December 2015 and is due to come into force in 2016/2017. The agreement aims to hold the increase in global average temperatures well below 2˚C above pre-industrial levels, and to pursue efforts to limit this to 1.5˚C. Within this context, energy production is a major source of greenhouse gases, and the UK intends to decarbonise the energy sector in the coming years to contribute to meeting legally binding UK targets and internationally agreed goals towards reducing the potential effects of climate change.

During the process of decarbonisation, which by 2050 is likely to comprise an increasing proportion of energy from renewable sources (for which the UK also has a legally binding target to generate 15% of its energy from renewable sources by 2020), plus abated (i.e. incorporating Carbon Capture and Storage, CCS) coal, biomass or gas-fired power stations and nuclear energy. Gas and oil will also continue to play a valuable role variously for heating, transport and electricity generation. In addition to decarbonising the energy supply sector, wider measures include reducing demand through greater energy efficiency in homes, businesses and in transport. The UK Government is presently reviewing its energy policy and the contribution to decarbonisation that this will make, with gas-fired power stations, new nuclear and offshore wind being indicated as the preferred means to achieve this, with continued use of coal-fired power stations only being realised through emissions abatement via CCS.

As indicated above, reliance on fossil fuel sources will continue during decarbonisation. The UK is now a net importer of both oil and gas, and a linked factor in the UK's security of energy supply is the need for more gas storage capacity. Ensuring security of energy supply is a key to UK energy policy. The UK remains the largest producer of oil and gas in the EU, and successive oil and gas licensing rounds have attracted significant interest. Reductions in the recent production and exploration of the UKCS sector led to the Wood Review in 2013, which set out a number of recommendations that were accepted by the UK Government, including maximising economic recovery, and the creation of the Oil & Gas Authority (OGA), an executive agency of DECC which was formally established in April 2015. DECC has produced a draft strategy with the principal objective of maximising the economic recovery of UK Petroleum (Maximising Economic Recovery of UK Petroleum strategy, MER UK), which sets out a central objective that relevant persons must take all steps necessary to secure that the maximum value of economically recoverable petroleum is achieved.

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[2] This target for the fifth carbon budget, covering the period 2028-2032 has been recommended by the Committee on Climate Change, but is yet to be formally legislated upon.

The draft plan/programme to be covered by this SEA will help to contribute to the Government targets outlined above by enabling future rounds of renewable leasing for offshore wind, wave and tidal devices, and licensing/leasing for seaward oil and gas rounds and gas storage (including carbon dioxide storage). The main objectives of the 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 DECC draft plan/programme under consideration is broad ranging and covers the majority of energy related activities in the UK marine environment. The elements of the draft plan/programme are:

Renewable Energy:

1. Wave – future leasing in the relevant parts of the UK Exclusive Economic Zone and the territorial waters of England and Wales. The Scottish Renewable Energy Zone and Scottish and Northern Irish waters within the 12 nautical mile territorial sea limit are not included. In view of the relatively early stage of technological development, a target generation capacity is not set in the draft plan/programme.

2. Tidal stream – future leasing in the relevant parts of the UK Exclusive Economic Zone and the territorial and internal waters of England and Wales. The Scottish Renewable Energy Zone and Scottish and Northern Irish waters within the 12 nautical mile territorial sea limit are not included. In view of the relatively early stage of technological development, a target generation capacity is not set in the draft plan/programme. Similarly, a minimum average tidal current velocity threshold is not proposed.

3. Tidal range – future leasing in the internal and territorial waters of England and Wales. It is considered unlikely that there will be tidal range developments outside of territorial waters.

4. Offshore wind – to enable further offshore wind farm leasing in the relevant parts of the UK Exclusive Economic Zone and the territorial waters of England and Wales. The technologies covered will include turbines of up to 15MW capacity and tethered (i.e. floating) turbines in waters up to 200m. The Scottish Renewable Energy Zone and the territorial waters of Scotland and Northern Ireland are not included in this part of the plan/programme.

Oil & Gas:

5. Exploration and production – further Seaward Rounds of oil and gas licensing of the UK territorial sea and UK Continental Shelf (UKCS).

6. Hydrocarbon gas importation and storage – further licensing/leasing for unloading and underground storage of hydrocarbon gas in UK waters (territorial waters and the relevant parts of the UK Exclusive Economic Zone), including hydrocarbon gas storage in other geological formations/structures such as constructed salt caverns, and the offshore unloading of hydrocarbon gas.

Carbon Dioxide:

7. Carbon dioxide (CO_2) transportation and storage – further licensing/leasing for underground storage of carbon dioxide gas in UK waters (the UK Exclusive Economic Zone and relevant territorial waters, excluding the territorial waters of Scotland). OESEA3

would include CO_2 storage in geological formations/structures including depleted reservoirs (and for enhanced oil recovery), aquifers and constructed salt caverns.

OESEA3 is expected to have a 5 year period of currency. Several of the technologies covered in the draft plan/programme remain to be deployed at a commercial scale, and are likely to undergo rapid development and change during the currency of the SEA, in order to assist in achieving medium to long-term targets in relation to UK greenhouse gas emissions. The currency of OESEA3 will be periodically reviewed by DECC (as the competent authority) in the context of new information on technologies, effects, or plan/programme status.

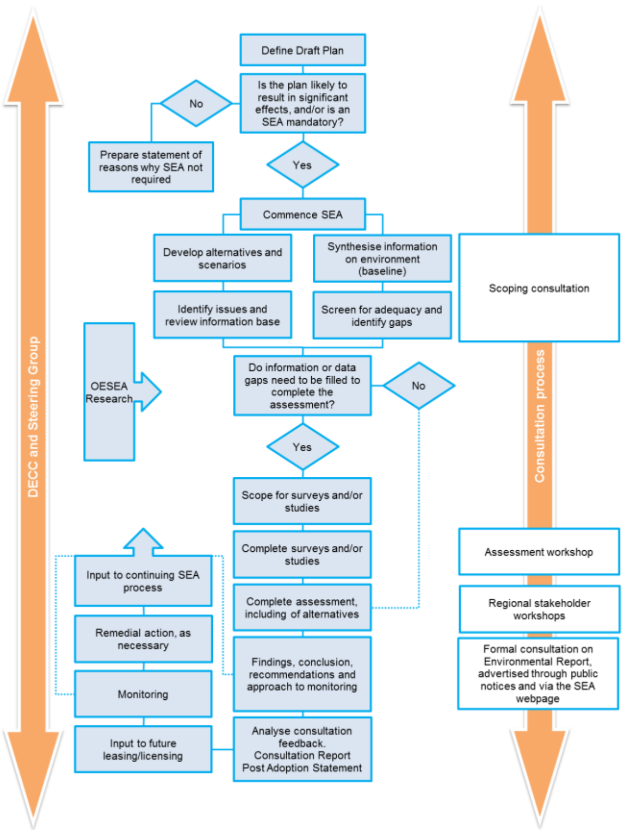
What are the alternatives to the draft plan/programme?

The following alternatives to the draft plan/programme for future offshore wind, wave and tidal leasing, oil and gas licensing and carbon dioxide 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

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.



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 to the left, but note that certain activities such as information gathering continue throughout the process.

Initial scoping for OESEA3 with the SEA Steering Group, environmental authorities and a range of academic and conservation organisations commenced early in 2015. A formal scoping exercise with the statutory Consultation Bodies/Authorities and other stakeholders was conducted from July 2015; a report of the scoping feedback is available on the SEA webpages of the gov.uk website.

Since 1999, the Department has conducted nine SEAs of the implications of further licensing of the UK Continental Shelf (UKCS) for oil and gas exploration and production (SEAs 1-7, OESEA (incorporating SEA 8) and OESEA2), an SEA for a second round (R2) of wind leasing – see the tabulation below and Map 1 overleaf:

SEA	Area	Sectors covered	Year	Licensing/leasing round
SEA 1	The deep water area along the UK and Faroese boundary	Oil & Gas	2001	19th Round
SEA 2	The central spine of the North Sea which contains the majority of existing UK oil and gas fields	Oil & Gas	2002	20th Round
SEA 2 extension	Outer Moray Firth	Oil & Gas	2002	20th Round
SEA 3	The remaining parts of the southern North Sea	Oil & Gas	2003	21st Round
R2	Three strategic regions off the coasts of England and Wales in relation to a second round of offshore wind leasing	Offshore wind	2003	Round 2
SEA 4	The offshore areas to the north and west of Shetland and Orkney	Oil & Gas	2004	22nd Round
SEA 5	Parts of the northern and central North Sea to the east of the Scottish mainland, Orkney and Shetland	Oil & Gas	2005	23rd Round
SEA 6	Parts of the Irish Sea	Oil & Gas	2006	24th Round
SEA 7	The offshore areas to the west of Scotland	Oil & Gas	2008	25th Round
OESEA	UK offshore waters and territorial waters of England and Wales	Oil & Gas, Offshore wind	2009	26th Round/ Round 3
OESEA2	UK offshore waters and territorial waters of England and Wales	Oil & Gas, Offshore wind, wave and tidal stream, gas and carbon dioxide storage	2011	27th Round 28th Round

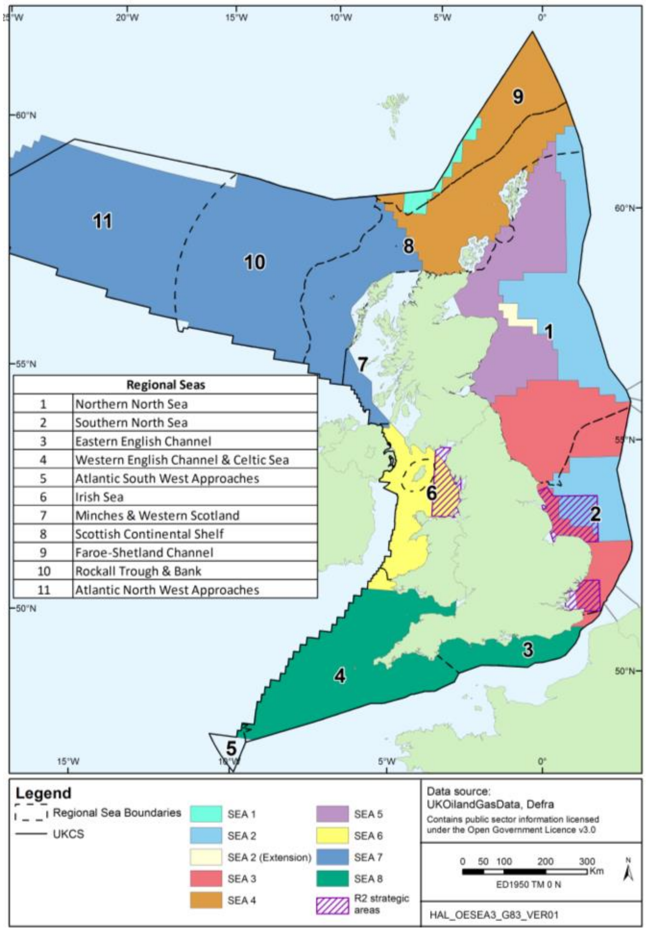
In addition, DECC SEA work was undertaken in 2010 for the potential exploitation of Severn Tidal Power (Severn Tidal Power Feasibility Study).

An Assessment Workshop involving the SEA Steering Group and SEA team was held in December 2015. 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 London, Bristol and Aberdeen in February 2016 at which stakeholders from a wide variety of organisations, sectors and areas participated. The stakeholder input on the information base and other issues of relevance to the SEA is summarised in Appendix 4 of the Environmental Report.

The Environmental Report and draft plan/programme are being issued for an 8 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 pages of the gov.uk website collating the comments and DECC responses to them.

Map 1: Past SEA areas (coloured) and Regional Seas (numbered)



Environmental Report

The Environmental Report of OESEA3 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, substrates and coastal geomorphology
- Landscape/seascape
- Water environment
- Air quality
- Climate and meteorology
- Population and human health
- Other users, material assets (infrastructure, other natural resources)
- Cultural heritage, including architectural and archaeological heritage
- Conservation of sites and species
- Interrelationships of the above

Information on the environmental baseline and its likely future evolution has been grouped into these subject areas, with the assessment sections being organised by identified sources of potentially significant effect.

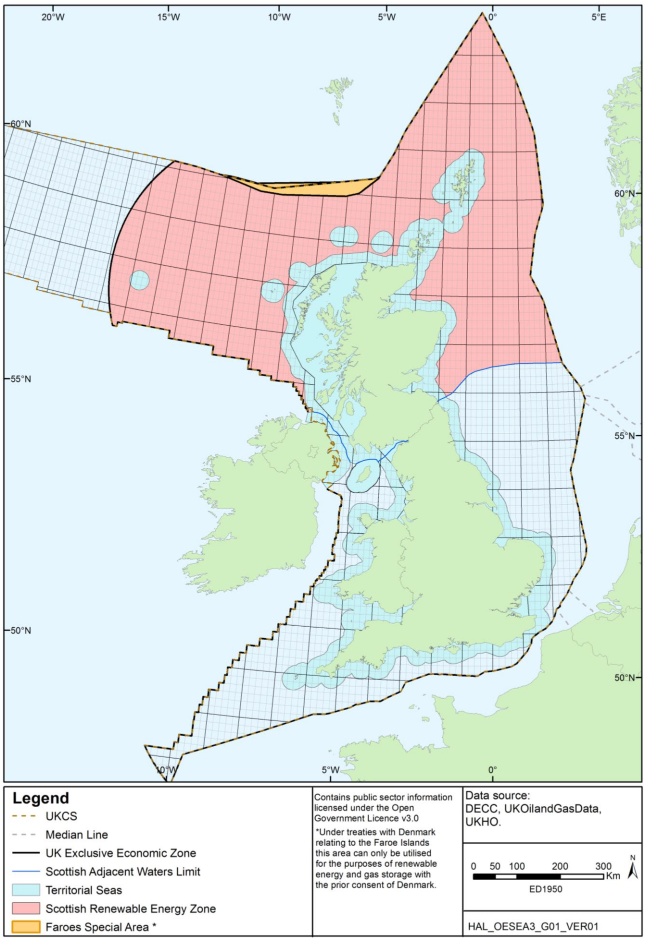
The key points and conclusions of the assessment are summarised in the sections which follow.

What areas are included in the SEA?

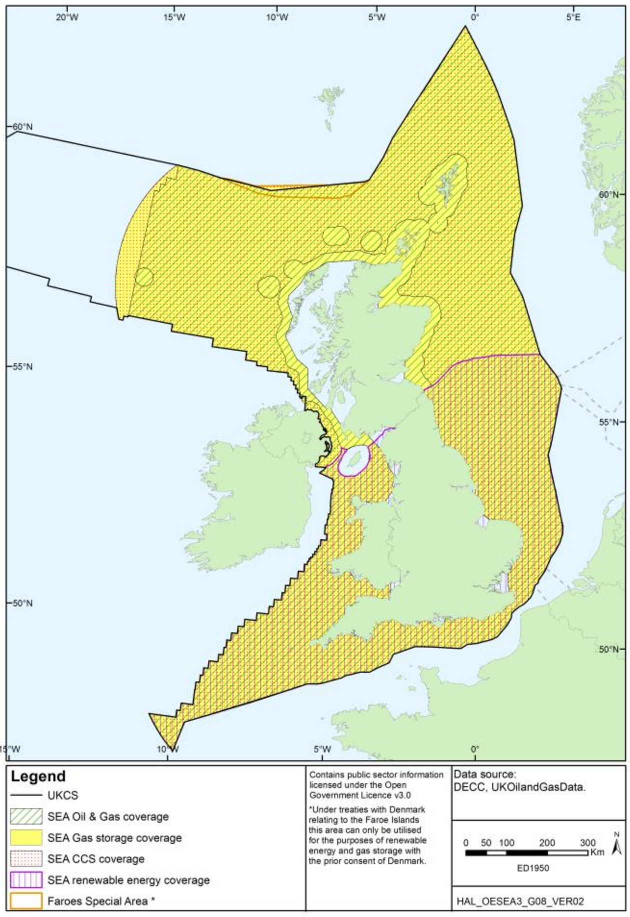
For offshore renewable energy this SEA considers potential leasing in the relevant areas of the UK Exclusive Economic Zone (EEZ), and also the territorial waters of England and Wales. The area covered by the Scottish Renewable Energy Zone and Northern Irish waters within the 12 nautical mile territorial sea limit are not covered by renewable energy aspects of the plan – see Maps 2 and 3. For gas storage and carbon dioxide storage, the SEA considers potential licensing/leasing in relevant UK territorial waters (note CCS in Scottish territorial waters is a devolved matter and so not covered in the OESEA3 draft plan/programme) and the UK EEZ. For offshore (seaward) oil and gas licensing, this SEA covers all UK waters.

Geographical coverage of the SEA

Map 2: Areas mentioned in the text



Map 3: Coverage for oil and gas, gas storage, CCS and marine renewables



Overview of the environment

The UK has a rich marine biodiversity reflecting both the range of habitats present in water depths from the shore to >2,400m, 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.

Following discussion with the SEA Steering Group it was agreed to use the draft Regional Seas divisions used in Defra's Charting Progress 2 as a basis for considering UK waters for this SEA, albeit modified to differentiate certain areas to maintain consistency with previous OESEAs – see numbered areas on Map 1. The use of these boundaries more closely aligns with other regional divisions of UK waters, including marine plan areas and the Marine Strategy Framework Directive sub-regions. In view of the time elapsed since the publication of OESEA2 (February 2011), a new environmental baseline has been prepared for OESEA3, incorporating information from numerous new sources and updates to baseline data. A comprehensive environmental baseline is provided in Appendix 1 and selected highlights are given below.

The bird fauna of the UK is western Palaearctic; 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 nearly 50%, and the Isle of Rum off western Scotland between a quarter and a third, of the world's breeding population of Manx shearwaters. The largest gannet colony in the world is on Bass Rock in the Firth of Forth.

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 almost 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 circumpolar pattern of occurrence. Spawning and nursery grounds have been identified for many species and 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 (approximately at 60°N), and a distinct species group found in the cold waters of the Faroe-Shetland Channel and Norwegian Sea. 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 north-east 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 and other activities.

The present geology and substrates of the UKCS reflect a combination of processes taking place over millions of years, most recently influenced by glacial reworking and sedimentation in successive ice ages which is now interacting with Holocene wave and tidal processes. This reworking is very slow for much of the UKCS, but more rapid at shallower depths and in proximity to the shore where wave interaction and strong tidal currents may enhance the rate of change. The speed and nature of such change is also linked to underlying geology, with softer coasts generally eroding and changing much faster, particularly those comprising poorly consolidated rock or sediments. The deep geological history of the UKCS has led to the maturation of hydrocarbons where conditions are favourable (suitable reservoirs at depth and structural traps), and other sedimentary formations such as saline aquifers provide potential opportunities for hydrocarbon gas or carbon dioxide storage.

The variability of the UK climate is largely due to its position on the edge of the Atlantic Ocean with its relatively warm waters, yet close to the continental influences of mainland Europe. Changes in topography and land use over relatively short distances, together with a long coastline and numerous islands, all add to the variety of weather. A network of coastal and marine stations and buoys around the UK monitor different meteorological parameters including air temperature, rainfall, wind speed and direction, and visibility, informing weather forecasting systems as well as the development of climate models projecting future changes to the UK climate.

Regular air quality monitoring is carried out by local authorities in coastal areas. The air quality of all local authority areas is generally within national standards set by the UK government’s air quality strategy, though several Air Quality Management Areas have been declared to deal with problem areas. Most of these are in urban areas and result from traffic emissions of nitrogen dioxide or particular matter (e.g. PM_{10}). Industrialisation of the coast and inshore area adjacent to certain parts of the central North Sea has led to increased levels of pollutants in these areas which decrease further offshore, though oil and gas platforms provide numerous point sources of atmospheric emissions.

The coasts and seas of the UK are intensively used for numerous activities of local, regional and national importance including coastally located power generators and process industries, port operations, shipping, oil and gas production, fishing, aggregate extraction, military practice, as a location for submarine cables and pipelines and for sailing, racing and other recreation. At a local scale, activities as diverse as saltmarsh, dune or machair grazing, seaweed harvesting or bait collection may be important. Population is also variable. General trends observed are lower population densities in coastal areas around much of the south-west of England, west and north Wales, the far north of England, and much of Scotland excluding the central belt. The highest population densities in coastal areas are around much of south-east England, part of north-east England, the Firths of Forth and Clyde, part of north-west England, south Wales and around the Severn Estuary. These areas are typically where conurbations are largest and most numerous.

The cultural heritage of the UK relevant to OESEA3 includes coastal sites which date to some of the earliest settlements in Britain (potentially to as early as 700-900,000 years ago), and submerged sites in shelf seas which were exposed during previous glacial periods. Later submerged heritage includes a significant shipwreck record and aircraft losses which predominantly relate to previous world wars. Designated sites are relatively few in number compared to those which are recorded, and those recorded are very few against the potential resource. With the exception of shipwreck, all designated sites to date are terrestrial.

Landscapes and seascapes, as defined by the European Landscape Convention, include natural, rural, urban and transition areas between rural and urban, land, inland water and marine areas, and includes areas that might be considered outstanding as well as everyday or degraded. The coasts and seas of the UK have a diverse character, which has or is being defined through the existing and ongoing identification of landscape and seascape character areas which account for the key characteristics of particular areas. Such characterisation and assessment may be undertaken at the regional and more local scale. The protection of areas regarded to be of particular importance in full or part for their landscape, has to date in the UK been through designation of, for example Areas of Outstanding Natural Beauty, National Scenic Areas and National Parks, however the wider recognition of landscape in the UK is now being brought about through national and regional planning policy, including marine planning.

Context to the draft plan/programme

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 Union, 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 aimed to complete a joint network of well managed MPAs by 2010 that, together with European sites (the Natura 2000 network), is ecologically coherent. As part of the UK implementation of such areas, the *Marine and Coastal Access Act 2009* and the relevant marine Acts of devolved administrations provide powers to designate Marine Conservation Zones (MCZs) in England, Wales and Northern Ireland, and Marine Protected Areas (MPAs) in Scotland.

More broadly, OSPAR periodically publishes assessments in the form of Quality Status Reports (QSRs) of the North-East Atlantic and its sub-regions, with the most recent being published in 2010. QSR 2010 informed 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 (MSFD) entered into force in July 2008. The *Marine Strategy Regulations 2010* transpose the Directive into UK law and require the development of the five elements of the marine strategy: (1) the assessment of marine waters;

(2) the determination of the characteristics of good environmental status for those waters (note these are qualitatively described in Annex I to the Directive); (3) the establishment of environmental targets and indicators; (4) the establishment of a monitoring programme; (5) the publication of a programme of measures.

The key objectives of the Directive are to achieve good environmental status (GES) 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. To fulfil these requirements the UK has prepared documents (e.g. the Marine Strategy Parts 1, 2 and 3, and proposals for UK monitoring programmes and programmes of measures to maintain or achieve GES). The Directive requires that programmes of measures be established to achieve GES, 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. Similar to the contribution to the wider OSPAR MPA network, existing and proposed Natura 2000 and MCZ/MPA sites will be used to contribute to this measure.

The MSFD complements measures being undertaken as part of the UK implementation of the Water Framework Directive (WFD), particularly in coastal waters where geographical scope of the Directives overlap (out to 1nm in England and 3nm in Scotland), and also in transitional waters (e.g. estuaries). River Basin Management Plans (RBMPs) are one of the principal means that the WFD has been implemented in the UK, with a second phase of planning now in progress covering the period 2015-2021. Whilst the implementation of WFD and MSFD may be complementary in these areas in terms of their objectives (e.g. particularly in relation to water chemical quality and some aspects of ecological quality), for coastal waters MSFD will only cover those aspects of GES not already covered by the WFD.

The *Marine and Coastal Access Act 2009*, and Acts of devolved administrations, amongst other provisions was instrumental in formalising marine spatial planning in the UK, which at the EU level is subject to Directive 2014/89/EU which came into force in July 2014. At the highest level, the 2011 UK Marine Policy Statement (MPS) provides the overarching framework for decision making and plan making in UK waters in keeping with the high level marine objectives agreed by the Governments of England, Scotland, Wales and Northern Ireland. The first set of marine plans in English waters, the East Inshore and Offshore Marine Plans, were adopted in 2014, with plans presently being prepared for the South Inshore and Offshore Regions. Scotland's National Marine Plan was adopted in 2015, and a number of smaller Scottish marine regions will be subject to regional planning in the coming years. Other plans are presently in preparation (e.g. for Wales and Northern Ireland). Each of the regional and country marine plans should be drafted in keeping with the MPS but informed by regionally specific information, and enforcement and authorisation decisions should be taken in accordance with these regional marine policy documents, or the MPS in advance of their adoption. The MPS, adopted plans and related policies have been considered during the preparation of the SEA Environmental Report. Where policies have spatial aspects relevant to the plan, these have either be mapped or cross-referenced as appropriate.

Overarching National Policy Statements for Energy are also relevant to plan activities, and provide planning policy in relation to nationally significant energy infrastructure projects (NSIPs), as defined in the *Planning Act 2008* – this includes almost all offshore renewable energy projects in England and Wales; however, although regulated, there is presently no planning policy for tidal lagoons.

Decision making in relation to licensing/leasing and also subsequent activities which could take place as a result of the adoption of the draft plan/programme is therefore split between a number of legislative and planning policy remits, including those of devolved administrations. 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 2.

Prospectivity

The UK has extensive offshore energy resources, including of oil and gas and marine energy including wind, wave and tidal, all of which are variable over space and time. The UK also has a long maritime history and growing use of offshore areas from other users, and therefore not all areas of technical resource may be practically available at a given time.

Oil and gas (Map 4)

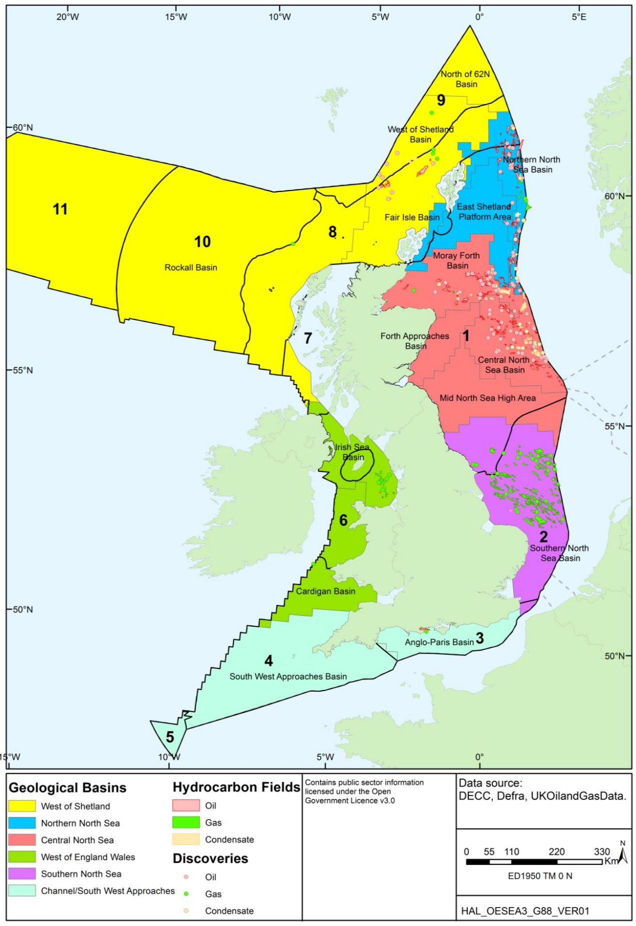
For commercial hydrocarbon resources to occur, a number of factors and features have to coincide, including:

- 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 28th Round held in 2014. 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. The southern North Sea and Irish Sea are largely gas provinces, with the central and northern North Sea, and West of Shetland areas being oil provinces. Whilst the major offshore hydrocarbon basins of the UK are at a mature stage of production, significant reserves remain in fields in production or development and further significant reserves are estimated to occur which are yet to be discovered.

The area of the Faroe-Shetland Channel, particularly north of 62˚N in UK waters, has been comparatively underexplored due to the presence of geology which poses barriers to seismic survey and drilling. However, new techniques are now available to improve the understanding of prospectivity in this area. Similarly, areas of the mid North Sea High and Rockall Basin are relatively underexplored and prospectivity is less well understood for these regions. The OGA undertook two regional seismic surveys in 2015 covering these areas, the results of which are expected to augment existing data and update current understanding of prospectivity to inform future licensing, in particular a 29th Frontier Round

Map 4: Major hydrocarbon basins, fields and discoveries on the UKCS



Gas storage

The inclusion in the current draft plan/programme of gas storage 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. Hydrocarbon gas storage in depleted and other hydrocarbon reservoirs and other geological structures 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, or in areas of extensive halite (rock salt) deposits. There are extensive halite deposits in the southern North Sea and eastern Irish Sea, and the most prospective area for halites with gas storage potential being in the East Irish Sea Basin.

Carbon dioxide storage

Carbon dioxide (CO_2) may be stored in a range of geological formations including depleted hydrocarbon reservoirs and saline aquifers. Hydrocarbon reservoirs have geological characteristics suited to trapping CO_2 over long timescales (e.g. a suitable porosity/permeability and impervious cap rock), and the injection of CO_2 into hydrocarbon reservoirs can also be used in enhanced oil recovery. In the longer term these reservoirs can be used exclusively for CCS. Due to the maturity of most of the UKCS hydrocarbon basins, the availability of sites for CO_2 storage is likely to increase in the coming years, and has the potential to exploit existing infrastructure. Saline aquifers can have similar characteristics to hydrocarbon reservoirs (i.e. suitably porous/permeable medium with geological constraints on migration) and may also be suited to CO_2 storage. The central North Sea, southern North Sea and East Irish Sea are presently most prospective due to the presence of suitable formations and proximity to areas of high CO_2 emissions (e.g. Thames Estuary, Humberside, Merseyside, the Firth of Forth, Teesside and Tyneside).

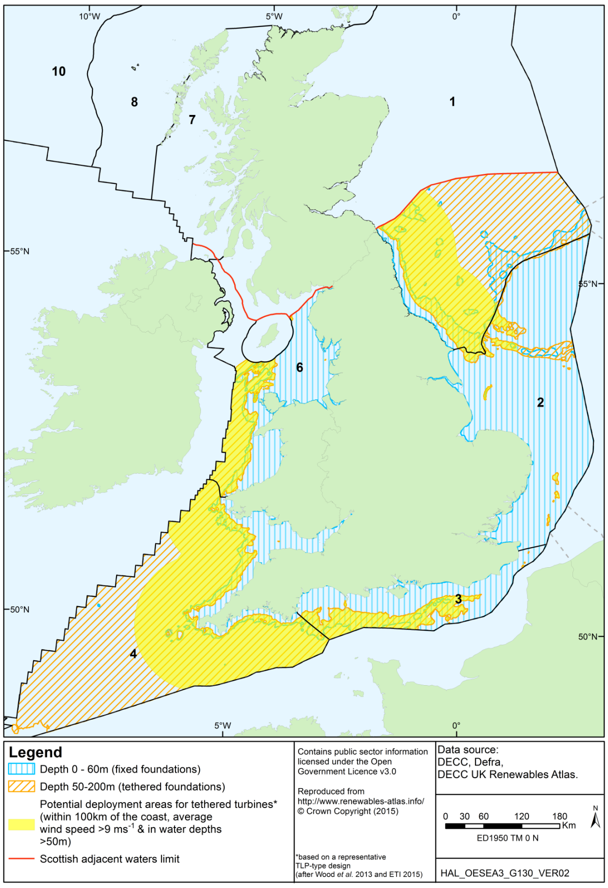
Offshore wind (Map 5)

In UK waters, offshore wind is the most developed renewable energy technology. Rounds 1 and 2 of offshore wind leasing were held in 2000 and 2003 respectively, with Round 3, held in 2009, being significantly larger in terms of the areas offered for leasing. Exclusivity agreements were signed for nine of the Round 3 areas, seven of which have thus far had planning applications submitted to develop areas within each zone. UK offshore wind generation capacity can be subdivided in that presently in planning (3.25GW), consented (14.94GW) and operational (5.01GW). Though not a consideration of this SEA, included in the above figures are areas within the territorial and offshore waters of Scotland have also been leased for offshore wind, which have 191MW of operational capacity and 4.3GW consented but not yet constructed. Away from the shelter of the coast, the total wind resource over a given year is relatively uniform across very large areas, although the occurrence and strength of wind is dependent 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.

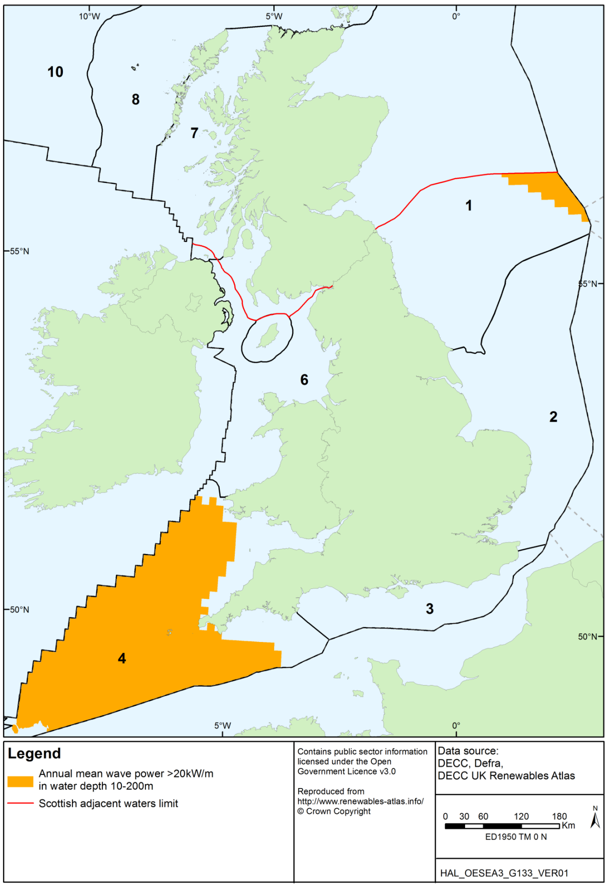
Water depth, distance from areas of high electricity demand, and the availability of connection points to the onshore transmission grid are significant factors in the preferred location of offshore wind developments. Installed or proposed wind turbine foundations have to date been dominated by fixed structures (e.g. monopiles, jackets or gravity bases), largely related to the cost of wind farm development. Such structures tend to be limited in the depth of waters they can be deployed effectively. For the purposes of OESEA3, it is considered that fixed foundations are likely to be deployed at depths of up to 60m. Floating structures similarly have a diverse range of designs (e.g. tension leg, semi-submersible, spar-buoy and a number of other concepts), with limited demonstrator deployment to date (e.g. the 2.3MW Hywind demonstrator off Norway), including proposals for demonstration in UK waters (e.g. five 6MW Hywind devices 30km off the coast of Peterhead, the Dounreay Floating Offshore Wind Development Centre (DFOWDC) being developed by Highlands and Islands Enterprise for up to five turbines of various designs, the Kincardine offshore wind farm comprising eight semi-submersible turbines located approximately 8 miles offshore from Aberdeen, and the PelaStar demonstrator to be installed at WaveHub off Cornwall). For the purposes of OESEA3, it is considered that floating foundations are likely to be deployed at depths from 50m to 200m.

Key resource areas considered in OESEA3

Map 5: Offshore wind



Map 6: Wave power



Wave (Map 6)

Exploitation of wave and tidal energy is not yet fully commercial in UK waters, although several test and demonstrator projects have been deployed or are in development. It is likely that over the coming years as devices reach commercial scale and their viability is demonstrated, larger scale deployment of wave and tidal energy generation devices will commence. Work to characterise the wave and tidal resources of UK waters has shown the key wave resource (for the purposes of OESEA3, >20kW/m wave crest) is broadly concentrated on the Atlantic facing coastline of the UK, notably the Western Isles of Scotland (not considered in this SEA) and the South West peninsula and south west Wales.

Tidal stream (Map 7)

Tidal stream resource is more geographically constrained – being localised around headlands and through straits between land masses. A number of areas in Scottish territorial waters have been leased for wave and tidal development (not considered in this SEA), with a further leasing for six new wave and tidal current demonstration zones taking place in 2014, as part of a programme to accelerate technology development. Demonstration sites include the European Marine Energy Centre (Orkney) and Wave Hub (Cornwall). Areas where commercial development may take place in the near future include the Pentland Firth and Orkney waters (Scotland), Rathlin Island and Torr Head (Northern Ireland) and Anglesey (Wales). For the purposes of OESEA3, the key resource areas are considered to be those with a current speed of >1.5m/s and a water depth of >5m.

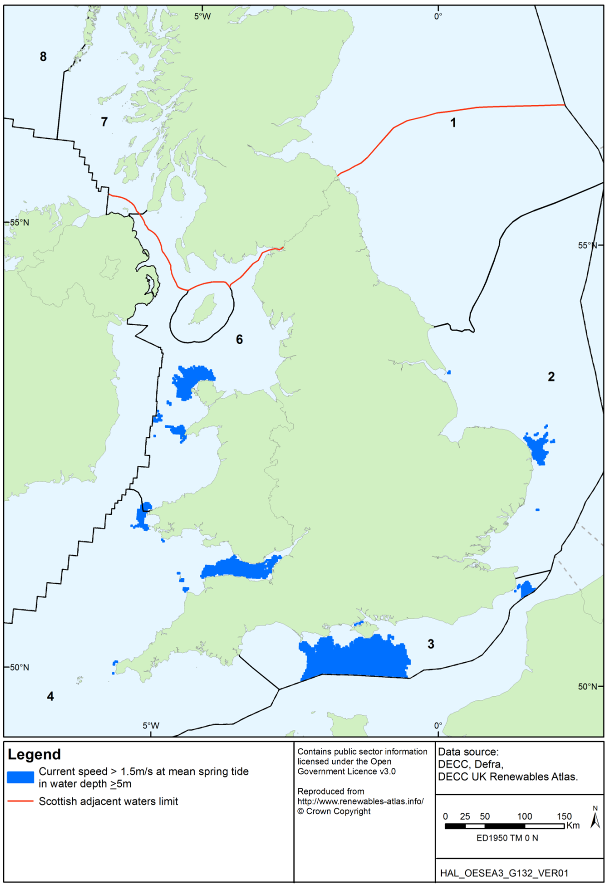
Tidal range (Map 8)

The potential future location of tidal range developments in relevant UK waters are guided by the available resource and are generally limited by other factors such as water depth (for the purposes of OESEA3, a mean tidal range of >5m and water depths ≤25m). The vast majority of the UK's tidal range resource is located in the territorial waters of England and Wales, but south-west Scotland has a large area with viable resources. As a result, any consideration of the Solway in OESEA3 has taken account of the potential for developments which could affect, or be part of, the two legislative and planning remits which meet within this estuary.

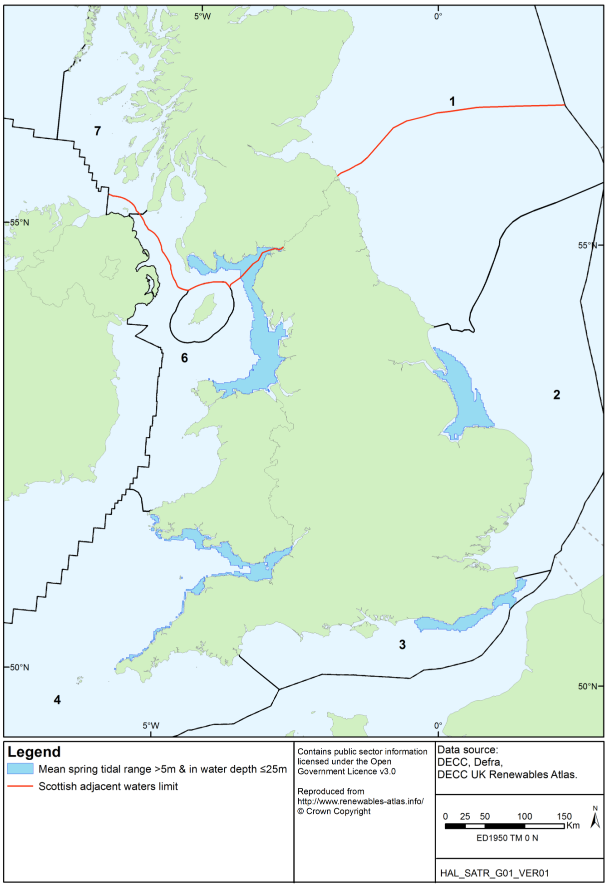
There has been much historical interest in tidal range development in the UK, particularly centred on the Severn Estuary, and a review of historical proposals revealed that they largely coincided with the prime energy resource identified above. Despite this interest, no commercial scale tidal range developments are operating in the UK. There are presently two tidal lagoon developments (Newport and Cardiff) which are in the pre-application stage of planning and one which has received consent (Swansea Bay) though this is yet to be granted a lease. The parent company behind these proposals, Tidal Lagoon Power Ltd, has plans for three other tidal lagoon developments in Bridgewater Bay, Colwyn Bay and West Cumbria.

Key resource areas considered in OESEA3

Map 7: Tidal stream



Map 8: Tidal range



Overview of main sources of effect and controls in place

The draft plan/programme includes the licensing/leasing of offshore oil and gas activities, the storage of gas and CO_2, offshore wind farms and marine renewables. An evidence-based consideration is presented in the SEA, which is summarised in the sections which follow. In addition, significant use has been made of Geographical Information System (GIS) tools to collate, process, analyse and present spatial information both in the assessment and environmental baseline presented in Appendix 1 of the SEA.

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

- Baseline understanding of the relevant receptors (including other users) grouped according to the SEA Directive, together with existing environmental problems and the likely evolution of the baseline conditions.
- The likely activities, and potential sources of effect and the existing mitigations, regulatory and other controls.
- The evolving regulatory framework.
- The evolution of technology.
- The SEA objectives.
- The evidence base regarding the relative risks and potential for significant effects from offshore wind farm, wave, tidal stream and tidal range developments, offshore oil and

gas exploration and production, carbon dioxide storage 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 specific meetings, and other communications.

The main stages of those activities covered by the plan are a variation on: exploration, development, operation, maintenance and decommissioning, and may be broadly summarised for the main technologies covered by the draft plan/programme as follows:

For oil and gas activity, including gas and carbon dioxide storage:

- Exploration, including seismic survey and exploration drilling
- Development, including production facility installation, generally with construction of an export pipeline (or transport pipeline in the case of gas and CO2 storage), and the drilling of producer and injector wells
- Production/operation, with routine supply, return of wastes to shore, power generation, chemical use, produced water reinjection management and reservoir monitoring
- Maintenance
- Decommissioning, including cleaning and removal of facilities

For renewables including offshore wind, wave and tidal technologies:

- Site prospecting/selection including collection of site specific environmental data, and seabed information by geophysical and geotechnical survey
- Development, including construction of foundations, barrages or lagoon walls, and any scour protection, turbine or device installation, cable laying including shoreline crossings and armouring, installation of gathering stations/substations and connection to the onshore national electricity transmission system
- Generation operations
- Maintenance
- Decommissioning, including 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 were informed through experience gathered from previous SEAs which included activity/effect matrices, which have sought to link human activities with effects on the marine environment. The list of potential effects and the plan activities to which they relate were subject to scoping and also discussions with the SEA Steering Group. These sources of effect include (in no particular order):

- Physical damage to biotopes from infrastructure construction, vessel/rig anchoring etc (direct effects on the physical environment)

- Sediment modification and contamination by particulate discharges from drilling etc or resuspension of contaminated sediment
- Offshore disposal of seabed dredged material
- Behavioural and physiological effects on marine mammals, birds and fish from noise (e.g. seismic or other geophysical surveys, construction, operation and decommissioning phase noise)
- The introduction and spread of non-native species
- Behavioural disturbance to fish, birds and marine mammals etc from physical presence of infrastructure and support activities
- Collision risks to birds, bats and water column megafauna (e.g. fish, marine mammals).
- Barriers to movement of birds, fish and marine mammals
- Changes/loss of habitats from major alteration of hydrography or sedimentation (indirect effects on the physical environment)
- Chemical contamination (routine) from produced or treated water, drilling and other discharges, antifouling coatings etc.
- Contamination by soluble and dispersed discharges saline discharges (aquifer water and halite dissolution in relation gas storage and CCS), and foundation construction
- Changes in seawater or estuarine salinity, turbidity and temperature from discharges and impoundment
- Electromagnetic Field (EMF) effects on electrosensitive species
- Accidental events – major oil or chemical spills, or major releases of carbon dioxide (water column, seabed and air quality related effects and socio-economic consequences)
- Physical effects of anchoring and infrastructure construction (including pipelines and cables) on seabed sediments and geomorphological features (including scour), and changes to sedimentation regime and associated physical effects
- Effects of reinjection of produced water and/or drill cuttings and carbon dioxide
- Onshore disposal of returned wastes – requirement for landfill
- Post-decommissioning (legacy) effects – cuttings piles, footings, foundations, in situ cabling etc.
- Potential effects of development on seascape including change to character (interactions between people (and their activities) and places (and the natural and cultural processes that shape them))
- Energy removal downstream of wet renewable devices
- Contributions to or reductions in net greenhouse gas emissions
- Positive socio-economic effects of reducing climate change

- Potential air quality effects including on human health resulting from atmospheric emissions associated with plan activities, or with discharges of naturally occurring radioactive material in produced water
- Interactions with fishing activities (exclusion, displacement, seismic, gear interactions, "sanctuary effects") and other users including shipping, military, potential other marine renewables and other human uses of the offshore environment
- Physical damage to submerged heritage/archaeological contexts from infrastructure construction, vessel/rig anchoring etc and impacts on the setting of coastal historic environmental assets and loss of access.

All the major stages of offshore oil and gas, offshore wind, wave and tidal installation and operation are covered by environmental regulations including the requirement for Environmental Impact Assessment at the development stage (see Appendix 3).

Assessment summary

Biodiversity, habitats, flora and fauna

In general, marine mammals show the highest sensitivity to underwater sound, particularly the intense pulses associated with seismic surveys, impact pile-driving and the use of explosives. The severity of potential effect has therefore been related principally to marine mammal species composition and abundance in an area, although effects on fish (including spawning aggregations) and other receptors have also been considered. The nature of effects range widely, from masking of biological communication and small behavioural reactions, to chronic disturbance, injury and mortality. For marine mammals and fish, effects will generally increase in severity with increasing exposure to noise; a distinction can be drawn between effects associated with physical injury 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 (and other renewable energy array) construction, pile-driving of foundations can generate high noise source levels and is widely recognised as a potential concern, in particular for large developments where construction may last over several years.

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, even in more complex coastal locations. There is less clarity about the potential effects on marine mammals (and other receptors including fish), but progress is continuously being made, particularly through direct observations in the field. Further support for these studies is given in this SEA, especially to fill gaps in knowledge with respect to less well studied species and sound sources.

With respect to injury, risk from an activity can be assessed using threshold criteria based on sound levels; with respect to disturbance however, establishing broadly applicable criteria based on exposure alone has proved much more difficult, because the same sound level is likely to elicit different responses depending on the individual's behavioural context and past exposure. Consequently, recent expert assessments have used evidence from field studies within a comparable context to link measurable changes in behaviour (i.e. displacement, change in foraging rate) to sound exposure levels.

In light of the available evidence the SEA concurs with the scientific consensus judgement that underwater sound generated during seismic and pile-driving operations has the potential to cause injury within a limited range (tens to hundreds of metres in marine mammals) and to cause some level of disruption of normal behaviour in marine mammals and possibly some fish species at ranges of several 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 injure or 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 how to minimise the risk of injury and disturbance and has concluded that current mitigation measures are sufficient in reducing the risk of injury to negligible levels whenever carefully applied by industry for all regular species that are common on the continental shelf. More uncertainty on their effectiveness exists for deep-diving species; a particular concern identified in this SEA is for beaked whales (deep water Regional Seas 9, 10, 11 in Map 1) which are known to be highly sensitive to some underwater sounds such as military sonar.

The main challenge when assessing the likelihood of significant disturbance effects stems from the need to assess these in terms of long-term population consequences while the available evidence relates to individual responses under relatively short-term conditions. Several modelling frameworks are being developed to assess population level impacts of acoustic disturbance. All frameworks rely on assumptions and on expert judgement to cope with the gaps in the data, but so far there are considerable differences in methodologies and outcomes, all of which need to be viewed with caution. The approach used by an expert group convened under the Habitats and Wild Birds Directives Marine Evidence Group led to a report with the conclusion that planned offshore construction activity up to 2020 will result in a non-trivial level of acute disturbance, but *'this will not compromise the long-term health of the population'*. However, it also raises the possibility for population size to be negatively affected if activities were to expand significantly. The report recommends the preferential adoption of mitigation measures such as reducing noise emissions through modifications to offshore wind installation and careful planning to minimise the impact from temporal and spatial overlap between harbour porpoises and construction activity, recommendations which are accepted by this SEA through the review of this and other sources of information.

Given the spatial distribution of predicted activities resulting from both future oil & gas licensing rounds, and further rounds of offshore wind leasing, seismic activity will be likely the focus of noise risk assessments in areas to the north and west of the UK (Regional Seas 8, 9 and 10) while in Regional Seas 1, 2 and 6 (the northern, central and southern North Sea and Irish Sea) the cumulative effects of both seismic activity and piling will need to be considered. Both activities may extend throughout much of the year (although seismic surveys are normally undertaken in summer when the risk of rough seas is reduced), and be audible to marine mammals over a large proportion of their regional range.

Previous SEAs have recommended consideration of the establishment of criteria for determining limits of acceptable cumulative impact; and for subsequent regulation of cumulative impact. The SEA recognises the advances made in this respect through the establishment of the indicator on low- and mid- frequency impulsive sounds under the Marine Strategy Framework Directive. While criteria have not yet been defined, the establishment of a database to collate occurrences of 'noisy activities' (the Noise Registry) represents the necessary precursor. In addition, increased anthropogenic activities in the marine environment, including all of those under consideration in this SEA, will contribute to the continued increase in ambient noise levels. Chronic exposure to increased levels of underwater sound has the potential to have long-term consequences for the health of marine species. At present the evidence is insufficient to be able to set targets under MSFD, but this may change in the future since an ambient noise indicator has been established.

Given the lack of definition of 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 only possible to make generic 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. In addition, Habitats Regulations Assessments will be required for activities which may affect marine mammal populations within designated SACs.

Activities associated with offshore wind farm development; exploration and production of oil and gas; carbon dioxide and gas storage; wave, tidal stream and tidal range can lead to physical disturbance of seabed habitats, with consequent effects on seabed features and habitats. 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. Monitoring of Round 1 and 2 sites indicates that scour effects are generally small in scale and local in extent and are only likely to be of concern in areas characterised by large mobile bedforms, palaeochannels or sandbanks, although mitigation measures are available. The potential impacts of tidal range schemes may be significant (the scale of impact dependent on design and operation mode), with the potential loss of large areas of inter-tidal habitats and salt marshes as a result of changes in water levels and sediment transport within an estuary or river basin. The significance of potential effects of alteration or loss of intertidal habitats on birds, at a species or population level, particularly waders e.g. oystercatcher, ringed plover, sanderling is still unknown and this SEA recognises the need for further research in this area.

The SEA has considered the spatial extent of predicted disturbance effects, and the sensitivity of seabed habitats (in particular habitats listed in Annex I of the Habitats Directive) and placed these in the context of natural disturbance events and current assessment of the major sources of direct, physical pressure from human activities on seabed environments. The SEA concludes that with the currently required assessment and mitigation, physical disturbance associated with activities resulting from the proposed draft plan/programme 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 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, including for e.g. light attraction and collision (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 carbon dioxide and 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 locations for seabirds and wintering locations for waterbirds), indicate a higher potential for physical presence effects. In relation to birds, these include displacement, leading to effective habitat loss, associated with exclusion from ecologically important (e.g. feeding, breeding) areas, barrier effects and disturbance of regular movements (e.g. foraging, migration), potentially increasing flight energy demands and collision risk.

There is currently little information available on the interaction of birds, marine mammals and fish with surface and submerged wave and tidal devices and the SEA recommends that for the deployment of single devices and small arrays, appropriately focussed surveys of animal activity and behaviour should be undertaken to inform commercial scale deployment risk assessments and consenting. Other potential effects considered 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 species (e.g. fish and seals) 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, while recognising that collision hazard risk could become significant if there is substantial renewable development in the North Sea. However, there are some important uncertainties in relation to bird distribution, including identifying important areas within UK waters where birds aggregate (i.e. for foraging, loafing), species-specific reactions to development sites, variability in migration routes and timings, and the statistical power of monitoring methods. There is also the issue of baselines potentially changing, and how this effects/is dealt with in determining risk, i.e. where for example climate change and prey distribution patterns impacts on bird population sizes and distribution. Therefore, recognising that a large proportion of the bird sensitivities identified are concentrated in coastal waters, it is recommended that the bulk of new OWF generation capacity should be sited away from the coast, generally outside 12 nautical miles (some 22km).

Although there has recently been significant survey effort in coastal waters and studies to improve understanding of e.g. foraging areas and migration routes, the lack of modern data on seabird and waterbird distributions in offshore areas is noted. 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, marine renewables, gas and carbon dioxide storage and oil industry activities could 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, although currently there is poor detailed survey coverage of UK waters as a whole. Direct impacts of device footprints and cable and pipeline laying on seabed sediments and features have the greatest potential effect. However, physical disturbance associated with activities resulting from proposed oil and gas licensing and OWF, wave and tidal stream leasing will be negligible in scale relative to natural disturbance and for example 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 potential impacts of tidal range schemes however may be significant, with the potential loss of large areas of intertidal habitats and salt marshes as a result of a change in water levels and sediment transport within an estuary or river basin. The level of impact will likely be dependent on the design, siting and mode of operation (e.g. two-way operation may reduce the scale of impact).

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, wave and tidal 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, now being augmented by post-construction monitoring and decommissioning studies.

Landscape/seascape

The maturity and likely scale of activity of the various technologies covered by the plan indicate that offshore wind, particularly if deployed in nearshore waters and any tidal range development has the potential to generate the greatest effect. Proposed offshore wind farms have increased significantly in scale, both in terms of spatial coverage and the size of turbines. In most instances in UK waters, there has been a concurrent movement of these developments to areas further from the coast, reducing the potential for seascape effects at the coast, but also introducing a new industrial component to offshore seascapes in areas where offshore energy has already contributed to changing the seascape character (e.g. presence of offshore installations, drilling rigs, related shipping and helicopter traffic etc.).

The tidal range resource, including areas which have historically been or are presently subject to interest from commercial developers, are coastal/nearshore. Tidal lagoons are expected to be the principal technology which could be deployed during the currency of this SEA, but the possibility of barrages being proposed cannot be discounted entirely. Project proposals made in the UK to date have been shore connected and it is not expected that offshore impoundments would be proposed. Tidal range developments have the potential to generate direct changes to the character of coastal landscapes and seascapes through the imposition of lagoon walls/barrages and turbine housings, related lighting etc. resulting in, for example, foreshortening of seascape views and the introduction of industrial components. Additionally, wider indirect changes to the character of coastal landscapes and seascapes may also be realised should developments result in other effects such as: reduced sediment loads leading to a change in water clarity, reductions in intertidal areas (and/or displacement if compensatory measures are considered) and related alteration of the fauna and flora, changes in tidal regime, and alterations to the pattern of vessel movements (e.g. if requiring traffic separation through locks).

The scope for cumulative impacts between different renewables aspects of the draft plan/programme is minimised by there being little overlap in the geographical range of energy resources. Due to the expected scale of wave and tidal stream developments arising from the draft plan/programme and for the currency of this SEA, significant visual effects are not expected, particularly for completely submerged devices. Any tidal range scheme would likely result in significant effects on landscape/seascape character.

In contrast, most new hydrocarbon developments are likely to be sub-sea facilities tied back to existing infrastructure which are well offshore and beyond sight of land. The promotion of exploration in previously underexplored areas could, in the medium term, result in the addition of new fixed infrastructure depending on commercially viable resources being discovered, however these are more likely to be further offshore and isolated compared with wider scale renewables deployments. These areas include the mid North Sea High and Rockall Basin (see Map 2). Gas storage and CO_2 storage facilities are likely to be at sufficient distance from shore in most circumstances that coastal impacts are unlikely, though prospectivity in, for instance the Irish Sea and nearshore southern North Sea, and the requirement for a larger number of fixed surface infrastructure for certain project types (e.g. where salt cavern construction is required) has the potential to generate incremental effects with other aspects of the plan and existing uses of the sea.

In all cases, temporary interaction with the coast is likely through landfall works (e.g. where pipelines or cables are taken ashore) as part of ancillary development, with more permanent changes resulting from the construction of onshore substations, or above ground installations for pipelines, and also overhead power lines or other onshore routeing to enable the offshore aspects of projects.

Major development of any aspect of the plan could result in significant effects on landscape/seascape, with the potential for effects being highly site specific and requiring individual project specific consideration, for instance due to the varying number, size and layout of potential devices, alterations to which could provide a suitable level of mitigation. Whilst National policy indicates that consent for energy development, and in particular to renewable energy, should not be refused solely on the grounds of an adverse effect on seascape, including visibility of the development from within designated sites, unless adverse effects are considered to outweigh the benefits. For example, secondary impacts on tourism and recreation, or on internationally recognised areas such as World Heritage Sites.

The siting of offshore wind farms well away from the coast is consistent with what is occurring in other European countries, and the potential use of alternative foundation types would facilitate OWF siting in deeper waters offshore. Reflecting the previous conclusions and recommendations of OESEA and OESEA2, and the relative sensitivity of multiple receptors in coastal waters, OESEA3 recommends that the bulk of new OWF generation capacity should be sited away from the coast, generally outside 12 nautical miles. The sensitivity of coastal areas is not uniform, and in certain cases new offshore wind farm projects may be acceptable closer to the coast, or be acceptable subject to changes in their layout and design. Conversely, siting beyond 12nm may be justified for some areas/developments.

In this context, the conclusions are consistent with alternative 3 of the draft plan/programme, to restrict the areas offered for leasing and licensing temporally or spatially, however in view of National policy and as the potential location and type of future developments are subject to commercial interest (with potential for limited mitigation), prescriptive restriction is difficult to make at this stage, other than providing the recommendation that wind farms be sited away from the coast. Therefore, project level assessment, including cumulative assessment with operational, consented and proposed developments, will be required to inform the potential impact on landscape and seascape character, and the suitability of future developments.

Water environment

The consequences of energy removal on natural marine systems are reasonably well understood for large tidal barrage schemes but are far less predictable and appreciated for smaller tidal range schemes (e.g. lagoons), wave and tidal stream devices. Tidal barrages may have far reaching, large scale impacts that potentially cause permanent changes to the physical nature and associated ecology of the estuary/river basin where they are located, although the exact level of impact is dependent on operation mode, design and siting. For this reason and because individual estuary/embayments are so different, the SEA recommends that detailed site specific data gathering and assessment is required before decisions can be taken on the acceptability or otherwise of a development.

Individual and small arrays of tidal stream and wave devices are thought to have localised effects that are detectable but unlikely to be highly significant at distance from the devices. However recent modelling work has suggested potentially significant, far reaching impacts, from larger arrays of these devices depending on site location and size/layout of the array. Studies have suggested that impacts could potentially be reduced at certain sites through careful siting, although uncertainty still arises as the natural complexity of the water movements of an area are often only broadly represented in the models. Current information is still based on modelling and some small demonstrator scale monitoring studies and much more work is needed to improve both aspects.

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 or prospective for hydrocarbons, gas and carbon dioxide 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. Offshore renewables are generally not thought of as a significant source of marine discharges although there is evidence for substantial use of maintenance chemicals which enter the sea. In addition, the presence of numerous offshore renewables installations may increase the risk of vessel collision and associated spill risk. However, given the likely scale of potential development and appropriate planning and siting of developments, the increase in risk is not thought to be significant. 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, marine renewables 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, installation and support vessels, and helicopters. Fugitive emissions such as those from cement tanks (used in well operations), diesel storage and cooling/refrigeration systems can result in emissions of dust/particulates, VOCs, hydrofluorocarbon refrigerants etc. depending on the source, however regulatory controls are now in place on the use of certain refrigerants. As a proportion of UK atmospheric emissions, those directly emitted from plan related activities form a small proportion, and the distance of most point sources from shore allows for significant dispersal and so effects on coastal and terrestrial air quality are not likely to be significant.

Emissions will also be associated with the construction of marine renewables and wind farm devices to be deployed and by the choice of construction materials. The potential expansion of ports to facilitate renewable energy development may have implications for local air quality in these areas, some of which may already have air quality management areas. Operational effects of offshore renewables are expected to be negligible, and effects at the strategic level are not considered to be significant.

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 offshore renewable developments, and hydrocarbon exploration, production and storage activities would be assessed through the statutory EIA and consenting processes (e.g. under the *Offshore Combustion Installations (Pollution Prevention and Control) Regulations 2013*), which would serve to identify if mitigation beyond the application of Best Available Techniques 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 renewables these will be offset by the production of renewable energy. CO_2 storage can also contribute to the decarbonisation of UK energy supply.

There are growing concerns about the effects of fossil fuel combustion in terms of climate change and related effects, which in the marine and coastal environment include sea-level change, ocean acidification and potentially enhanced extreme weather events, but have wider reaching effects on terrestrial environments of the UK, Europe and elsewhere. The contribution of atmospheric emissions from hydrocarbon related activities that may result from implementation of draft plan/programme alternative 2 or 3 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, in addition to being party to international initiatives such as the Paris Agreement. All of these 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 storage 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, but with a change in security of supply. Thus domestic hydrocarbon production would be neutral in terms of resultant emissions, with reductions attainable in the medium term through energy sector decarbonisation by the attainment of UK climate change legislative commitments.

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 layout of turbines within a wind farm. The potential for tidal range projects to impact coastal flooding patterns will depend on their location, nature and extent and will form an important part of the consideration of any future projects.

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 renewable energy industry and offshore gas storage, including carbon dioxide 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)

Often, views of the 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 1,000s of square kilometres), formal marine spatial planning through the establishment of the Marine Management Organisation (MMO), the national Marine Policy Statement and now regional scale Marine Plans is a key reform included in the *Marine and Coastal Access Act 2009*. The range and importance of existing and some potential uses of the sea are described in Appendix 1h of the Environmental Report, with key aspects summarised below. In advance of formal regional scale marine spatial planning in many areas of UK seas, 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. Approximately 95% of the goods entering or leaving the UK are transported by ship, and substantial numbers of vessels transit 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 have 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 allows precise tracking of individual vessels, however has a limited range, and also has limited coverage of smaller vessels (e.g. small commercial and fishing vessels and recreational users). Such vessels are starting to carry AIS equipment (AIS-B) and therefore understanding of their movements is improving. New national scale data made available by the MMO for 2012 and 2013 have been analysed to provide 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. Monitoring data of existing OWF pre- and post-construction suggest that regular users of the area are currently able to take altered routes and in busy areas the introduction of a traffic separation scheme can aid routeing, and navigation assessments and consultation informed by guidance provided by the Maritime and Coastguard Agency in the siting of new offshore wind farms can contribute to the identification of major shipping routes and the avoidance of conflict. The MPS and now regional scale marine plans recognise the strategic importance of shipping to the UK but also the potential for this to be compatible with other offshore activities, and a number of policies and policy maps have been produced to provide an indication of major routes and requirements placed on new developments to ensure safe navigation and shipping is not adversely affected. Additionally, navigation lighting requirements (including recent recommendations for lighting to fulfil both maritime and aviation requirements) and mandatory charting of new developments further reduces risks to shipping and navigation.

As wave and tidal developments are currently at demonstrator scale, the spatial extent of arrays of these and the implications for navigation are difficult to ascertain, although regulations on lighting and navigational aids mean that they are unlikely to be any more of an issue than OWF developments. The displacement of shipping and subsequent impact on the cost of shipping and port revenues is potentially significant, and should be taken into account when siting arrays of offshore renewable devices. The SEA concluded that wind farm (and other large footprint development) 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 2014, there were approximately 12,000 working fishermen in the UK (of which 82% were full time), operating over 6,300 vessels, 5,000 of which were smaller inshore boats (<10m). These vessels landed 756,000 tonnes of fish and shellfish in 2014, with a total value of £861 million. On top of this, fish processing provides over 19,500 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, from 2005 to vessels >15m, and is soon to be extended to vessels >12m. To inform the SEA, VMS data for UK vessels from 2013 was obtained and analysed to provide information on, and derive maps showing, important fishing areas for larger vessels and offshore areas.

Military use of the coasts and seas of the UK is extensive, with all three Services (army, airforce, navy) 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 parts 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. Developments which jeopardise national security for example through interference with radar systems or cause unacceptable impact on training areas should not be consented unless the impacts can be appropriately mitigated or are deemed acceptable.

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 consult helicopter operators and offshore installation operators for developments within 9nm of a platform to maintain the safety of helicopter approaches, and in particular missed approach procedures and navigation in poor visibility where instrument (as opposed to visual) approaches are being made. With adequate risk assessment and consultation, the siting of wind farms within 9nm of installations can be agreed. Additionally, the CAA identify a number of helicopter main routes which relate to the oil service industry and are therefore concentrated in the northern, central and southern North Sea and Morecambe Bay. Though not having a statutory basis the CAA recommends a 4nm corridor be kept clear of obstructions along these preferred routes. Comparable to consultation zones around platforms, further consultation may permit development and alteration to routes where possible (e.g. as experienced in recent Round 3 wind farm sites in the southern North Sea).

Various areas of sea are used or licensed/leased for marine aggregate extraction, telecommunications and other cables, disposal of capital and other dredging wastes, offshore wind farms, surface and subsea oil and gas production and export infrastructure. These have been mapped and considered in this SEA. Potential future uses of the sea considered in

OESEA3 include gas (natural gas and carbon dioxide) storage in geological formations, aquifers or constructed salt caverns and marine renewables such as wave, tidal stream and tidal range. Where available, information on potentially suitable locations for these has been considered in the assessment, considering likely and potential spatial constraints on these types of development.

The implementation of the draft plan/programme will result in some associated development onshore including the installation of additional equipment at existing gas terminals for gas storage, and pipelines and associated infrastructure for the transport and storage of carbon dioxide. The considerable ancillary onshore development necessary for major expansion of offshore wind generation includes reinforcements to the national electricity transmission system (as considered by National Grid as the National Electricity Transmission System Operator for Great Britain) and enhancements to the capacity of the UK's port facilities. Some ancillary offshore grid reinforcements will also be required, however the nature of any potential offshore (e.g. North Sea) grid is not the subject of this SEA. The influence of wave and tidal development within the scope of OESEA3 on port and manufacturing facilities development will likely be comparable in nature, but considerably smaller in scale than that associated with offshore wind. These will have some environmental impacts, with habitat loss/modification, noise, landscape impacts and interactions with other users among the key issues to be considered at the project planning stage, guided by National policy for ports.

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. Finds of flint artefacts in Suffolk and Happisburgh, Norfolk, tentatively push early human occupation back to a maximum age of approximately between 700 and 950,000 years BP. The current understanding of marine prehistoric archaeology is largely based on findspots recovered by fisheries and aggregates operations, now being augmented by interpretations of the palaeolandscapes of the continental shelf between the UK and Europe which would have been exposed and inhabitable during previous glacial phases.

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 (e.g. the UK Hydrographic Office wrecks database contains approximately 70,000 records, and the wider wreck resource of the UKCS has been estimated to hold between 100,000 and 500,000 locations). A number of coastal sites have been designated as World Heritage Sites in full or part due to their cultural past, for example, the Cornwall and West Devon Mining Landscape and the Heart of Neolithic Orkney.

Offshore marine activities have the potential to affect cultural heritage through physical disturbance of the seabed, which can result from all the technologies covered by the plan (e.g. seabed preparation for fixed structures and foundation installation, trenching of pipeline and cable routes, including in intertidal areas). Known wrecks and other obstructions are charted, but there is an accepted disparity between the number of known and likely remains on the seabed, many of which may be settlement contexts rather than wrecks. A comprehensive set of guidelines has been drafted in recent years to promote the consideration of marine heritage in offshore development assessment, including in survey design. National scale policies contained in the Marine Policy Statement (MPS), and now regional marine plans, emphasise the importance of non-designated sites (which can be exemplified by the contribution of knowledge to the early settlement history of Britain from the findings of work undertaken in relation to the aggregates industry), and this is now being implemented at a project level, with Development Consent Order conditions generally requiring a written scheme of archaeological investigation in consultation with relevant bodies such as Historic England, and where relevant, subsequent post-consent monitoring and material archiving.

No further strategic level controls were identified during the SEA assessment, and it is through development and site specific surveys that cultural heritage features would be identified and mitigation measures and monitoring measures developed.

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 offshore renewables and oil and gas (including gas storage) 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 hydrocarbon or renewable 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. Displacement, barrier effects and collision risk represent potentially significant sources of cumulative effects to birds (and potentially marine mammals) at a local or regional level but are considered unlikely to be significant to bird populations at a strategic level, while recognising potential cumulative (and in-combination) impact assessments and the determination of significant effects and appropriate mitigation will be required on a project-specific basis. The SEA recommends a precautionary approach to facility siting in areas known to be of key importance to bird and marine mammal populations unless evidence indicates otherwise, and also that information on the distribution, behaviour and interactions with offshore renewable devices is in many cases limited and that additional work is required to improve current models on marine mammal and bird response/collision risk.

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, other marine renewables, and gas storage (including CO_2 storage) related infrastructure at the coast and within visible distance from the coast. 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. Progress is being made on mitigating the effects on military and civilian radar from offshore wind farms, but no universal solution is yet available, and further work is required to refine solutions at the site and development specific level.

Atmospheric emissions resulting from fossil fuel use during offshore renewables 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, and reflects the need to reduce the carbon intensity of energy production. 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, but could in part be abated through CCS. 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 and decarbonise the energy industry.

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 effect of multiple noise sources is an area which requires 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 implementation of marine planning in the UK has set a national scale policy framework through the MPS, which in many instances formalised a number of accepted practices which together represented *de facto* marine planning in advance of the Marine and Coastal Access Act and related initiatives. Subsequent marine planning provides a regional to local scale emphasis which, in combination with the national energy policy statements, will help to inform developers and decision makers including in relation to the activities covered by the draft plan/programme subject to this SEA. It is expected that a complete set of marine plans for UK waters will be adopted by 2021, by which time reviews of older plans will have commenced. The SEA has in the past contributed to both an understanding of potential interactions with the environment and wider range of other users for the draft plan/programme, and now is also informed by work undertaken as part of marine spatial planning.

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, and be made in the context of a move to decarbonise the energy supply sector, while maximising economic recovery of resources from what are mature hydrocarbon basins. 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 used, rather than mostly flared as in some other potential sources of supply.

The expansion of offshore renewables and the transport and storage of carbon dioxide following capture, will make positive contributions to UK Government targets of reducing greenhouse gas emissions (34% reduction on 1990 levels by 2020), in addition to the achievement of producing 15% of energy from renewable sources by 2020, which will be significantly progressed by the expansion of offshore renewables. Achieving these goals (including maximising economic recovery) also promotes energy security through the maximisation of domestic supplies, and may further contribute to other national goals such as reducing dependency on gas imports, and the enhancement of gas storage infrastructure.

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 have been or are in the process of being extended. In addition, the *Marine and Coastal Access Act 2009* introduced further requirements for identification and designation of Marine Conservation Zones (or Marine Protected Areas under the *Marine (Scotland) Act 2010*), a number of which have been identified and designated. These will require careful consideration in the selection of offshore wind farm and other marine renewables sites and oil and gas/gas storage (including carbon dioxide storage) infrastructure to avoid adverse effects on the integrity of the sites by compromising conservation objectives. Additionally, frameworks for the wider improvements in the environmental and ecological/chemical status of UK water bodies are provided by the Marine Strategy Framework Directive and Water Framework Directive respectively. A number of targets have been set in relation to aspects of the marine and coastal environment through these initiatives and work is ongoing to achieve these. Any leasing/licensing decisions will need to be cognisant of these targets, and their integration into development consenting can be seen, for example, with the implementation of the noise registry (see above).

Closely related to the above are shoreline management plans and other initiatives (e.g. flood risk management strategies) which consider the potential implications of coastal and nearshore development, and the possible changes in the coast and flood risk from sea-level rise linked to climate change – the appropriateness of development in areas potentially affected by sea-level rise is also a consideration of the MPS and terrestrial policy such as the National Planning Policy Framework. Linked to coastal change is the potential need for future defences or else managed realignment, and the compatibility of this, particularly in estuarine areas, with maintaining the integrity of Natura 2000 sites. Activities associated with the draft plan/programme have the potential to interact with the coast and therefore the objectives of the above through landfall of pipelines and cables (though temporary) and installation of tidal range devices.

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 OESEA3 covers a range of activities, some of which could take place in all UK waters, and others which are considered only for England and Wales. Transboundary effects are therefore 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

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.

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 together with a number of mitigation measures to prevent, reduce and offset significant adverse impacts on the environment and other users of the sea. It is considered that the objectives of the draft plan/programme can be achieved through this option.

There is limited data on the impacts of potential commercial arrays of wave and tidal stream technologies on the physical environment and habitats. Similarly, there is little information on the interaction of birds, marine mammals and fish with wave and tidal devices. The SEA recommends that for the deployment of single devices and small arrays (likely in the lifetime of OESEA3), appropriate surveys of animal activity and behaviour should be undertaken to inform commercial scale projects. The nature and uses of the range of estuaries and embayments in which tidal range developments have been and may be proposed vary widely; similarly there is a wide diversity in the type and location of installations to exploit tidal range. Consequently the SEA recommends that site specific assessments are undertaken before decisions can be taken on potential leasing and the desirability and acceptability of individual tidal range projects. Additionally, a series of proposals are made regarding precautions, areas to be withheld, operational controls and certain data gaps. The SEA has also identified a number of other data gaps for which recommendations are made to prioritise future research.

Significant steps towards formal marine spatial planning in UK waters have been taken in recent years, with national marine policy clarified at a UK level through the Marine Policy Statement. Most areas are yet to be subject to regional scale marine planning, but those undertaken to date have involved further opportunities for coastal regulators and communities to provide input to the way the marine environment in their areas is managed, which is in addition to the existing routes for consultation as part of the development consent process.

Next steps

The Offshore Energy SEA 3 Environmental Report and supporting documents are available for review and public comment for a period of 8 weeks from the date of publication. The documents are being made available from the SEA webpages of the gov.uk website and https://www.gov.uk/government/consultations/. Comments[3] and feedback should be marked "OESEA3 Consultation" and may be made via the website or by letter or e-mail addressed to:

Email: oesea3@decc.gsi.gov.uk

Postal address:

Offshore Energy SEA 3 Consultation
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Aberdeen AB11 6AR

The Department will consider comments received from the public consultation in their decision making regarding the draft plan/programme. Following public consultation a Post Consultation Report will be prepared and placed on the SEA webpages collating the comments, DECC responses to them. On adoption of the plan/programme a Statement will be published detailing:

- how environmental considerations have been integrated into the plan/programme
- how the Environmental Report has been taken into account
- how opinions expressed by the consultation bodies and public consultees on the relevant documents have been taken into account
- how the results of any consultations entered into with other Member States have been taken into account (if required)
- the reasons for choosing the plan/programme as adopted, in the light of the other reasonable alternatives dealt with; and
- the measures that are to be taken to monitor for potential significant environmental effects of the implementation of the plan/programme.

[3] **Confidentiality and data protection:** We will summarise all responses and place this summary on the OESEA3 section of the GOV.UK website. This summary will include a list of organisations that responded, but not people's personal names, addresses or other contact details. Information provided in response to this consultation, including personal information, may be subject to publication or disclosure in accordance with the access to information legislation (primarily the Freedom of Information Act 2000, the Data Protection Act 1998 and the Environmental Information Regulations 2004). If you want information that you provide to be treated as confidential please say so clearly in writing when you send your response to the consultation. It would be helpful if you could explain to us why you regard the information you have provided as confidential. If we receive a request for disclosure of the information we will take full account of your explanation, but we cannot give an assurance that confidentiality can be maintained in all circumstances. An automatic confidentiality disclaimer generated by your IT system will not, of itself, be regarded by us as a confidentiality request.

1 Introduction

1.1 Offshore Energy Strategic Environmental Assessment 3

This Environmental Report has been prepared as part of the United Kingdom Department of Energy and Climate Change (DECC) Offshore Energy Strategic Environmental Assessment (OESEA) programme and is hereafter referred to as OESEA3. The SEA process aims to help inform licensing and leasing decisions by considering the environmental implications of the proposed plan/programme and the potential activities which could result from their implementation. The relevant areas for OESEA3 and a summary of the Draft Plan under consideration are described in Sections 1.5 and 2.4 respectively.

Previous SEAs undertaken as part of this programme included the OESEA in January 2009 and OESEA2 in February 2011, which built on a series of earlier regional scale SEAs undertaken by DECC and its forerunner departments since 1999. OESEA considered the environmental implications of a draft plan/programme to enable: further seaward rounds of oil and gas licensing, including gas storage in UK waters; and further rounds of offshore wind farm leasing in the UK Renewable Energy Zone (now Exclusive Economic Zone)[4] and the territorial waters of England and Wales to a depth of 60m. During 2010, DECC undertook an exercise to update and extend the scope of the OESEA Environmental Report and issued OESEA2 for consultation for further licensing/leasing for offshore energy including oil and gas, gas storage including carbon capture and storage (CCS) and marine renewables (wind, wave and tidal technologies).

The indicative time horizon (i.e. period of currency) for OESEA2 was 5 years from publication. During this period, as with previous SEAs, DECC has maintained an active SEA research programme; identifying information gaps (some of which were outlined in the recommendations of previous SEA Environmental Reports), commissioning new research where appropriate, and promoting its wider dissemination through a series of research seminars. This has also involved continued engagement with the SEA Steering Group and review of the information base for the SEA, including the environmental baseline, other relevant plans and programmes, and policy and regulation. OESEA3 is intended to:

- Consider the environmental implications of DECC’s draft plan/programme to enable further licensing/leasing for offshore energy (oil and gas, hydrocarbon gas storage, carbon dioxide storage and marine renewables including wind, wave, tidal stream and tidal range). This includes consideration of the implications of alternatives to the plan/programme and consideration of potential 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

[4] this part of the plan/programme did not include the territorial waters of Scotland and Northern Ireland.

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 (now codified by Directive 2011/92/EU, which is itself amended by Directive 2014/52/EU). Under the terms of Article 3(2a) of the SEA Directive, all plans/programmes prepared for energy must be subject to environmental assessment.

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 SEA Directive. This 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.

A required part of SEA is consultation with the consultation bodies/authorities (see Section 1.4.1) and public, together with such neighbouring states as may be potentially significantly affected.

1.3 Previous DECC SEAs

The SEA process aims to 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, in addition to OESEA and OESEA2, the Department has conducted seven regional SEAs of the implications of further licensing of the UK Continental Shelf (UKCS) for oil and gas exploration and production (SEAs 1-7[5]), an SEA for a second round (R2) of wind leasing – see Table 1.1 and Figure 1.1 overleaf – and also SEA work for the potential exploitation of tidal range power in the Severn.

OESEA3 builds on the work completed for the previous SEAs. Preparatory to OESEA, 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. A similar exercise was undertaken for other types of marine renewable energy generation, which led to the inclusion of wave, tidal stream and tidal range in OESEA2, and engagement with initiatives of the devolved administrations and the Severn tidal power feasibility study. The draft plan/programme for OESEA3 (Section 2.4) includes those elements of former plans/programmes but also includes more detailed consideration of tidal range technologies.

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[5] The SEA 8 area was incorporated into OESEA.

Table 1.1: Previous DECC Offshore Energy SEAs

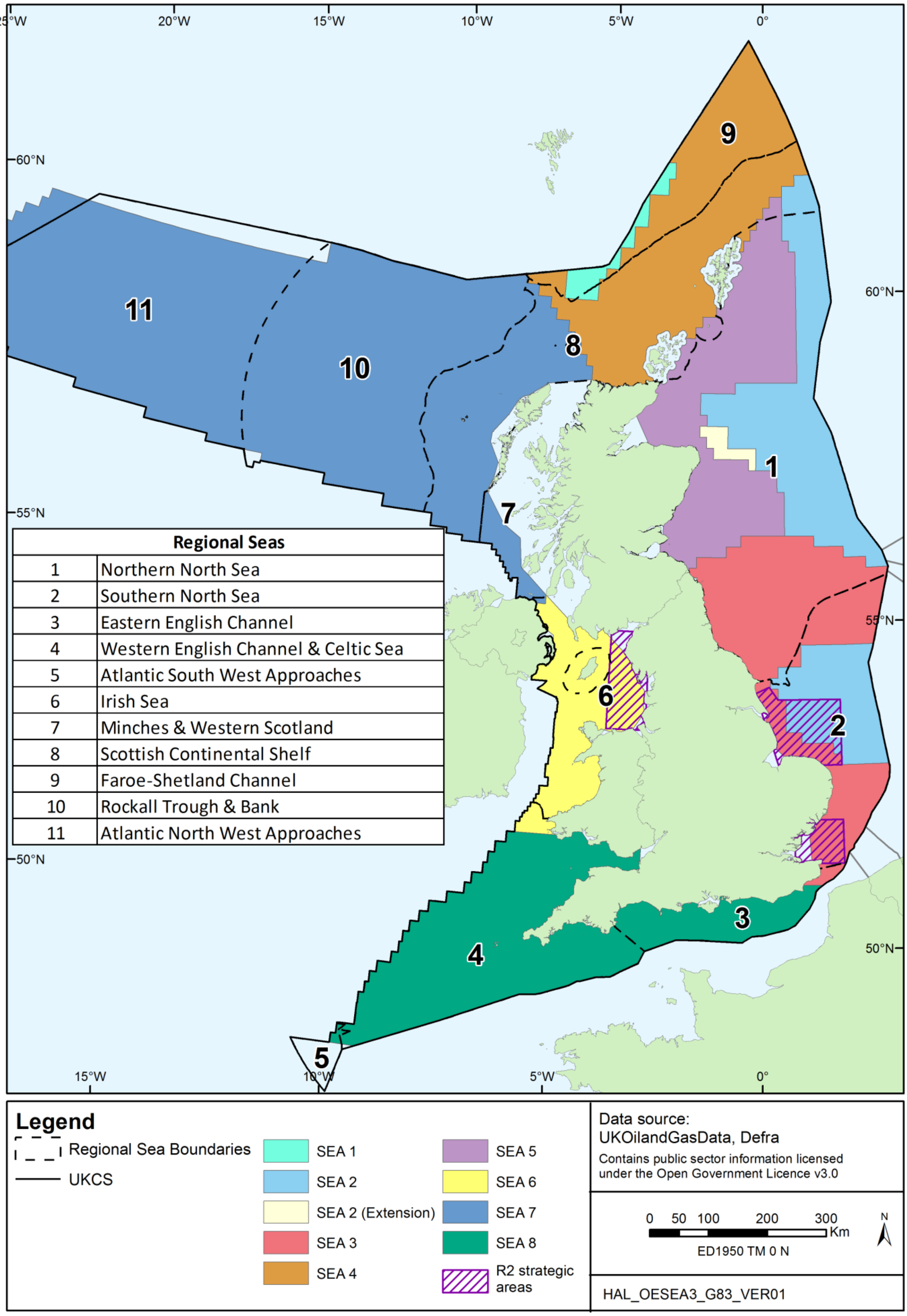
SEA	Area	Sectors covered	Year	Licensing/leasing round
SEA 1	The deep water area along the UK and Faroese boundary	Oil & Gas	2001	19th Round
SEA 2	The central spine of the North Sea which contains the majority of existing UK oil and gas fields	Oil & Gas	2002	20th Round
SEA 2 extension	Outer Moray Firth	Oil & Gas	2002	20th Round
SEA 3	The remaining parts of the southern North Sea	Oil & Gas	2003	21st Round
R2	Three strategic regions off the coasts of England and Wales in relation to a second round of offshore wind leasing	Offshore wind	2003	Round 2
SEA 4	The offshore areas to the north and west of Shetland and Orkney	Oil & Gas	2004	22nd Round
SEA 5	Parts of the northern and central North Sea to the east of the Scottish mainland, Orkney and Shetland	Oil & Gas	2005	23rd Round
SEA 6	Parts of the Irish Sea	Oil & Gas	2006	24th Round
SEA 7	The offshore areas to the west of Scotland	Oil & Gas	2008	25th Round
OESEA*	UK offshore waters and territorial waters of England and Wales	Oil & Gas, Offshore wind	2009	26th Round/Round 3
OESEA2	UK offshore waters and territorial waters of England and Wales	Oil & Gas, Offshore wind, wave and tidal stream, gas and carbon dioxide storage	2011	27th Round
			2014	28th Round

*Note: *incorporated the SEA 8 area*

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.

Figure 1.1: Previous DECC Offshore Energy SEAs



1.4.1 Consultation Bodies/Authorities

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 statutory consultation bodies/authorities for this SEA:

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

In addition, the Joint Nature Conservation Committee, Marine Management Organisation and Marine Scotland will also be included as consultation bodies for this SEA and the Isle of Man will also be consulted.

1.5 The relevant areas

For offshore renewable energy, this SEA considers potential leasing in the relevant areas of the UK Exclusive Economic Zone (EEZ), and also the territorial waters of England and Wales. The area covered by the Scottish Renewable Energy Zone and Scottish and Northern Irish waters within the 12 nautical mile territorial sea limit are not included for this part of the plan.

For gas storage and carbon dioxide storage, the SEA considers potential licensing/leasing in relevant UK territorial waters (excluding Scottish territorial waters where CCS is a devolved matter) and the UK EEZ.

For offshore (seaward) oil and gas licensing, this SEA covers all UK waters (previous SEA 1 to 8 areas).

It should be noted that the establishment of the EEZ[6] follows agreement on a number of treaties with adjacent states, and that some activities may be subject to certain restrictions in the part of the EEZ known as the Faroes Special Area.

The geographical coverage within which areas may be leased/licensed following adoption of the plan is shown in Figures 1.2 and 1.3. The prospectivity of these areas in relation to plan activities is discussed in Section 2.

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[6] See *The Exclusive Economic Zone Order 2013*

Figure 1.2: Areas mentioned in the text: the UKCS, UK Exclusive Economic Zone, Scottish Renewable Energy Zone and Territorial seas

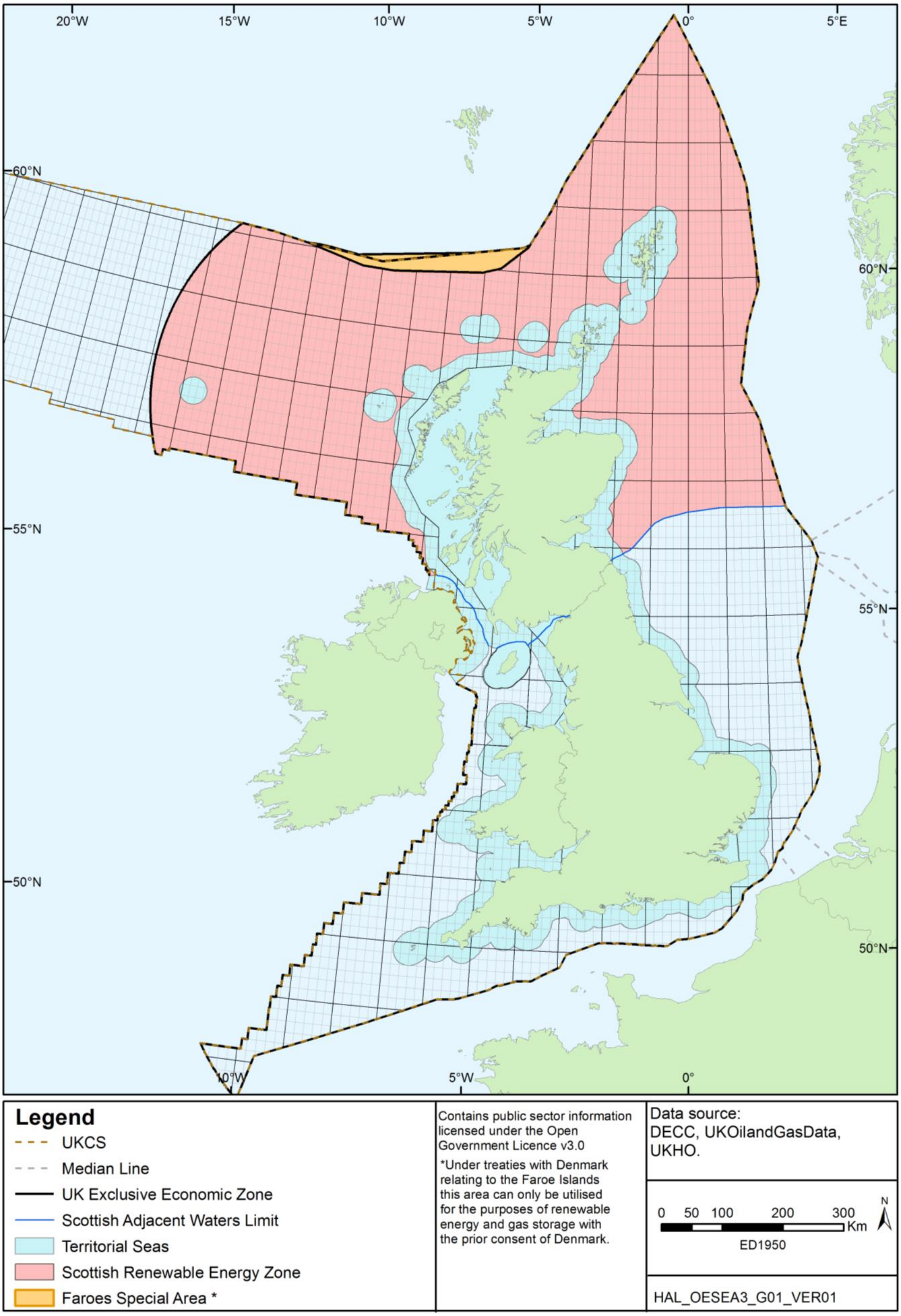


Figure 1.3: Geographical coverage of the SEA (Offshore Renewables)

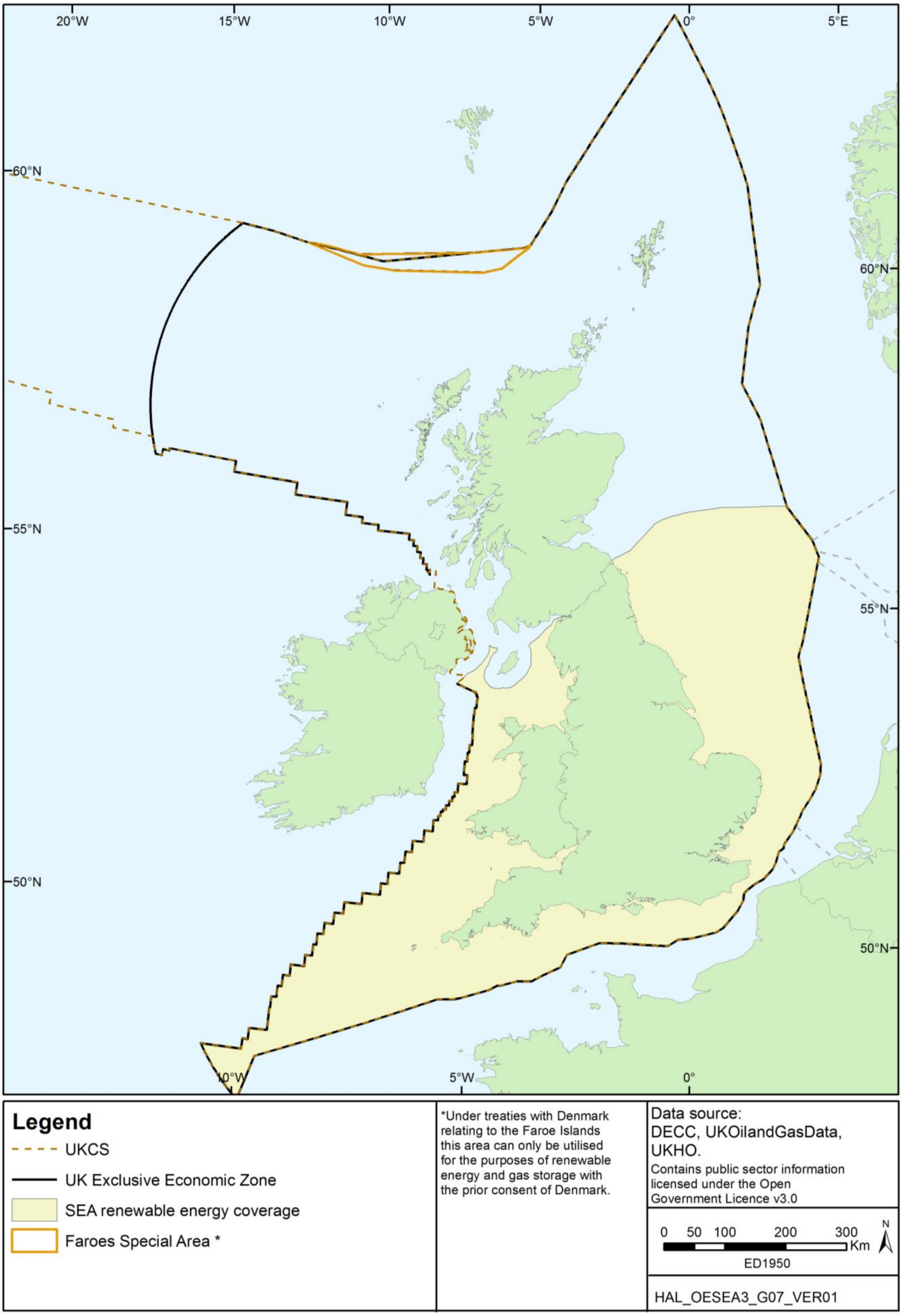
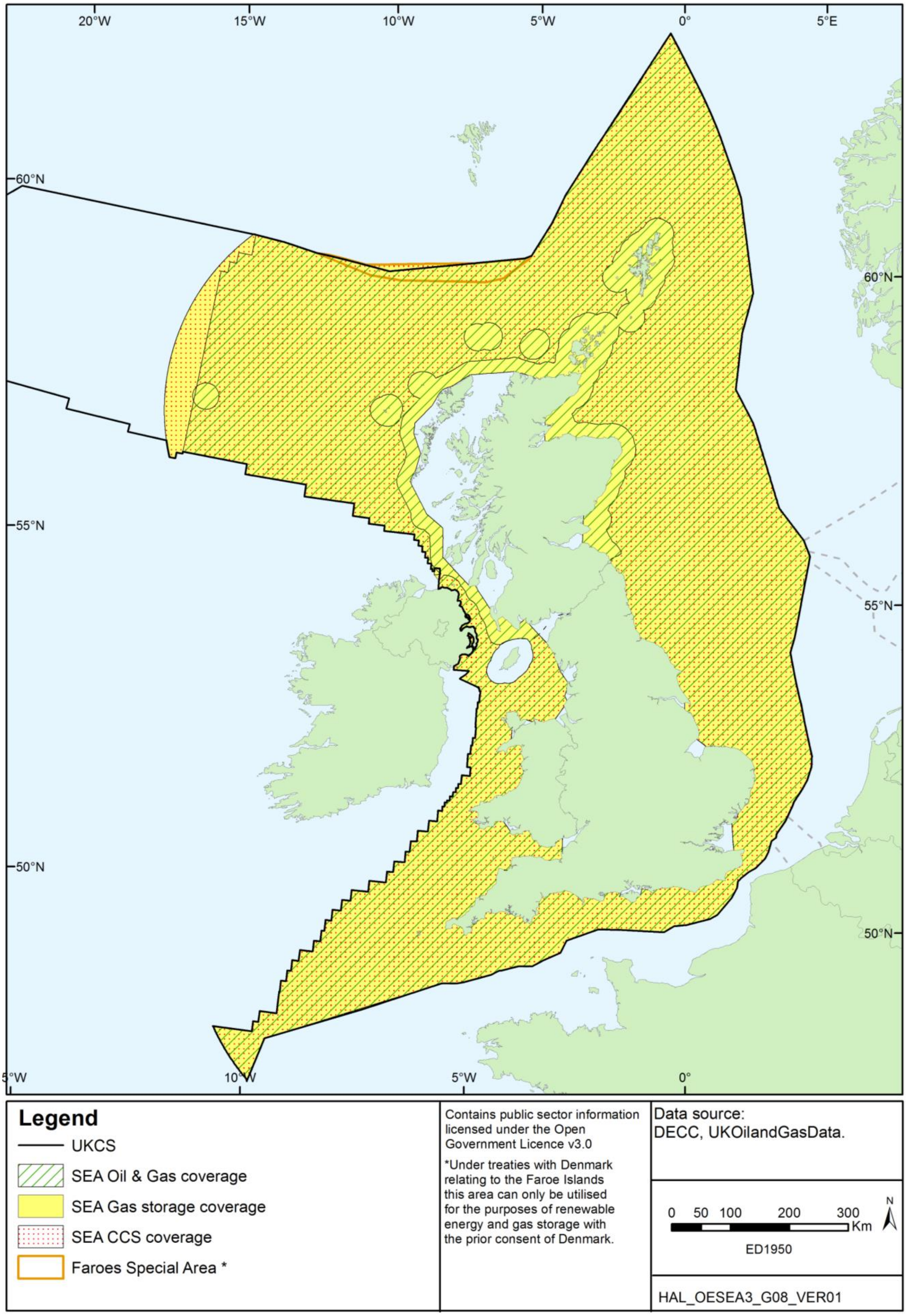


Figure 1.4: Geographical Coverage of the SEA (Oil and Gas, Gas Storage, CCS)



1.5.1 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 1.2. 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 1.2: 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 interrelationship 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 1.3.

Table 1.3: 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.

1.6 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, the following table 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 1.4: Structure of the Environmental Report

Section	Summary
Non-technical summary	A stand alone summary in non technical language of the SEA, its findings and conclusions.
1. Introduction	Describes the background to the draft plan/programme and the regulatory context and purpose of the SEA and the ER.
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.
3. SEA approach	Describes the scope and methodology of the SEA.
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.
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.
6. Recommendations and monitoring	Provides an overall conclusion on the likely implications of the proposed licensing/leasing and alternatives, together with recommendations for mitigation and monitoring, and identification of relevant gaps in understanding.
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.
	References
	Glossary and abbreviations
Appendix 1: Environmental Baseline	Underpins Section 4 and contains a series of sub-appendices (A1a to A1j) describing the key characteristics in relation to biodiversity, habitats, flora and fauna; geology, substrates and coastal geomorphology; 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 (see Figure 1.1 for Regional Seas boundaries).
Appendix 2: Other Initiatives	Describes other initiatives, plans and programmes of relevance to the proposed plan/programme, the implications of these for the proposed plan/programme and vice versa.
Appendix 3: Regulatory and other controls	Summarises the key environmental legislation and controls applying to the activities encompassed by the draft plan/programme.
Appendix 4: SEA Stakeholder Workshops	Contains summaries of the range of workshops (assessment, regional stakeholder and sector) which contributed to the SEA process and information base.

1.7 The study team

This report was prepared by independent consultants, Hartley Anderson Limited, in conjunction with DECC. Contributions/input to the assessment process from the SEA Steering Group, studies commissioned for the DECC SEA process and the participants in the SEA workshops are reflected in the Environmental Report.

1.8 Public consultation

The Environmental Report and draft plan/programme will be issued for formal consultation as required by the SEA Regulations. The OESEA consultation process has been designed to be in keeping with the Cabinet Office 2016 guidance on Consultation Principles for engaging stakeholders which as available at https://www.gov.uk/government/publications/consultation-principles-guidance.

2 Overview of the draft plan/programme & relationship with other initiatives

2.1 Introduction

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 2.

2.2 Energy policy context

The UK Government is committed to the reduction of greenhouse gas emissions[7] by 80% on 1990 levels by 2050, with an interim target of 34% by 2020, as implemented in the *Climate Change Act 2008* (as amended). Subsequent *Climate Change Act Orders* outline carbon budgets for defined time periods, with the most recent (fourth) carbon budget (*The Carbon Budget Order 2011*), containing a target of 50% reduction in emissions on 1990 emissions by 2025. A further target of 57% by 2032 has been recommended by the CCC (2016) for the fifth carbon budget but is yet to be accepted and applied. DECC are due to set the level of the fifth carbon budget by the end of June 2016.

DECC have made a series of energy and emissions projections against UK targets and policies to help inform the requirement to develop new policy to meet carbon budget targets which were last updated for 2015 (in February 2016). Projections for 2013 to 2022 suggest that the UK will meet its second and third carbon budgets but that there is a shortfall in the fourth carbon budget assuming no new effort (e.g. additional policy), and uncertainty over the long-term policy framework beyond 2020 has been identified by the Committee on Climate Change (CCC) (2015) as a key risk to future progress. The Carbon Plan (2011) set out how the UK Government intended to achieve the fourth carbon budget, which will include the transition to a low carbon economy while maintaining the security of energy supply[8]. During this transition, which by 2050 is likely to comprise an increasing proportion of energy from renewable sources,

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[7] These emissions are usually framed in terms of carbon dioxide (CO_2) equivalent, and include other notable greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O). Carbon dioxide is the principal greenhouse gas of concern, accounting for 82% of total provisional UK emissions in 2014.

[8] See the Energy Security Strategy (2012). There is a statutory duty on Ofgem under the *Energy Act 2004* (as amended) to report annually on the availability of electricity and gas, which also meets UK obligations under, for instance Directive 2009/73/EC, the Gas Directive.

plus abated (with CCS) coal, biomass or gas-fired power stations and nuclear energy[9]; gas and oil will continue to play a valuable role for heating and electricity generation. In addition to decarbonising the energy supply sector, wider measures include reducing demand through greater energy efficiency in homes, businesses and in transport. The UK Government is presently reviewing its energy policy and the contribution to decarbonisation that this will make[10], with gas-fired power stations, new nuclear and offshore wind indicated as helping to achieve this, with continued commitment to CCS through gas- or coal-fired power station emissions abatement.

The Paris Agreement was adopted by parties to the United Nations Framework Convention on Climate Change (UNFCCC) in December 2015 and will likely come into force in 2016/2017 when ratified. The agreement (see Appendix 2 for more information) aims to hold the increase in global average temperatures well below 2˚C above pre-industrial levels, and to pursue efforts to limit this to 1.5˚C. It indicates that peaking of emissions should take place as soon as possible, with rapid reductions thereafter to achieve a balance between anthropogenic emissions and removals by sinks in the second half of this century. Other provisions contained in the Articles of the agreement include goals on adaptation which is recognised as a global challenge and a key component in addressing the response to climate change, financial support to developing countries by developed countries, and others on a voluntary basis with respect to mitigation and adaptation, and the transfer of knowledge and technology. National reporting and a "global stocktake" of progress provide means of establishing progress in implementing the agreement.

In this context, the UK has a target to generate 15% of its energy from renewable sources by 2020, stemming from the EU Renewable Energy Directive (2009/28/EC). Scenarios for achieving this were initially outlined in the 2009 UK Government Renewable Energy Strategy, superseded by the Renewable Energy Roadmap in 2011[11] (last updated in 2013), which was produced with advice from the CCC and the renewables industry. Both installed renewables capacity and energy generation have increased significantly in recent years. Provisional 2014 figures indicate that renewable generation was 17.9% of gross electricity consumption, 4.1% above 2013 levels. Overall, the generation of electricity from renewable sources has increased significantly over the past 10 years to approximately 64.7TWh in 2014. Using the reporting method for the Renewable Energy Directive, all UK renewable sources contributed approximately 7% to the UK's energy consumption in 2014[12]. Much of this has been delivered by offshore wind, and as indicated above, a recent announcement by the Energy Secretary indicates further support for this aspect of the draft plan, including of three further CfD auctions within the current parliament. Other renewables aspects of the plan are at a demonstration scale, and the UK Government has recently announced that a review is to be undertaken of how tidal lagoons could contribute to the future of the UK's energy mix in the most cost effective way[13].

While reliance on fossil fuel sources will continue during the transition (including through CCS), the UK is now a net importer of both oil and gas. Since 2000, UK domestic gas supply has

[9] See the DECC 2050 Pathways Calculator: https://www.gov.uk/2050-pathways-analysis, which shows that it is possible to meet the 80% emissions reduction target in a range of ways, and allows people to explore the combinations of effort which meet the emissions target while matching energy supply and demand.
[10] See: https://www.gov.uk/government/speeches/amber-rudds-speech-on-a-new-direction-for-uk-energy-policy
[11] Note that the devolved administrations have their own programmes and related targets, which are expanded upon in Section 2.
[12] Defined as the percentage of capped gross final energy consumption using normalised net calorific values, see DECC (2015). The UK met its 2011/12 and 2013/14 interim targets of 4.04% and 5.4% respectively (DECC 2013).
[13] https://www.gov.uk/government/news/review-of-tidal-lagoons

declined at an average rate of 8% per year, with net imports commencing in 2004, and similarly, UK oil production has been in decline since a peak in 1999, with net imports of oil commencing in 2005. In 2014, imports met approximately 48% of the UK's oil and gas demand. A linked factor in enhancing security of supply is the need for more gas storage capacity, since until recently seasonal fluctuations in UK gas demand were met by varying production rates from UK fields.

Despite these declines, the UK remains the largest producer of oil and gas in the EU, and successive oil and gas licensing rounds attract significant interest – the 27th Round attracted the highest number of applications since licensing began, and the most recent 28th Round attracted the third largest number. Reductions in the recent production and exploration of the UKCS sector led to the Wood Review in 2013, which set out a number of recommendations that were accepted by Government, including maximising economic recovery and the creation of the Oil & Gas Authority (OGA). The OGA was formally established as an executive agency of DECC in April 2015 and is scheduled to become a Government Company by summer 2016. The OGA has responsibilities including oil and gas licensing, exploration and production, fields, wells and other infrastructure, and CCS licensing. The *Infrastructure Act 2015* amended the *Petroleum Act 1998* (Part 1A), creating an obligation on the Secretary of State to produce a Strategy for enabling the principal objective of "maximising the economic recovery of UK Petroleum" and for this strategy to be produced by April 2016. This has resulted in the "Maximising Economic Recovery of UK Petroleum Strategy for the UK" (MER UK). The MER UK Strategy sets out a central obligation (effectively that relevant persons must take all steps necessary to secure that the maximum value of economically recoverable petroleum is recovered), and a number of supporting obligations and actions. The MER UK Strategy will be supported by a number of other amendments to the *Petroleum Act 1998*, to be enacted through the 2015/16 *Energy Bill* in due course (full details are provided in Appendix 2).

The development of CCS is another important element of the Carbon Plan, which is expected to be commercially deployed in the 2020s. In preparation for this, all new fossil fuel power stations of a type covered by the Large Combustion Plant Directive and with a capacity of 300MW or greater are not to be consented unless it can be demonstrated that carbon capture technology can feasibly be retrofitted, and the UK Government has reiterated its commitment to the phasing out of unabated coal-fired power stations, with a consultation due to commence in spring 2016 on the timing of plant closures.

The draft plan/programme to be covered by OESEA3 is therefore of key importance to the above policy context, and has the potential to significantly contribute to Government targets by enabling future rounds of renewable leasing for offshore wind, wave and tidal devices, and licensing for seaward oil and gas rounds and gas storage including for carbon dioxide.

2.3 Marine management context

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 Union, 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 MPAs by 2016 that, together with the Natura 2000 network, is ecologically coherent and well managed. As part of the UK implementation of such areas, the *Marine and Coastal Access Act 2009* and the Acts of devolved administrations provide powers to designate Marine Conservation Zones (MCZs) in England, Wales and

Northern Ireland, and equivalent Marine Protected Areas (MPAs[14]) in Scotland (see Appendix 1j).

OSPAR periodically publishes assessments in the form of Quality Status Reports (QSRs) of the North-East Atlantic and its sub-regions, with the most recent being published in 2010. QSR 2010 informed 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 2008/56/EC (MSFD) entered into force in July 2008. The *Marine Strategy Regulations 2010* transpose the Directive into UK law and require the development of the five elements of the marine strategy: (1) the assessment of marine waters; (2) the determination of the characteristics of good environmental status for those waters (note these are qualitatively described in Annex I to the Directive); (3) the establishment of environmental targets and indicators; (4) the establishment of a monitoring programme; (5) the publication of a programme of measures.

The key objectives of the Directive are to achieve good environmental status (GES) 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 (Figure 2.1). 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. To fulfil these requirements the UK has prepared documents (e.g. the Marine Strategy Parts 1, 2 and 3, and proposals for UK monitoring programmes and programmes of measures to maintain or achieve GES). 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. Analogous to the contribution to the wider OSPAR MPA network, existing and proposed Natura 2000 and MCZ/MPA sites will contribute to this measure.

The MSFD complements measures being undertaken as part of the UK implementation of the Water Framework Directive (WFD), particularly in coastal waters where geographical scope of the Directives overlap (out to 1nm in England and Wales, and 3nm in Scotland), and also in transitional waters (see Figure 2.1). River Basin Management Plans (RBMPs) are one of the principal means through which the WFD has been implemented in the UK[15]. Whilst the implementation of WFD and MSFD may be complementary in these areas in terms of their objectives (e.g. particularly in relation to water chemical quality and some aspects of ecological quality and hydromorphological quality), for coastal waters MSFD will only cover those aspects of GES not already covered by the WFD.

The *Marine and Coastal Access Act 2009*, and Acts of devolved administrations, amongst other provisions was instrumental in formalising marine spatial planning in the UK, which at the EU level is subject to the Maritime Spatial Planning Directive 2014/89/EU which came into force in September 2014. At the highest level, the 2011 UK Marine Policy Statement (MPS) provides

[14] Note that Scottish MPAs may be designated for nature conservation (NCMPA), or demonstration and research (DRMPA), which are largely for nature conservation interests, or for historic interests (HMPA).
[15] A second cycle of river basin planning will cover the period 2015-2021.

the overarching framework for decision making and plan making in UK waters in keeping with the high level marine objectives agreed by the Governments of England, Scotland, Wales and Northern Ireland. The first set of marine plans in English waters, the East Inshore and Offshore Marine Plans, were adopted in 2014, with plans presently being prepared for the South Inshore and Offshore Regions[16]. Scotland's National Marine Plan was adopted in 2015, and a number of smaller Scottish marine regions will be subject to regional planning in the coming years. Other plans are presently in preparation (e.g. for Wales and Northern Ireland). Each of the regional and country marine plans should be drafted in keeping with the MPS but informed by regionally specific information, and enforcement and authorisation decisions should be taken in accordance with these regional marine policy documents, or the MPS in advance of their adoption. The MPS and adopted plans and related policies have been considered during the preparation of the SEA Environmental Report – National and regional marine planning areas are shown in Figure 2.2. Where policies have spatial aspects relevant to the plan, these have either be mapped or cross-referenced as appropriate.

Overarching National Policy Statements for Energy are also relevant to plan activities, and provide planning policy in relation to nationally significant infrastructure projects (NSIPs) for energy, as defined in the *Planning Act 2008* – this includes almost all offshore renewable energy projects in England and Wales; however, although regulated, there is presently no specific planning policy for tidal lagoons. (For more information see Section 2.7.5 and onshore aspects of certain projects e.g. onshore sections of marine pipelines in relation to CCS, gas storage and oil and gas.)

Decision making in relation to licensing/leasing and also subsequent activities which could take place as a result of the adoption of the draft plan/programme is therefore split between a number of legislative and planning policy remits, including those of devolved administrations (see Section 2.6 and Appendix 3).

[16] https://www.gov.uk/south-inshore-and-south-offshore-marine-plan-areas

Figure 2.1: Geographical coverage of the SEA in relation to MSFD sub-regions and relevant WFD waters

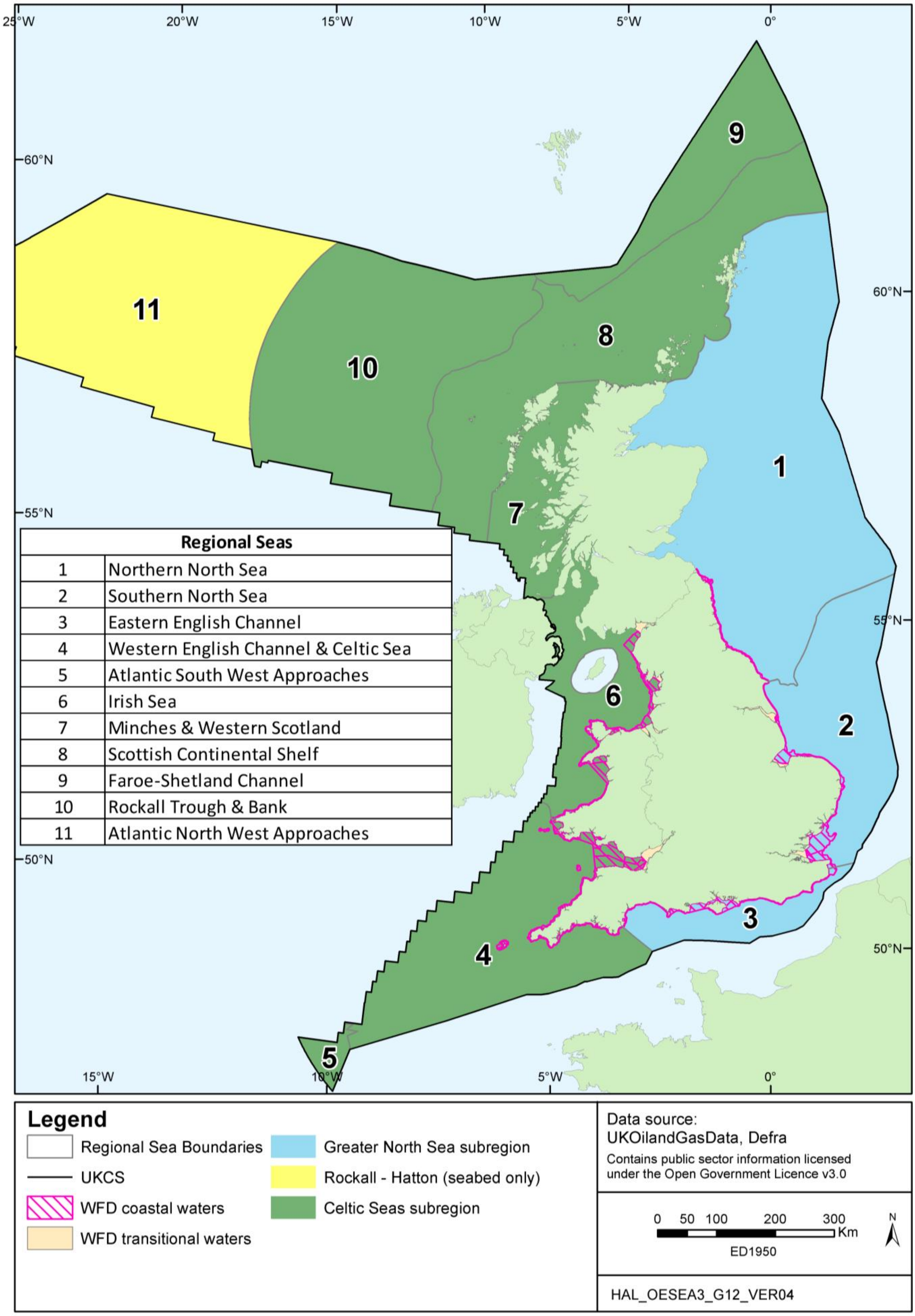
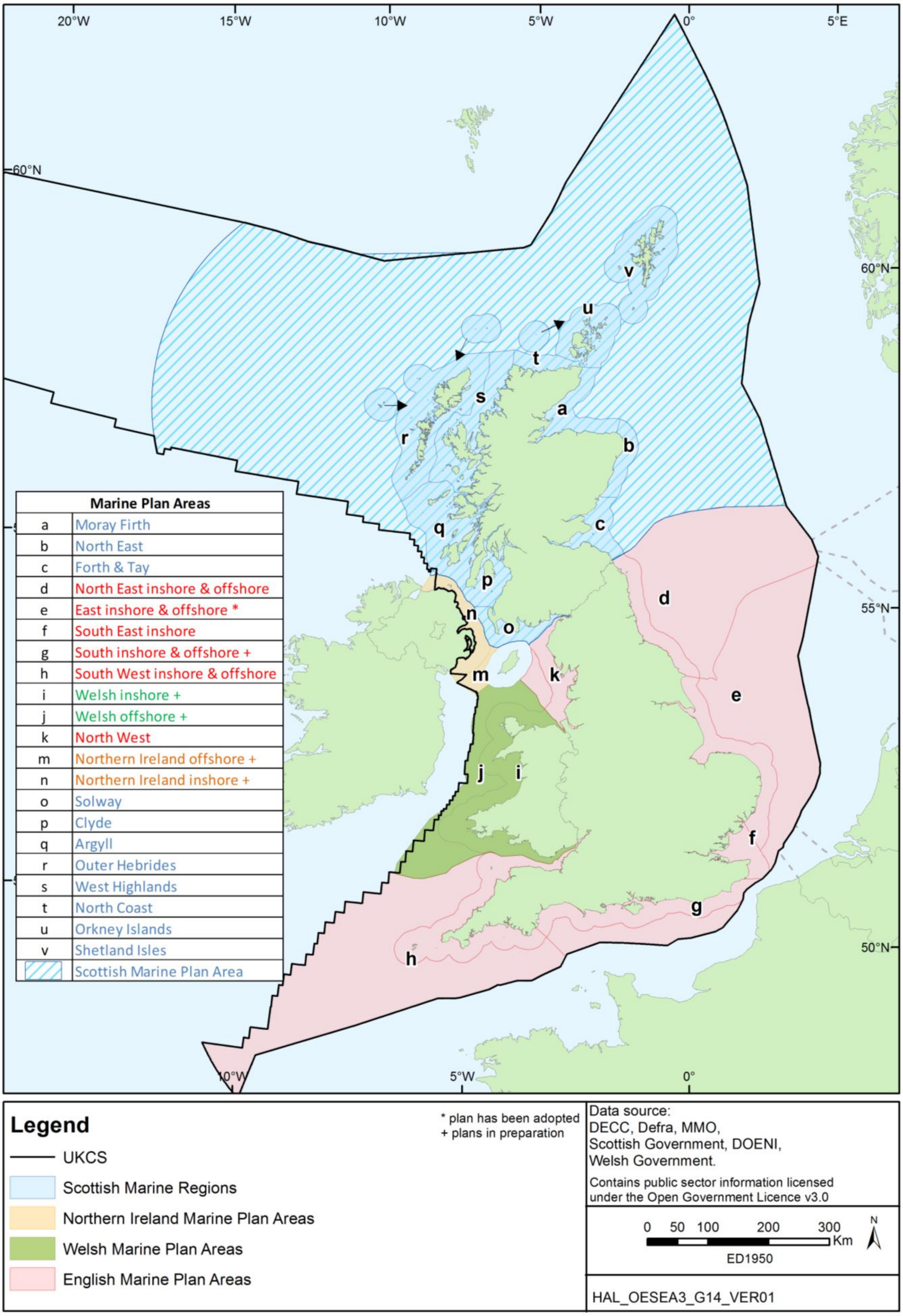


Figure 2.2: Geographical Coverage of the SEA in relation to UK Marine Spatial Planning Boundaries



2.4 The draft plan/programme

The DECC draft plan/programme under consideration is broad ranging and variously covers the range of energy related activities in the UK marine environment. The limits of areas mentioned below are graphically represented in Figures 1.2-1.4 above. The elements of the draft plan/programme are:

Renewable Energy:

1. Wave – future leasing in the relevant parts of the UK Exclusive Economic Zone[17] and the territorial waters of England and Wales. The Scottish Renewable Energy Zone[18] and Scottish and Northern Irish waters within the 12 nautical mile territorial sea limit are not included. In view of the relatively early stage of technological development, a target generation capacity is not set in the draft plan/programme.
2. Tidal Stream – future leasing in the relevant parts of the UK Exclusive Economic Zone and the territorial and internal waters of England and Wales. The Scottish Renewable Energy Zone and Scottish and Northern Irish waters within the 12 nautical mile territorial sea limit are not included. In view of the relatively early stage of technological development, a target generation capacity is not set in the draft plan/programme. Similarly, a minimum average tidal current velocity threshold is not proposed.
3. Tidal Range – future leasing in the internal and territorial waters of England and Wales. It is considered unlikely that there will be tidal range developments outside of territorial waters.
4. Offshore Wind – to enable further offshore wind farm leasing in the relevant parts of the UK Exclusive Economic Zone and the territorial waters of England and Wales to contribute the achievement of UK renewable energy targets and longer term decarbonisation goals. The technologies covered will include turbines of up to 15MW capacity and tethered turbines in waters up to 200m. The Scottish Renewable Energy Zone and the territorial waters of Scotland and Northern Ireland are not included in this part of the plan/programme.

Oil & Gas:

5. Exploration and production – further Seaward Rounds of oil and gas licensing of the UK territorial sea and UK Continental Shelf (UKCS).
6. Hydrocarbon gas importation and storage – further licensing/leasing for unloading and underground storage of hydrocarbon gas in UK waters (territorial waters and the relevant parts of the UK Exclusive Economic Zone), including in hydrocarbon gas storage in other geological formations/structures including constructed salt caverns, and the offshore unloading of hydrocarbon gas.

Carbon Dioxide:

7. Carbon dioxide (CO_2) transportation and storage – further licensing/leasing for underground storage of carbon dioxide gas in UK waters (the UK Exclusive Economic Zone and relevant

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[17] *The Exclusive Economic Zone Order 2013*
[18] *The Renewable Energy Zone (Designation of Area) (Scottish Ministers) Order 2005*

territorial waters, excluding the territorial waters of Scotland19). OESEA3 would include CO_2 storage in geological formations/structures including depleted reservoirs (and for enhanced oil recovery), aquifers and constructed salt caverns.

For this SEA it is anticipated that renewable energy devices will not be deployed in water depths of more than 200m, with the majority of developments expected to be in water depths of less than 60m. No depth constraints are envisaged for hydrocarbon exploration and production, or hydrocarbon and other gas storage activities. It should be noted that whilst the geographic remit of OESEA3 does not cover the entirety of the UKCS for some activities, DECC maintain links with the relevant devolved administrations, including on the SEA process and consultation exercises for this SEA.

OESEA3 is expected to have a 5 year period of currency. Several of the technologies covered in the draft plan/programme remain to be deployed at a commercial scale, and are likely to undergo rapid development and change during the currency of the SEA, for instance, in order to assist in achieving medium to long-term targets in relation to UK greenhouse gas emissions. The indicative time horizon will be periodically reviewed by DECC (as the competent authority) in the context of new information on technologies, effects, or plan/programme status.

2.5 Alternatives to the draft plan/programme

The following alternatives to the draft plan/programme 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

An overview of these alternatives including reasons for their selection is provided in Section 3.8.

2.6 Context to leasing and licensing

2.6.1 Oil & Gas

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 UKCS are vested in the Crown and the *Petroleum Act 1998* (as amended) gives the Secretary of State for Energy and Climate Change the power to grant licences to explore for and exploit these resources (note the impending changes to the Petroleum Act 1998 are referenced in Section 2.2). 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 but does not constitute any form of approval for activities to take place in the Blocks, nor does it confer any exemption from other legal or regulatory requirements.

[19] *The Storage of Carbon Dioxide (Licensing etc.) (Scotland) Regulations 2011, The Storage of Carbon Dioxide (Amendment of the Energy Act 2008 etc.) Regulations 2011*

There are presently 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. OGA at its discretion can offer different term lengths if an applicant makes a strong enough case, for instance where a high pressure high temperature (HPHT) prospect will take longer to plan and explore. In such cases the initial and/or second terms may be extended to six years.
- Frontier Production Licences are a variation of the Traditional Production Licence with longer terms. A Frontier Production Licence has a longer Initial Term (six years as opposed to four) with the objective of allowing companies to screen larger areas. After 3 years, the licensee must relinquish 75% of the licensed acreage. At the end of the Initial Term, 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). A variation on the Frontier Production Licence was introduced prior to the 26th Round. Designed for the particularly harsh West of Scotland environment, it is similar to the existing Frontier Licence but with an initial term of nine years with a Drill-or-Drop decision to be made by the end of the sixth year and (if the licensee chooses to drill) drilling to be completed within the remaining three years of the 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, OGA 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 OGA to complete the Work Programme (e.g. to drill a well). By the same point, it must also have satisfied OGA of its technical, safety, environmental and financial capacity to do so. A Promote licensee cannot pursue activity permitting or undertake operations until they have continued to the second phase of the initial term.

Applicants for licences are required to provide the OGA with a number of submissions in support of their applications, including submissions to enable the Competent Authority[20] to assess their safety and environmental competence and capability. It should be noted that the existing licence types may be subject to change; however, the general principles of the licences set out above are likely to remain the same.

2.6.2 Gas Storage

The *Energy Act 2008* (as amended) made provision for the designation of Gas Importation and Storage Zones (now encapsulated and superseded by the Exclusive Economic Zone) and

[20] DECC and the Health and Safety Executive (HSE)

creates a licensing framework for the unloading and storage of combustible gas offshore. The Act prohibits the carrying out of the activities below except in accordance with an Energy Act licence:

- 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 the above activities

A “controlled place” is a place in, under or over waters within the UK territorial sea, or within any area extending beyond the territorial sea within the Exclusive Economic Area. Carrying on such an activity without a licence, and in certain cases the breach of the conditions of a licence is a criminal offence, and the Licensing Authority for the issuance and regulation of licences is OGA. Operators will also need to obtain a grant of the appropriate rights (a lease) from The Crown Estate.

This Act also makes provision with respect to the interaction between activities regulated under the *Petroleum Act 1998* and gas storage activities (e.g. that the Secretary of State may give a direction that operations to recover gas from a formation are not regarded as boring for and getting petroleum within the meaning of the *Petroleum Act*).

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

2.6.3 Carbon Dioxide Storage

The *Energy Act 2008* (as amended) also provides for a similar licensing regime governing the offshore storage of carbon dioxide and makes it an offence to carry out storage activities without a licence. The regime applies to storage in the offshore area comprising both the UK territorial sea, and any area extending beyond the territorial sea within the Exclusive Economic Zone (EEZ). The licensing of carbon dioxide storage in Scottish territorial waters has been devolved to Scottish Government and so is not a consideration of this SEA. The *Energy Act 2008* (as amended) and related Regulations implement Directive 2009/31/EC in the UK. Licences specifically cover:

- Storage of carbon dioxide
- Conversion of a natural feature (for example, a saline aquifer) for such storage
- Exploration for a carbon dioxide storage site
- Establishment or maintenance of an installation for any of those purposes

The licensing authority for those waters relevant to the offshore carbon dioxide storage is the Secretary of State for Energy and Climate Change except in the case of the territorial sea adjacent to Scotland for which Scottish Ministers are the Licensing Authority. The use of the seabed or areas under the seabed for these activities also requires a Crown Estate lease. The licensing arrangements for carbon dioxide storage for the area indicated above, is contained within the *Storage of Carbon Dioxide (Licensing etc.) Regulations 2010* for England and Wales, and the *Storage of Carbon Dioxide (Licensing etc.) (Scotland) Regulations 2011*.

2.6.4 Offshore Pipelines

The activities listed above may require a subsea pipeline to export oil and gas, and for the transport of gas or carbon dioxide to underground storage. In order to place and use/modify a pipeline on the continental shelf a Pipeline Works Authorisation (PWA) or PWA variation is required (as per Part III of the *Petroleum Act 1998*) for both gas, carbon dioxide transport and offshore petroleum production activities, the consent for which is granted by OGA's Pipeline Works Authorisation Unit. Where a pipeline falls within territorial waters (i.e. within 12nm of the coast) a lease is required for that section of the pipeline from The Crown Estate. Any works which precede the installation of any pipeline (e.g. deposits of rock prior to a PWA being in place), may require marine licences under the *Marine and Coastal Access Act 2009*. Any part of a marine pipeline which extends above the low water mark is subject to the terrestrial planning regime, including the *Planning Act 2008* where appropriate (and not part of this SEA).

2.6.5 Offshore Wind Farms

Under *The Crown Estate Act 1961*, The Crown Estate is entrusted to manage assets on behalf of the Crown including most of the UK seabed out to 12nm, over half of the foreshore, as well as certain sovereign rights in respect of areas beyond the territorial sea. Such sovereign rights are vested in the Crown by the virtue of the designation of the EEZ, formerly covered by areas including the Gas Importation and Storage Zone (GISZ) or Renewable Energy Zone (REZ) under the *Energy Act 2008* and *Energy Act 2004* respectively. A lease from The Crown Estate 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. The Crown Estate grants rights in the form of an Agreement for Lease or Option Agreement. An Agreement for Lease generally grants a developer an option over an area of seabed. Exercise of the option by the developer will be conditional on it satisfying certain conditions. If the conditions are satisfied and the developer exercises the option, The Crown Estate will be obliged to grant a Lease of the seabed to the developer. The conditions to be satisfied before the developer may exercise the option will include the obtaining by the developer of all statutory consents for the proposed development. If the developer is unable to satisfy all the conditions within a certain time provided for in the Agreement for Lease, the option will lapse. During the option period the developer will be permitted to undertake surveys and deploy anemometry equipment etc. However, the developer is not permitted to commence construction of its development until and unless a Lease is granted. Potential offshore wind farm developers also require statutory consents from a number of Government departments before development can take place. During Rounds 1 and 2 of UK offshore wind farm development, successful applicants were awarded an Option for Lease by The Crown Estate.

The *Energy Act 2004* provided for the designation of Renewable Energy Zones from 12nm out to 200nm (now the UK EEZ and the Scottish Renewable Energy Zone) 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. For Round 3, The Crown Estate proposed that development would be undertaken within exclusive Zones and exclusivity agreements were signed for nine Round 3 zones, seven of which went on to receive planning applications for development. Similarly (outside of the remit of the Round 3 programme and this plan/programme), The Crown Estate offered exclusivity agreements to companies and consortia for 10 zones in Scottish territorial waters in 2009. Four projects have received development consent to date.

Under the *Planning Act 2008*, the Planning Inspectorate (PINS) assumed responsibility for consent applications for offshore electricity generating stations with a capacity of more than 100MW. Such applications to PINS will be under the Planning Act (which replaces the provisions of the *Electricity Act 1989*) for these developments. While PINS deals with the acceptance and examination of the application and provides a recommendation to the relevant

Secretary of State (in this case of Energy and Climate Change), the ultimate decision maker in these cases is the Secretary of State.

The *Marine and Coastal Access Act 2009* provided for the creation of the Marine Management Organisation (MMO). The MMO took over the processing of offshore renewable energy generating station applications in under section 36 of the *Electricity Act 1989* (i.e. those not considered to be nationally significant, >1MW but below 100MW[21]) in English and Welsh territorial waters and the UK EEZ. A single Marine Licence is required for activities formerly covered by the *Coast Protection Act 1949* and *Food and Environment Protection Act 1985* (FEPA). In the Scottish Renewable Energy Zone, Scottish Ministers are responsible for *Electricity Act 1989* consent decisions. Marine licensing in Scotland is handled by Scottish Ministers through the *Marine (Scotland) Act 2010* and the *Marine and Coastal Access Act 2009.*

2.6.6 Wave and Tidal Devices

The leasing and consenting processes for wave and tidal stream renewable energy generating developments are as described above for offshore wind, though tidal range developments consenting requirements may differ from those of offshore wind to reflect the likelihood of their being land-connected and being more akin to large terrestrial infrastructure development. The Crown Estate has not, to date, carried out any wave or tidal stream energy leasing rounds for English and Welsh waters but has offered leases for test devices or small arrays. No leases for tidal range proposals have yet been granted.

In a wider UK context, The Crown Estate launched a wave and tidal stream leasing round in the Pentland Firth strategic area in 2009 and six agreements for leases were entered into in 2010, with an associated potential capacity of 1.6GW. As part of the Scottish Government's Saltire Prize, which was open to applications between 2010 and 2015, four competitors gained Crown Estate leases and have either received consent or are in planning. A Northern Ireland SEA for its territorial waters was published in March 2010, and The Crown Estate has been discussing potential opportunities and supporting actions for offshore renewable energy deployment with the Department of Energy, Trade and Industry (DETI). The only operational device in Northern Ireland waters to date was the SeaGen turbine in Strangford Lough, which is now due to be decommissioned. During 2011-2012 following a leasing round for tidal projects in the strategic areas of Rathlin Island and Torr Head, Northern Ireland, two projects were awarded rights for commercial-scale developments. These projects have a combined total capacity of 200MW and are currently in development.

2.7 Prospectivity and likely scale of OESEA3 related activity

Though activities for the whole UKCS (for reserved matters) will be considered in the Environmental Report, the potential for areas to be leased/licensed for plan level activities to take place in any given area is spatially controlled to some extent by prospectivity. This may be the conditions in which hydrocarbons have accumulated over geological time, the presence of geological structures capable of trapping gas or carbon dioxide in the long term (see Appendix 1b for an overview), or the location of the best wind, tidal or wave energy resource (see Appendices 1d and 1f). The following sections outline the prospective conditions for each of the plan elements, which are followed by a series of maps showing prospectivity against existing or proposed projects which are part of former licensing/leasing of these activities. In each instance, the likely scale of activity envisaged during the lifetime of the SEA and the potential

[21] See the Electricity Act 1989 (Requirement of Consent for Offshore Wind and Water Driven Generating Stations) (England and Wales) Order 2001.

locations of any technologies to be deployed have been informed by past licensing/leasing Round experiences and input from industry and other relevant stakeholders.

2.7.1 Oil & Gas

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 for example 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 28th Round held in 2014. 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, see Figure 2.4. The southern North Sea and Irish Sea are largely gas provinces, with the central and northern North Sea, and West of Shetland areas being oil provinces.

The area of the Faroe-Shetland Channel, particularly north of 62˚N in UK waters, has been comparatively underexplored due to the presence of geology which poses barriers to seismic survey and drilling. However, techniques are now available to improve the understanding of prospectivity in this area. Similarly, areas of the mid North Sea High and Rockall Basin are relatively underexplored and prospectivity is less well understood for these regions. The OGA undertook two regional seismic surveys in 2015 covering these areas, the results of which are expected to augment existing data and update current understanding of prospectivity to inform future licensing, in particular the 29th Frontier Round.

The number of exploration and development wells drilled on the UKCS shows a general decline over time, aligned with a decline in domestic gas and oil production. Recent UKCS oil and gas licensing Rounds (27th and 28th Rounds) have maintained interest in exploration, including of mature hydrocarbon areas. 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 are increasingly well explored and understood, however, the possibility of future major commercial finds cannot be discounted entirely. It is considered likely that the scale of future licensing Rounds will be analogous to that of the recent 27th and 28th Rounds (although the number of applications received may be reduced reflecting the current low price of oil); for context, the scale of former licensing rounds and the number of exploration wells drilled on the offshore UKCS over the last 15 years is shown in Figures 2.3 and 2.4.

Figure 2.3: Trends in number of blocks offered during each round and those applied for/licensed, 2000-2015

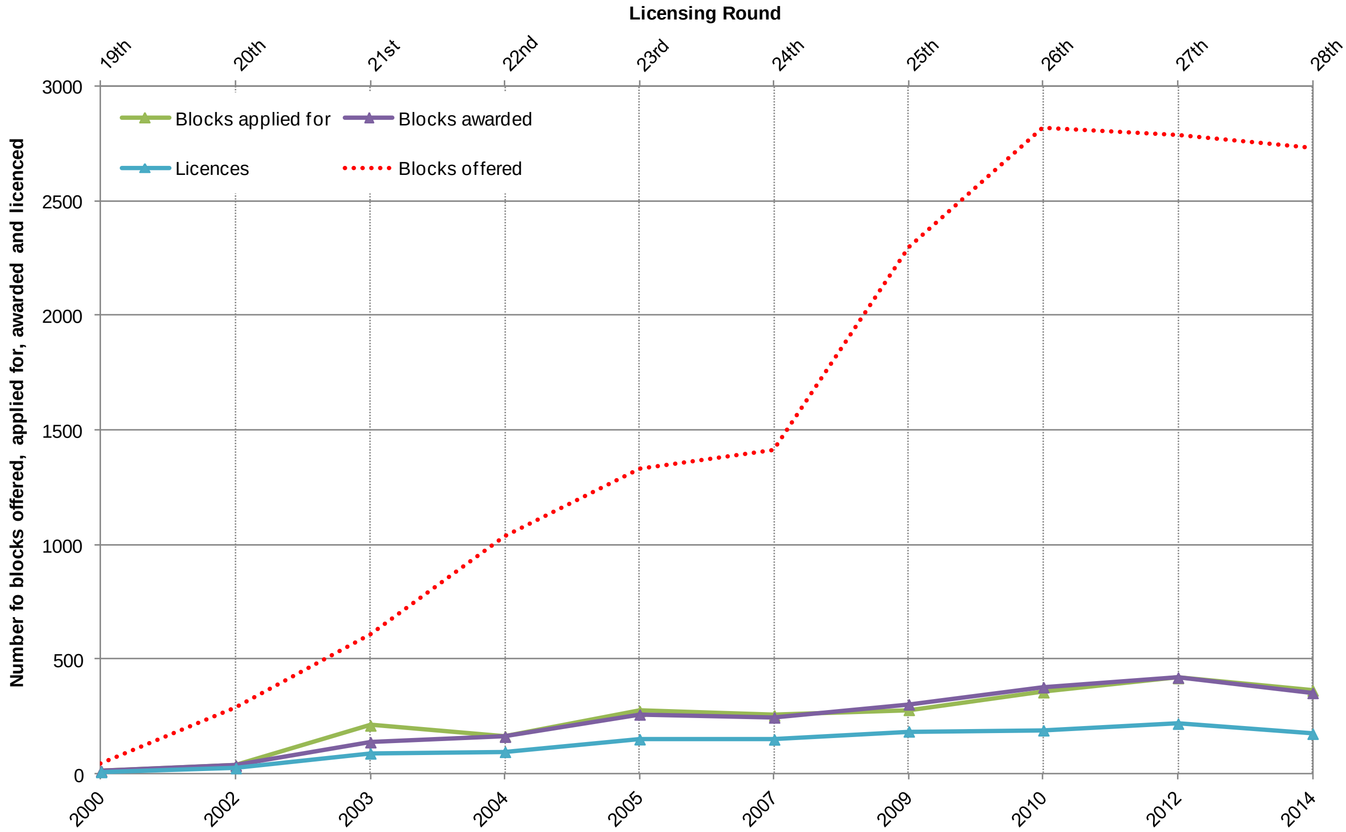


Figure 2.4: Trends in exploration drilling in different areas of the UKCS, 2000-2015

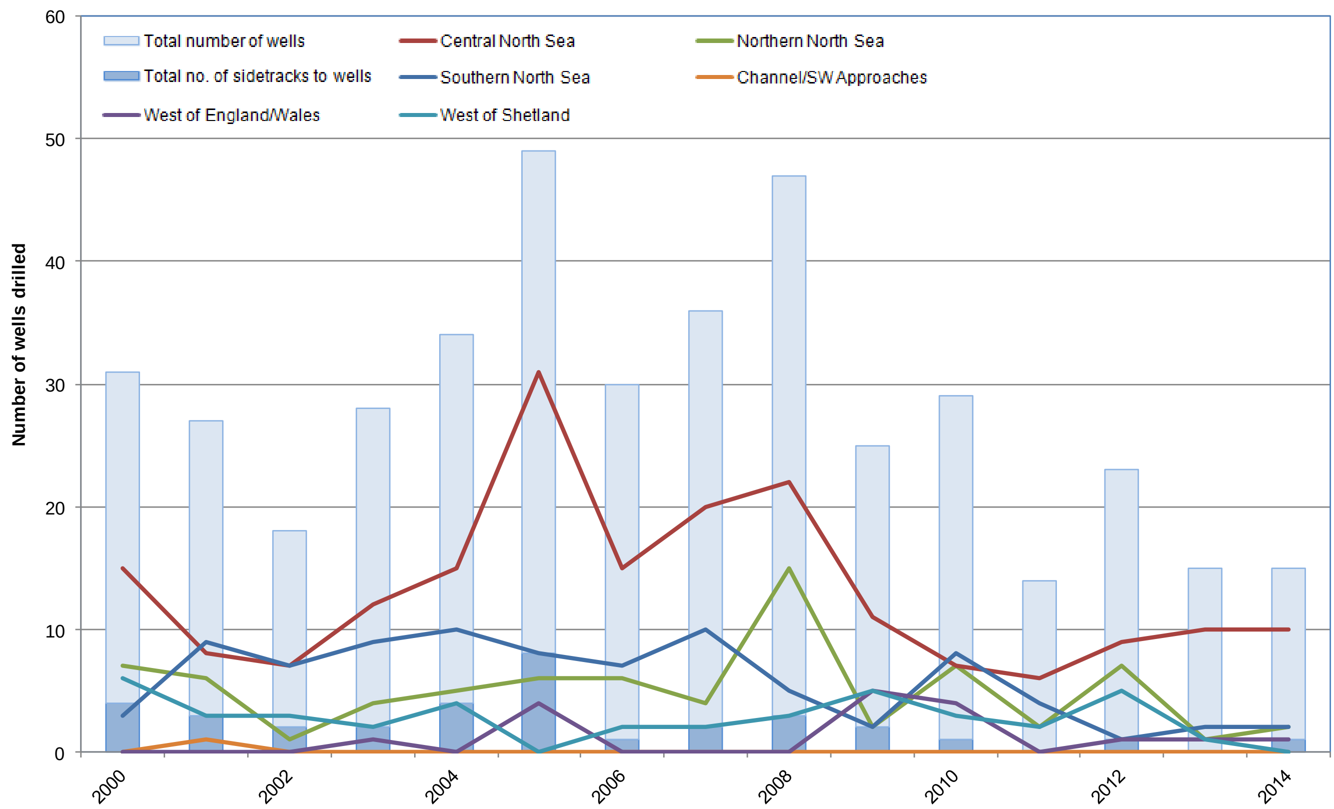


Figure 2.5: Location of existing oil and gas fields, infrastructure and licence areas

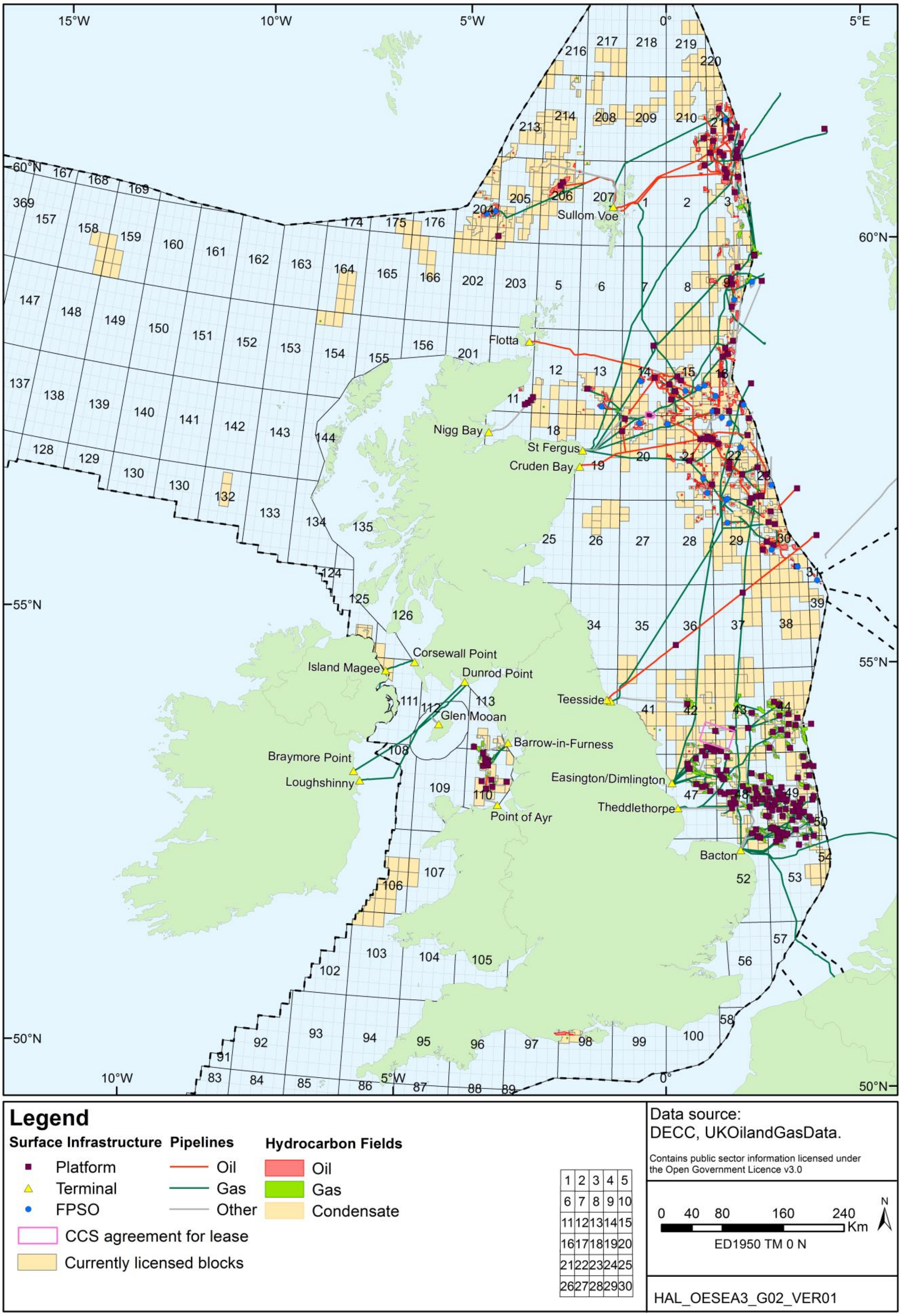
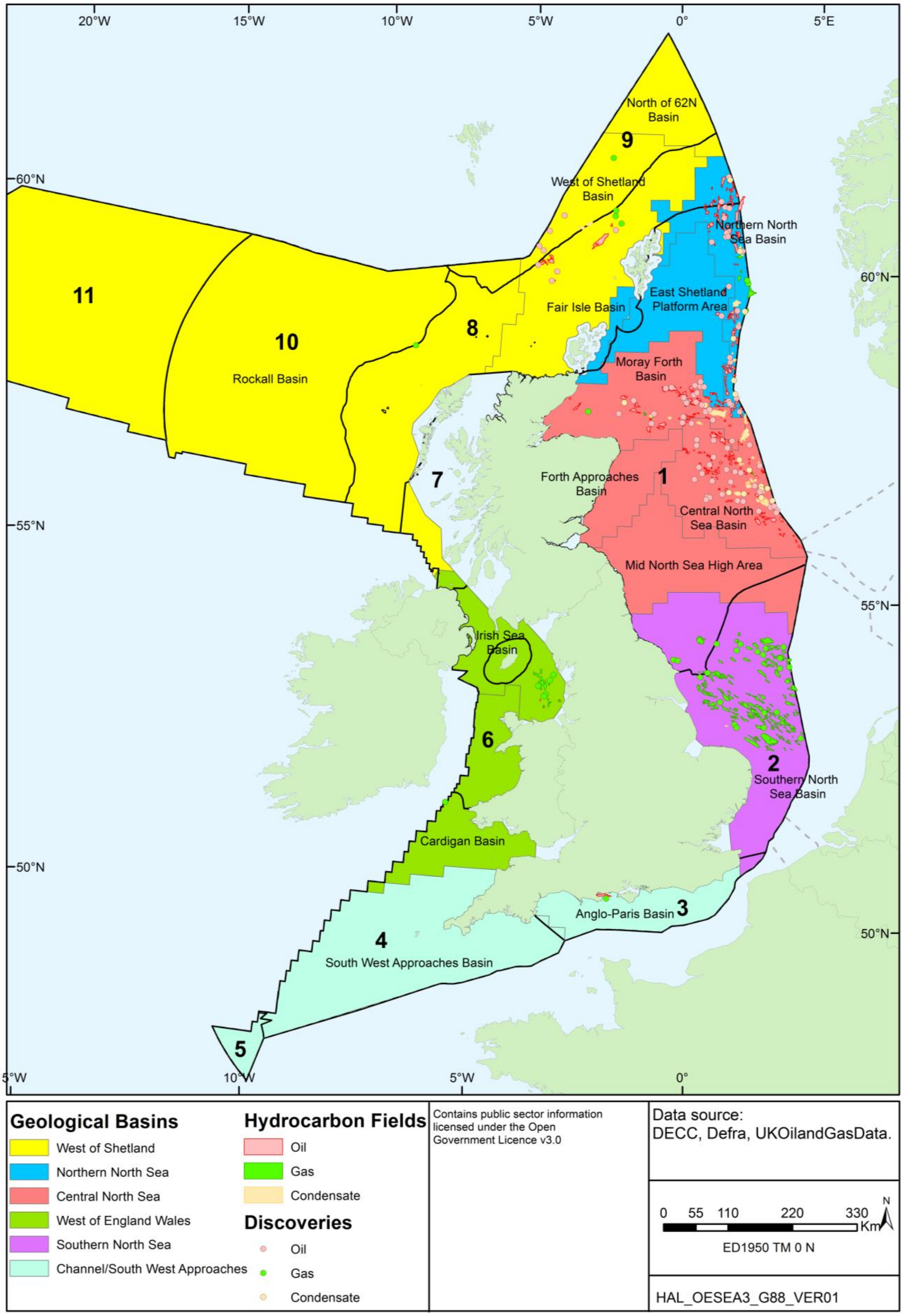


Figure 2.6: Major hydrocarbon basins, fields and discoveries on the UKCS



The main stages of oil and gas activity following licensing are:

- Exploration and appraisal: this involves initial exploratory drilling with well evaluation and testing typically using mobile drilling rigs, possibly preceded by seismic survey (note that purchase and reprocessing of existing seismic data is often used). Based on previous experience, typically less than half the wells drilled reveal hydrocarbons, and of that half less than half again will yield an amount significant enough to warrant development.
- Development: includes production facility installation which may be fixed or floating, and generally the installation of pipeline(s), which for major developments could come ashore but are more often "tied back" to existing export infrastructure, and the drilling of producer and injector wells.
- Production and export operations: involves routine supply, return of wastes to shore, power generation, chemical use, flaring, produced water management/reinjection and reservoir monitoring and maintenance.
- Decommissioning: including cleaning and removal of facilities, for reuse, recycling or disposal.

2.7.2 Hydrocarbon gas storage and unloading

The inclusion in the current draft plan/programme of gas storage 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. Hydrocarbon gas storage in depleted and other hydrocarbon reservoirs and other geological structures 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, or in areas of extensive halite (rock salt) deposits. Salt caverns, unlike hydrocarbon reservoirs or aquifers, are created in thick halite formations through solution mining, where some of the salt is made soluble and discharged allowing space for the storage of hydrocarbon gas. There are extensive halite deposits in the southern North Sea and eastern Irish Sea, and the most prospective area for halites with gas storage potential (Smith *et al*. 2005) is the Triassic Preesall formation in the East Irish Sea Basin.

Smith *et al.* (2005) note that "...*based solely on geological criteria, large parts of the offshore Wessex Basin, Peel Basin, Solway Firth Basin, Cardigan Bay Basin and Forth Approaches Basin could also support such facilities. However, these areas currently have no infrastructure, and some have very few wells within the salt depositional area. Without knowing the economic viability of the various elements of the facility, the future competition with onshore facilities, and the total import of gas by this method, it is difficult to assess whether facilities could also be developed in such areas remote from existing infrastructure."* Most other deposits in the UKCS are too thin or buried at too great a depth to be viable, though some salt diapirs that rise to shallow depths may be prospective in the Central and Southern North Sea.

2.7.3 Carbon dioxide storage

Prospective areas on the UKCS suitable for storage of CO_2 resulting from CCS operations primarily include depleted offshore oil and gas reservoirs and saline aquifers. Constructed salt caverns have the potential to store gas, however they are not considered likely targets during the currency of the SEA. A theoretical P50[22] storage capacity of 78Gt has been estimated collectively for UKCS hydrocarbon fields and saline aquifers (Bentham *et al.* 2014).

Hydrocarbon reservoirs have geological characteristics suited to trapping CO_2 over long timescales (e.g. a suitable porosity/permeability and impervious cap rock), and the injection of CO_2 into hydrocarbon reservoirs can also be used for enhanced oil recovery. In the longer term these reservoirs can be used exclusively for CCS. Due to the maturity of most of the UKCS hydrocarbon basins, the availability of sites for EOR or dedicated CO_2 storage is likely to increase in the coming years, and has the potential to exploit existing infrastructure.

Saline aquifers can have similar characteristics to hydrocarbon reservoirs (i.e. suitably porous/permeable medium with geological constraints on migration) and may also be suited to CO_2 storage. The capacity of saline aquifers is not yet well established for the UKCS, but they have a theoretically large volume – for instance the most prospective southern North Sea formation, the Bunter Sandstone, is estimated to have a capacity of between 2.2Gt and 14.25Gt CO_2 (Holloway *et al*. 2006, Smith *et al*. 2010, Heinemann *et al*. 2012), and more generally, saline aquifers provide the majority of the potential storage capacity on the UKCS (60Gt excluding chalk aquifers, Bentham *et al.* 2014).

Information on over 500 potentially prospective storage structures is available through the CO_2stored database, which makes available some of the information on the UK Storage Appraisal Project commissioned by the Energy Technologies Institute, and which is now being updated by The Crown Estate and the British Geological Survey (Bentham *et al.* 2014). CO_2 storage potential is largely confined to depleted hydrocarbon fields which largely coincide with the major mature hydrocarbon basins of the UKCS (see field boundaries in Figure 2.6).

Saline aquifers provide the largest potential storage capacity on the UKCS, with the highest proportion of this capacity being in the central North Sea. Potential storage areas include the Triassic Bunter Sandstone and Ormskirk Sandstone of the southern North Sea and East Irish Sea Basins respectively, the Captain Sandstone of the Moray Firth, and numerous overlapping formations of the central and northern North Seas having a similar distributed to that area where hydrocarbon production has taken place to date.

[22] that is, having a 50% certainty of being achieved

2.7.4 Offshore wind

In UK waters, offshore wind is the most developed renewable energy technology. Rounds 1 and 2 of offshore wind leasing were held in 2000 and 2003 respectively, with Round 3, held in 2009, being significantly larger in terms of the areas offered for leasing. Exclusivity agreements were signed for nine of the Round 3 areas, seven of which have thus far had planning applications submitted to develop areas within each zone. UK offshore wind generation capacity can be subdivided in that presently in planning (3.25GW), consented (14.94GW) and operational (5.01GW) [23] (see Figure 2.7). Though not a consideration of this SEA, included in the above figures are areas within the territorial and offshore waters of Scotland that have also been leased for offshore wind, which have 191MW of operational capacity and 4.3GW consented but not yet constructed. Figures 2.9 and 2.10 provide an indication of the growth in the number and scale of wind farm proposals since 1998, and the likely scale of that which could be deployed by 2020.

Away from the shelter of the coast, the total wind resource over a given year is relatively uniform across very large areas (Figure 2.7), although the occurrence and strength of wind is dependent 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 shore, distance from areas of high electricity demand, environmental impacts and the availability of connection points to the onshore transmission grid are significant factors in the preferred location of offshore wind developments.

To date most UK offshore wind farms have used 3.6MW or smaller turbines. More recently 5MW and 6MW turbines have been deployed. Projects commissioning between 2016 and 2020 will mostly use larger 6MW, 7MW and 8MW turbines. Larger turbines (between 8MW and 15MW) are in development and have the potential to 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. The UK Government presently envisages that 10GW of offshore wind will be installed by 2020.

Installed or proposed wind turbine foundations have to date been dominated by fixed structures (e.g. monopiles, jackets or gravity base), largely related to the cost of wind farm development. Such structures tend to be limited in the depth of waters they can be deployed effectively. For the purposes of this SEA, it is considered that fixed foundations are likely to be deployed at depths of up to 60m (see Figure 2.8). Floating structures similarly have a diverse range of designs (e.g. tension leg, semi-submersible, spar-buoy and a number of other concepts, see the Carbon Trust 2015), with limited demonstrator deployment to date (e.g. the 2.3MW Hywind demonstrator off Norway). Proposals for demonstrator scale deployments include: five 6MW Hywind devices 30km off the coast of Peterhead, the Dounreay Floating Offshore Wind Development Centre (DFOWDC) being developed by Highlands and Islands Enterprise for up to five turbines of various designs, the Kincardine offshore wind farm comprising eight semi-submersible turbines located approximately 8 miles offshore from Aberdeen, and the PelaStar demonstrator to be installed at WaveHub off Cornwall.

[23] Correct at January 2016: https://www.gov.uk/government/statistics/renewable-energy-planning-database-monthly-extract

Figure 2.7: Annual mean wind speed and wind farm status

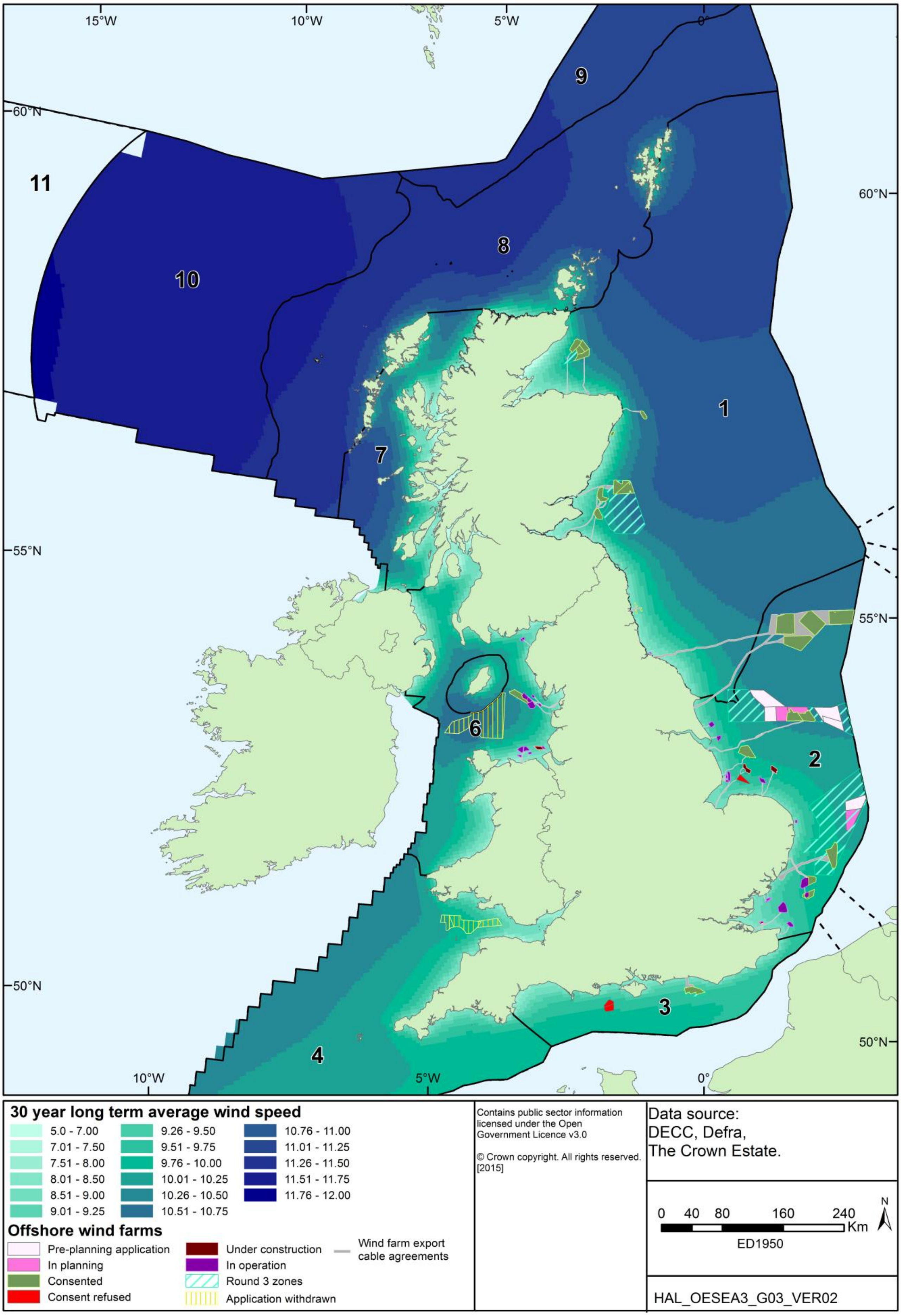


Figure 2.8: Offshore wind resource areas considered in OESEA3

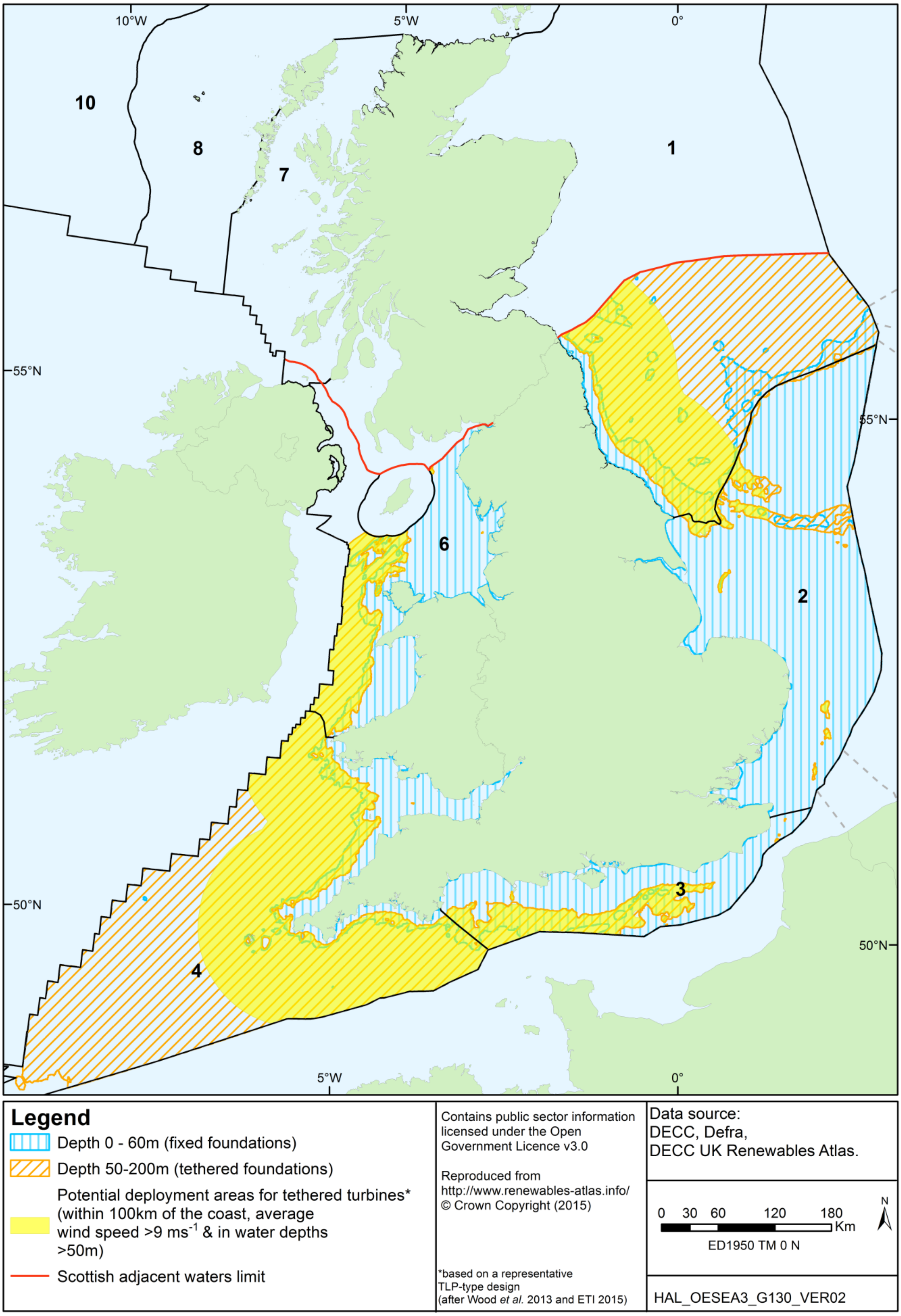
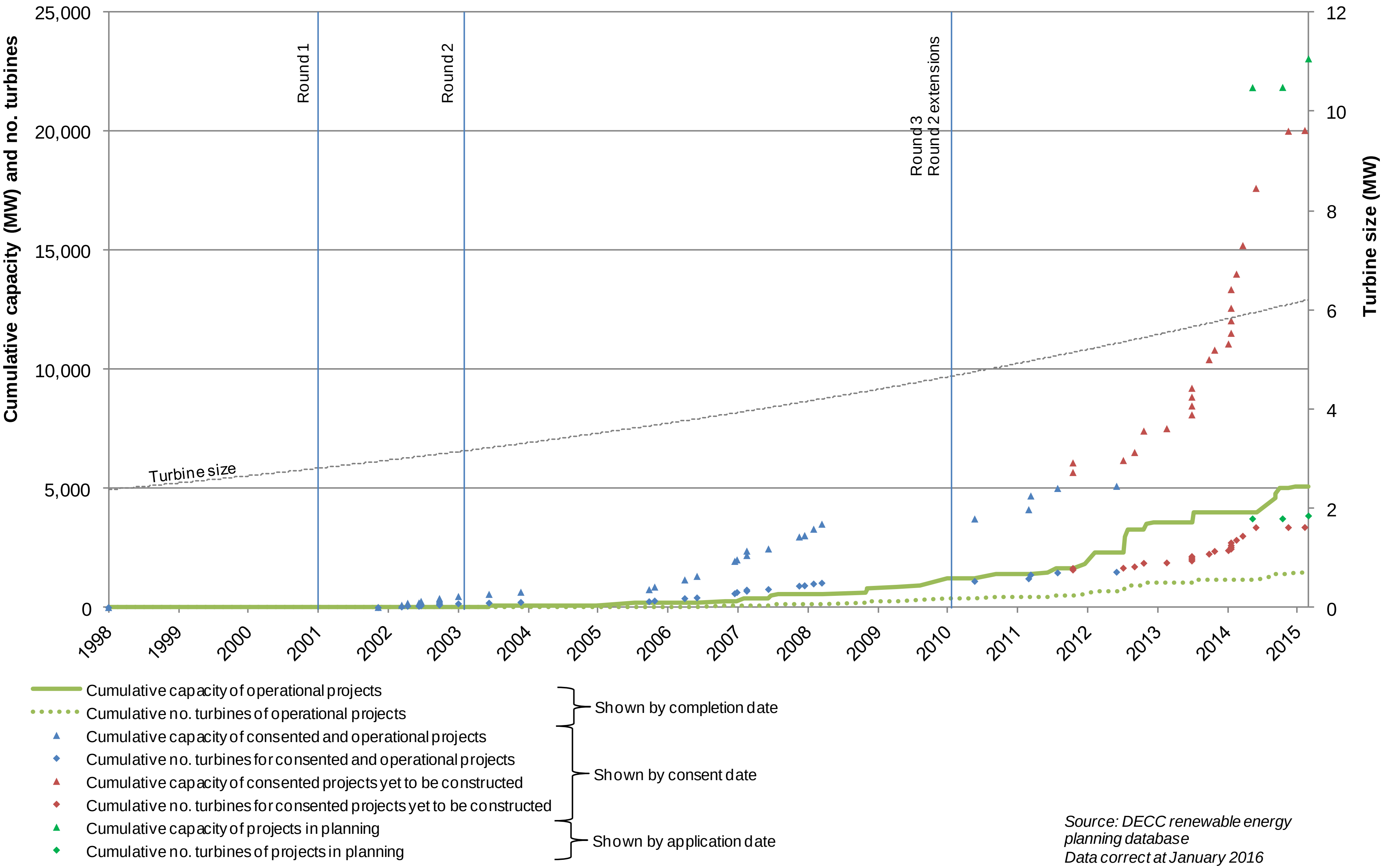


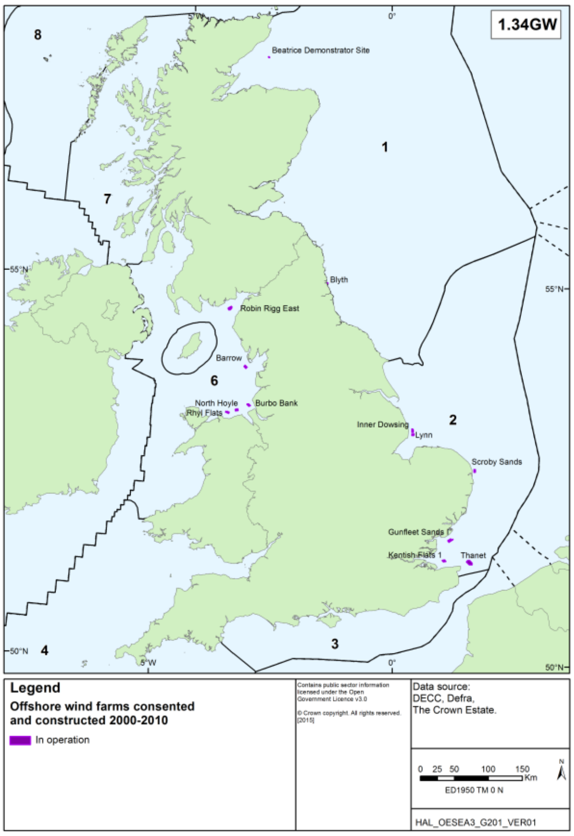
Figure 2.9: Capacity and number of turbines by consent and operational date (UK)



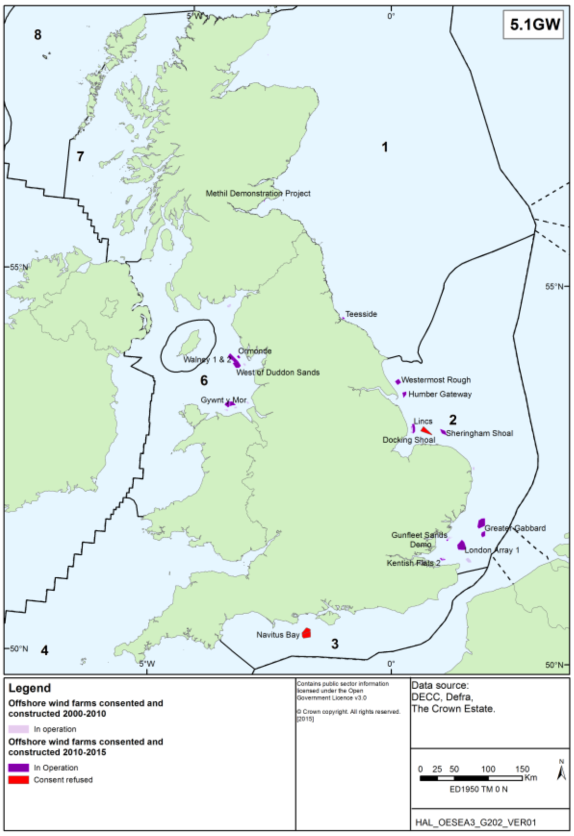
Source: DECC renewable energy planning database
Data correct at January 2016

Figure 2.10: Wind farm construction 2000-2015 and those likely to be constructed 2015 onwards, with approximate cumulative installed capacity

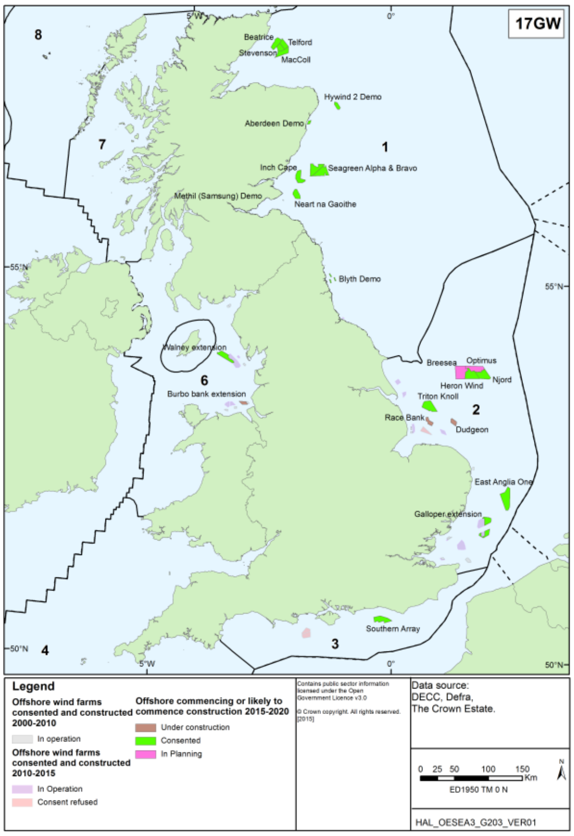
Constructed 2000-2010



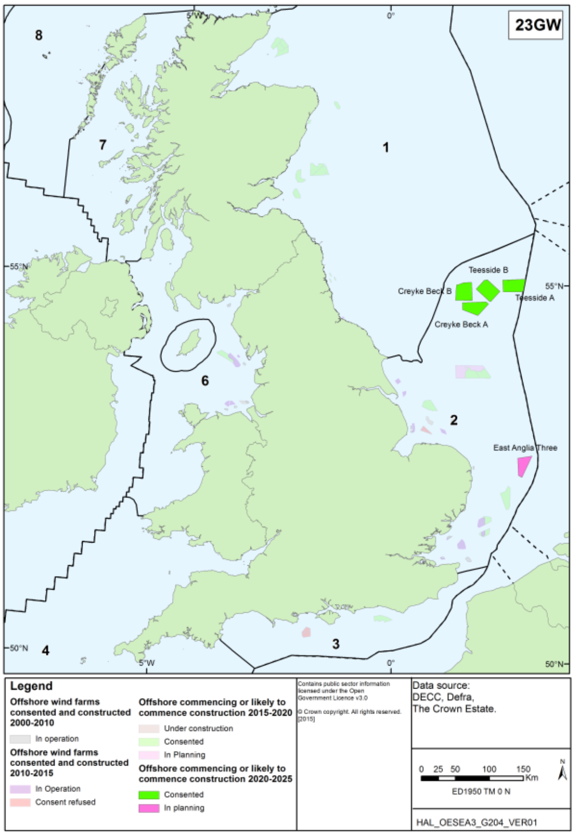
Constructed 2010-2015



Likely to be constructed 2015-2020



Likely to be constructed 2020 onwards



Source: Modified from RUK (2015). Figures are approximate and subject to change.

2.7.5 Tidal range

Studies including the Sustainable Development Commission's "Turning the Tide" (SDC 2007) and the Severn Tidal Power Feasibility Study (STPFS, DECC 2010) have shown potential for the extraction of power from the tidal range of various estuaries, inlets and bays such as the Severn, Mersey, Solway and Wash (Figure 2.11), with the UK wide potential theoretical capacity estimated to be 59GW (TCE 2012). Though no commercial scale tidal range developments are operating in the UK, there are presently two tidal lagoon developments (Newport and Cardiff) which are in the pre-application stage of planning and one which has received consent (Swansea Bay)[24] though this is yet to be granted a lease. The parent company behind these proposals, Tidal Lagoon Power Ltd, has plans for three other tidal lagoon developments in Bridgewater Bay, Colwyn Bay and West Cumbria.

The Severn was not considered in OESEA2 as it was being subject to a feasibility study and separate SEA (DECC 2010) which concluded that a case could not be made to bring forward a Severn tidal power scheme in the immediate term, but that this did not preclude separate private sector developments coming forward outside of the Severn. It was anticipated a review of the case for Severn tidal power would not be needed before 2015. Severn tidal power has been considered in OESEA3 following a review of the conclusions and recommendations of the feasibility study SEA. This review was undertaken in part due to a number of private Severn tidal range proposals made since the completion of the feasibility study which have included:

- The 600MW "Stepping Stones" lagoon proposed by Parsons Brinckerhoff and Black & Veatch
- A 6,000MW tidal "reef" between Aberthaw in South Wales and Minehead in Somerset proposed by Evans Engineering and Power Ltd
- An 18km Severn barrage proposed by Hafren Power Ltd between Brean in England and Lavernock Point in Wales
- A number of lagoons in the Severn proposed by Tidal Lagoon Power Ltd, ranging in size between 240MW (Swansea) and up to 2,800MW (Cardiff and Newport)

The Energy and Climate Change Committee (ECC 2013) recommended in 2013 that, *"...consideration is given to first developing a smaller scale tidal project, in order to build a stronger evidence base for assessing impacts, risks and costs before proceeding with any larger scale scheme. The Government should take this into consideration before approving the development of projects in the Severn estuary."* It was also concluded that a more incremental approach to development should take place, looking at alternatives technologies to barrages (such as tidal lagoons). It is therefore considered that, while there is no case to review the need for a strategic Severn tidal power plan (i.e. the conclusions of the STPFS remain valid and it is not suggested that any of the review points outlined in the feasibility study have been met), there is the need to make a strategic consideration of potential future leasing for tidal range power in the Severn.

The wider potential future location of tidal range developments in relevant UK waters are guided by the available resource (for the purposes of OESEA3, a mean tidal range of >5m) and are generally limited by other factors such as water depth (e.g. TCE 2013 suggest 25m as the depth limit of existing tidal range technologies and this has been used in OESEA3, see Figure 2.12). The vast majority of the UK's tidal range resource is located in the territorial waters of England

[24] http://infrastructure.planninginspectorate.gov.uk/projects/wales/

and Wales, but south west Scotland has a large area with viable resources. As a result, any consideration of the Solway in relation to tidal power in OESEA3 has taken account of the potential for developments which could affect, or be part of, the two legislative and planning remits which meet within this estuary.

To provide historical context to UK tidal range power, and the potential scale of proposals which may come forward for leasing during the currency of OESEA3, a review of potential resource areas and formerly or currently proposed tidal range schemes within the wider relevant area of England and Wales was undertaken (summarised in Table 2.1 and Figure 2.11). These are largely concentrated in the Severn and eastern Irish Sea, with barrages ranging in scale from crossing estuary mouths (e.g. Solway) to smaller riverine schemes (e.g. such as the Mersey, Dee and Wyre) and lagoons being of moderate scale and encompassing parts of small to large embayments with large tidal ranges. Other technologies have been proposed such as the small-scale Solway Energy Gateway which does not rely on impoundment.

Table 2.1: Potential capacities of tidal range devices identified for key tidal range resource areas based on previous proposals and resource assessments

Location	Lagoon	Barrage	Capacity (MW)
Cardiff	✓		1,800-2,800
Newport	✓		1,000-2,800
Clevedon	✓		940
Bridgewater Bay	✓		3,250-9,900
Severn outer barrage		✓	12,000-14,800
Severn inner barrage		✓	7,200-8,640
Swansea Bay	✓		60-320
Shoots		✓	1,050
Rhoose	✓		640
Minehead	✓		2,050
Loughor Estuary		✓	5
Milford Haven		✓	96
Colwyn Bay	✓		1,400-4,450
Mersey		✓	620-700
Southport	✓		5,400
Dee		✓	800
Blackpool	✓		4,600
Wyre Estuary		✓	60-64
Morecambe Bay		✓	3,040
Ribble		✓	72
Duddon Estuary		✓	100-220
West Cumbria	✓		not known
Solway	✓		3,200-5,580
Solway		✓	120-2,700
Solway (other)	-	-	160
Humber		✓	1,200
The Wash		✓	1,050-2,760
Thames		✓	500-1,120
Barrage associated with a new Thames flood barrier		✓	800

Location	Lagoon	Barrage	Capacity (MW)
Hamford water		✓	20
Hastings	✓		2,200
Brighton	✓		1,300
Littlehampton	✓		3,700
Langstone Harbour		✓	24
Cornwall		✓	28

Source: AEA (2007), Baker (1991), DECC (2010), Joule Centre (2009), PB (2015), Peel Energy (2011), SDC (2007), Solway Energy Gateway (http://www.solwayenergygateway.co.uk/), TCE (2013), Tidal Lagoon Power (http://www.tidallagoonpower.com/, http://infrastructure.planninginspectorate.gov.uk/projects/wales/tidal-lagoon-cardiff/, http://infrastructure.planninginspectorate.gov.uk/projects/wales/tidal-lagoon-swansea-bay/)

On the basis of the above information, it is envisaged that during the currency of OESEA3, and not including proposals which have already been made, a number of tidal lagoon projects may come forward, probably of a scale in the order of between 1,000-3,200MW, though larger schemes may be possible, including the potential for barrage, fence or other tidal range technology types.

The main stages of tidal range development are:

- Site prospecting/selection: including collection of site specific resource and constraint data, and seabed information by geophysical and geotechnical survey.
- Development: includes selection and construction of foundations, device installation, cable laying including shoreline and potentially other cable/pipeline crossings and armouring, installation of gathering stations/substations and connection to the onshore national electricity transmission system.
- Generation operations, including maintenance
- Decommissioning[25]

The potential effects of tidal range developments are considered in Section 5.

[25] See: DECC (2015). Addendum to decommissioning of offshore renewable energy installations under the Energy Act 2004. Guidance notes for industry: Tidal Lagoons.

Figure 2.11: Mean spring tidal range and former/existing tidal range proposals

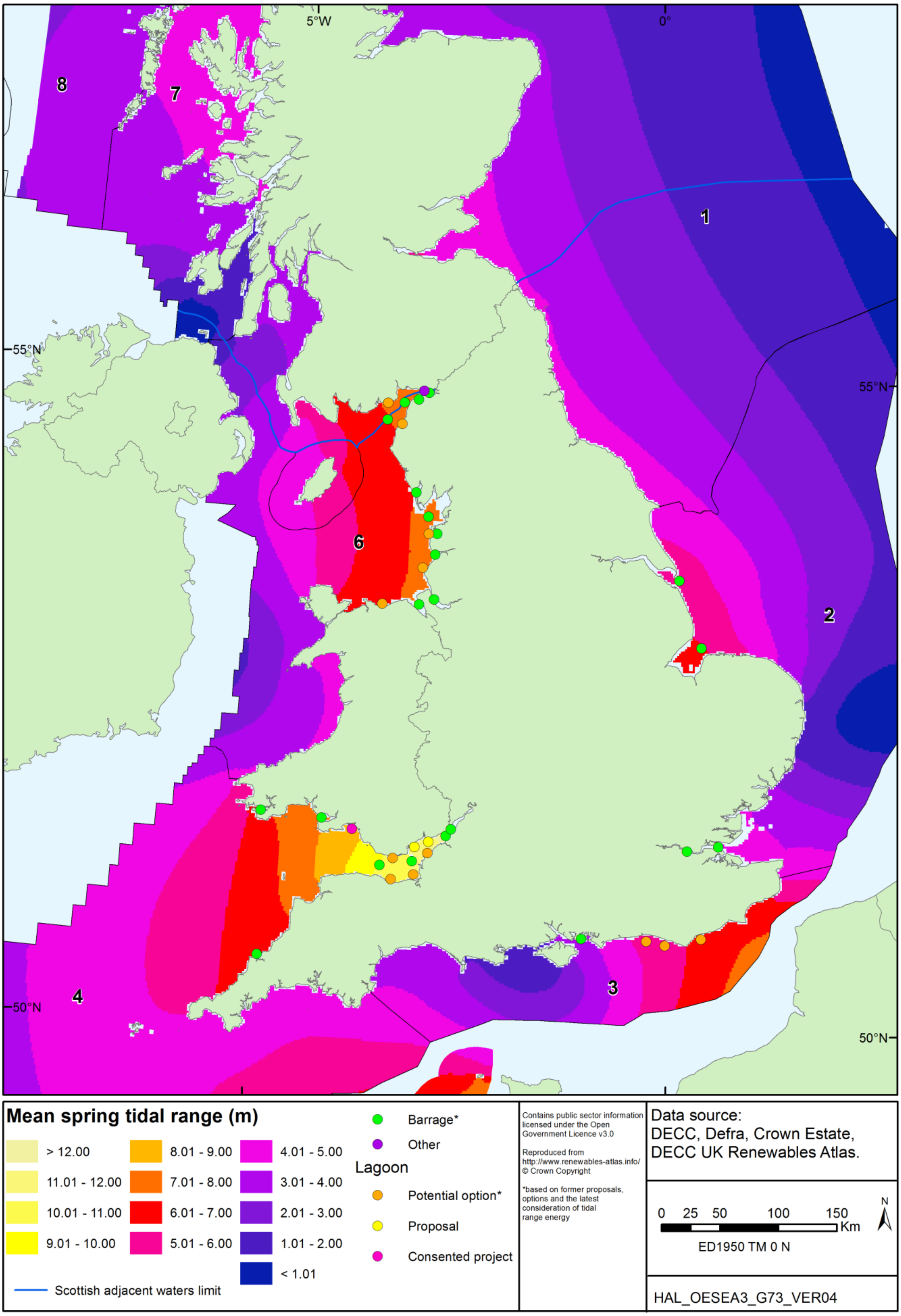
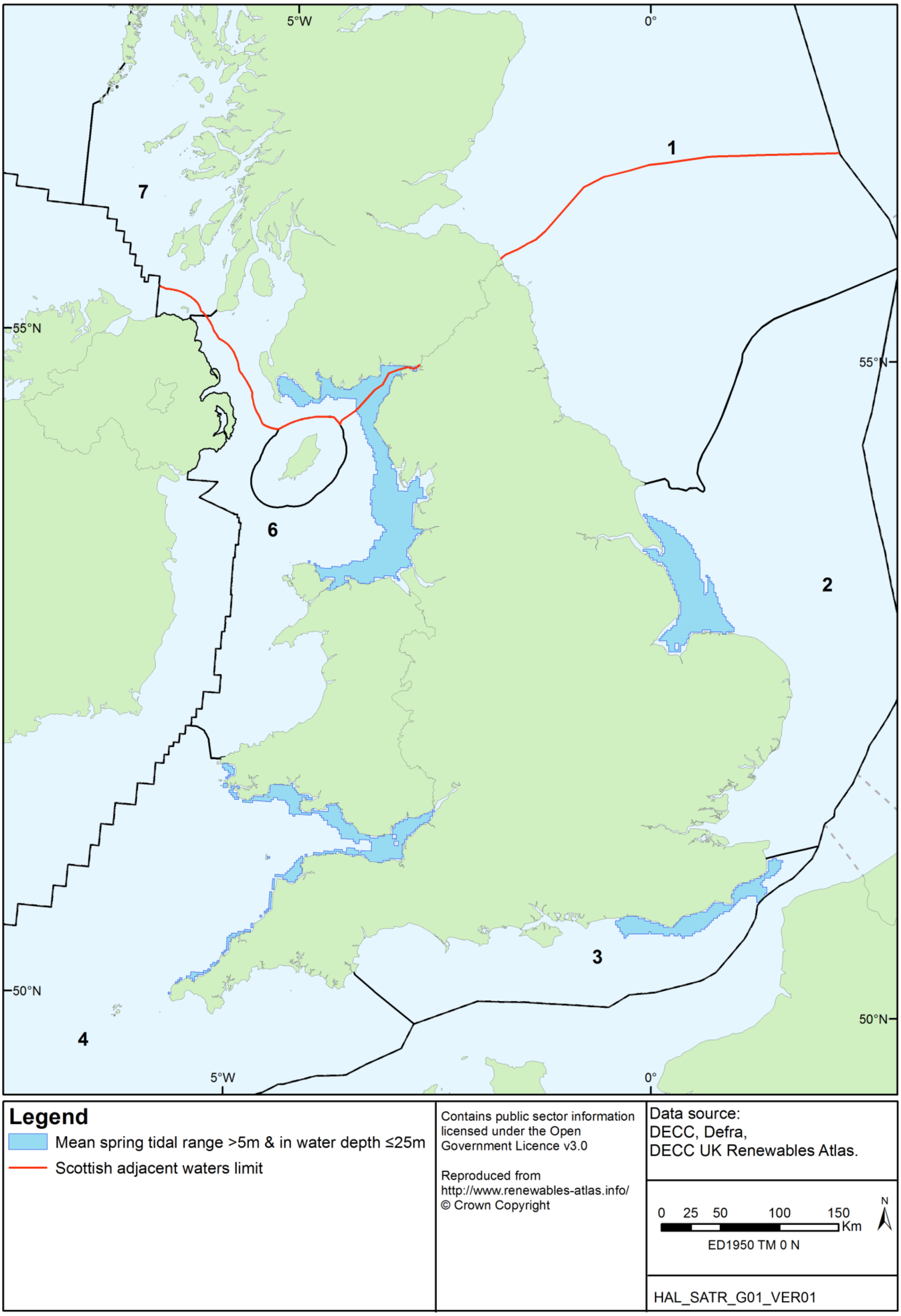


Figure 2.12: Tidal range resource areas considered in OESEA3



2.7.6 Wave & Tidal Stream

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. It is likely that over the coming years as devices reach commercial scale and their viability is demonstrated, larger scale deployment of wave and tidal stream energy generation devices will commence.

Work to characterise the wave and tidal stream resources of UK waters has shown wave resource is broadly concentrated on the Atlantic facing coastline of the UK (Figures 2.13 & 2.15) – notably the Western Isles of Scotland and the South West peninsula and SW Wales[26]. Tidal stream resource is more geographically constrained – being localised around headlands and through straits between land masses. Potential deployment sites within English and Welsh waters are shown in Figures 2.14 & 2.16).

A number of areas in Scottish territorial waters have been leased for wave and tidal stream development, with a further leasing for six new wave and tidal stream demonstration zones taking place in 2014, as part of a programme to accelerate technology development. Demonstration sites include the European Marine Energy Centre (Orkney) and Wave Hub (Cornwall). Areas where commercial development may take place in the near future include the Pentland Firth and Orkney waters (Scotland), Rathlin Island and Torr Head (Northern Ireland) and Anglesey (Wales).

[26] ABPMer (2008). Atlas of UK Marine Renewable Energy Resources. The Crown Estate (2012). UK Wave and Tidal Key Resource Areas Project.

Figure 2.13: Annual mean wave power and current wave leasing areas and status

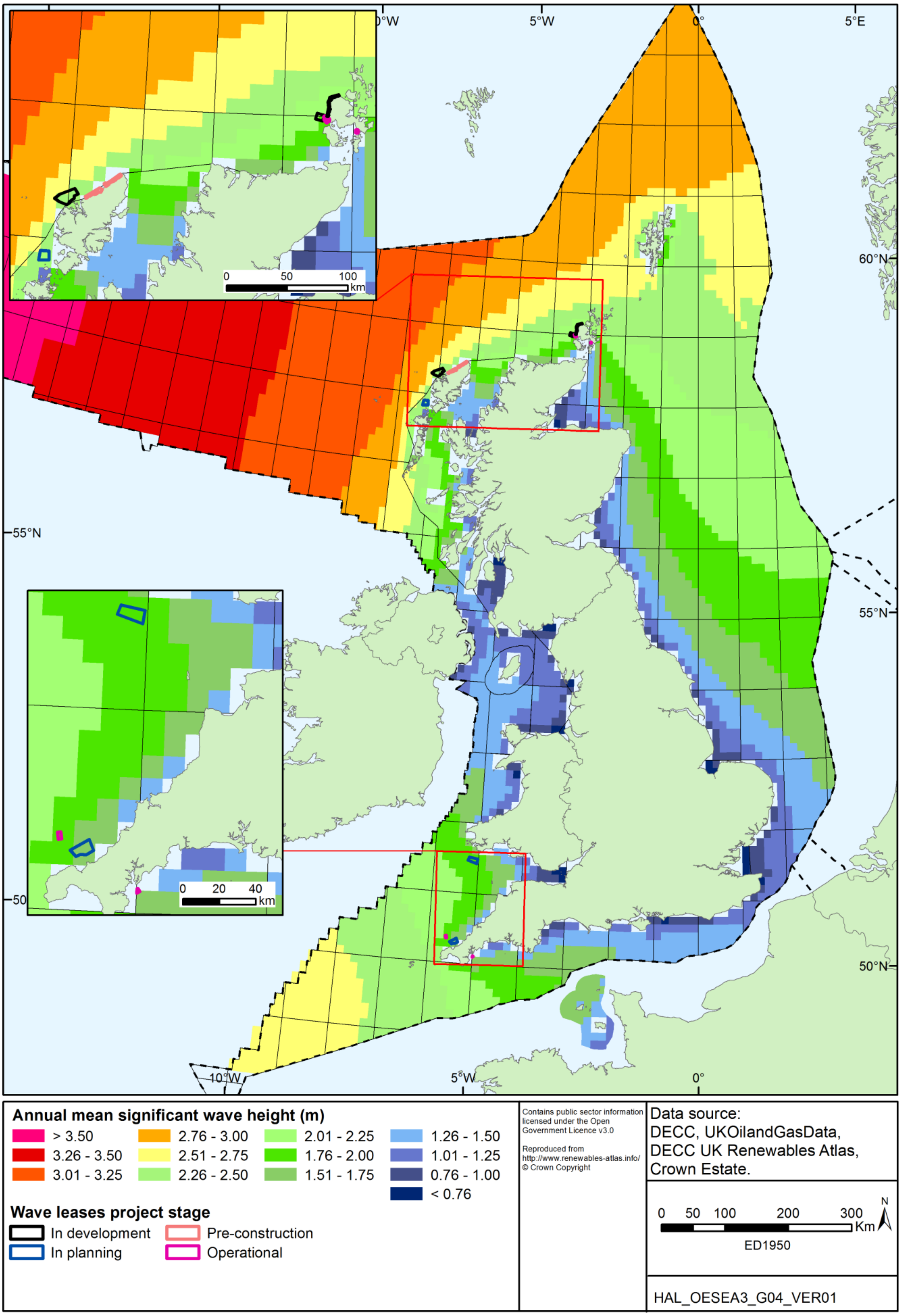
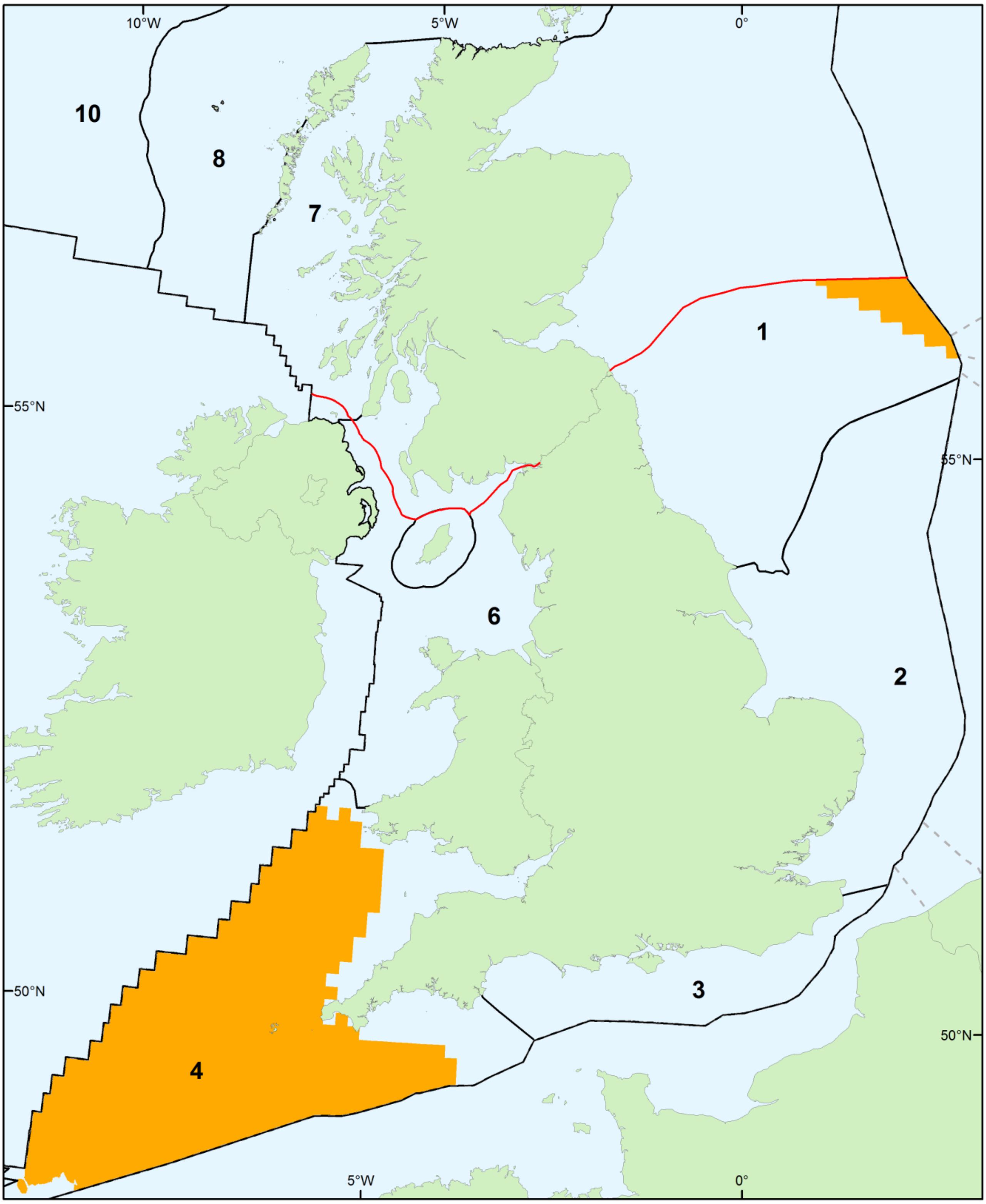


Figure 2.14: Wave power resource areas considered in OESEA3



Legend

Annual mean wave power >20kW/m in water depth 10-200m

Scottish adjacent waters limit

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Data source:
DECC, Defra,
DECC UK Renewables Atlas

0 30 60 120 180 Km

ED1950 TM 0 N

HAL_OESEA3_G133_VER01

Figure 2.15: Annual mean tidal power and current tidal stream leasing areas and status

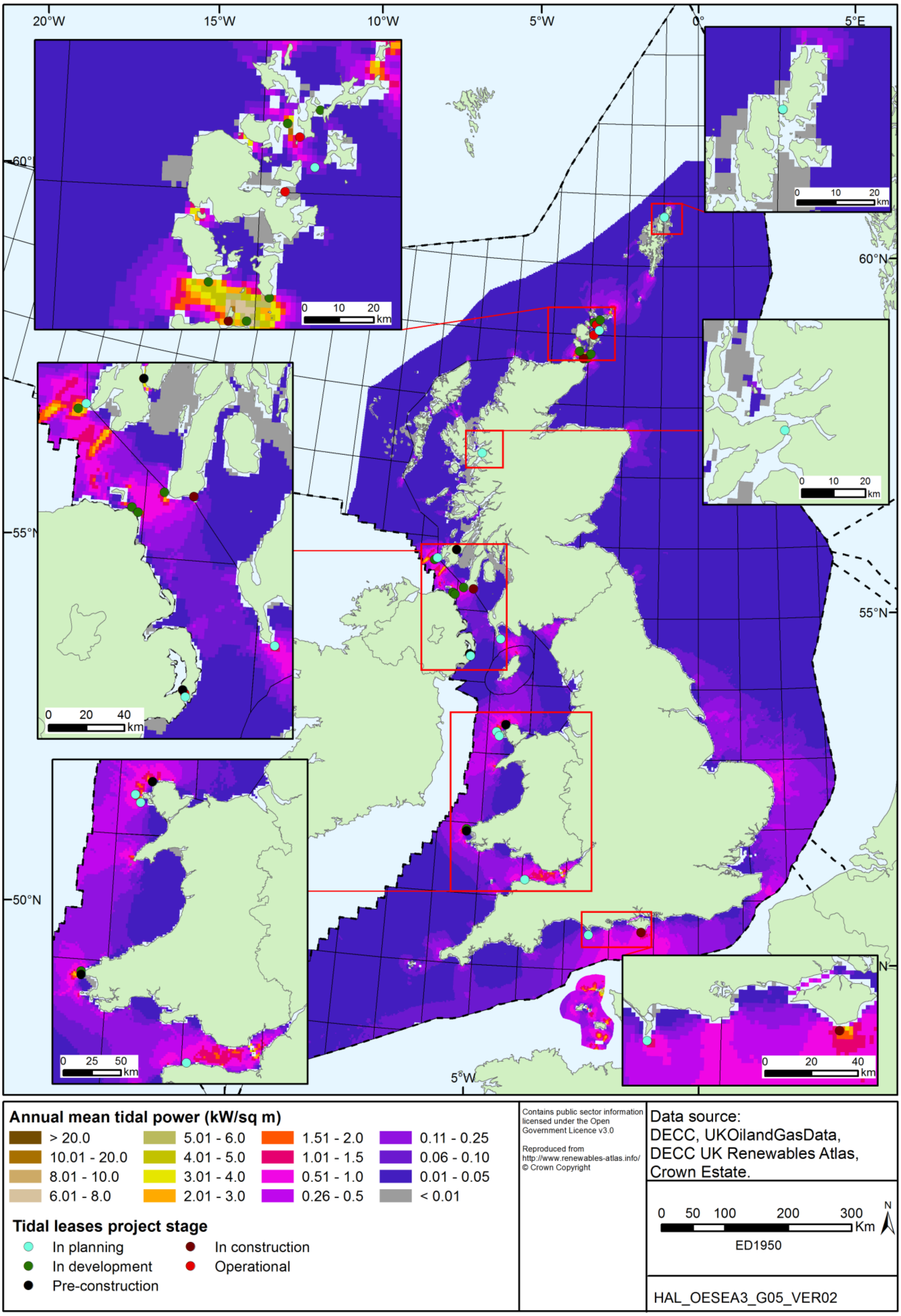
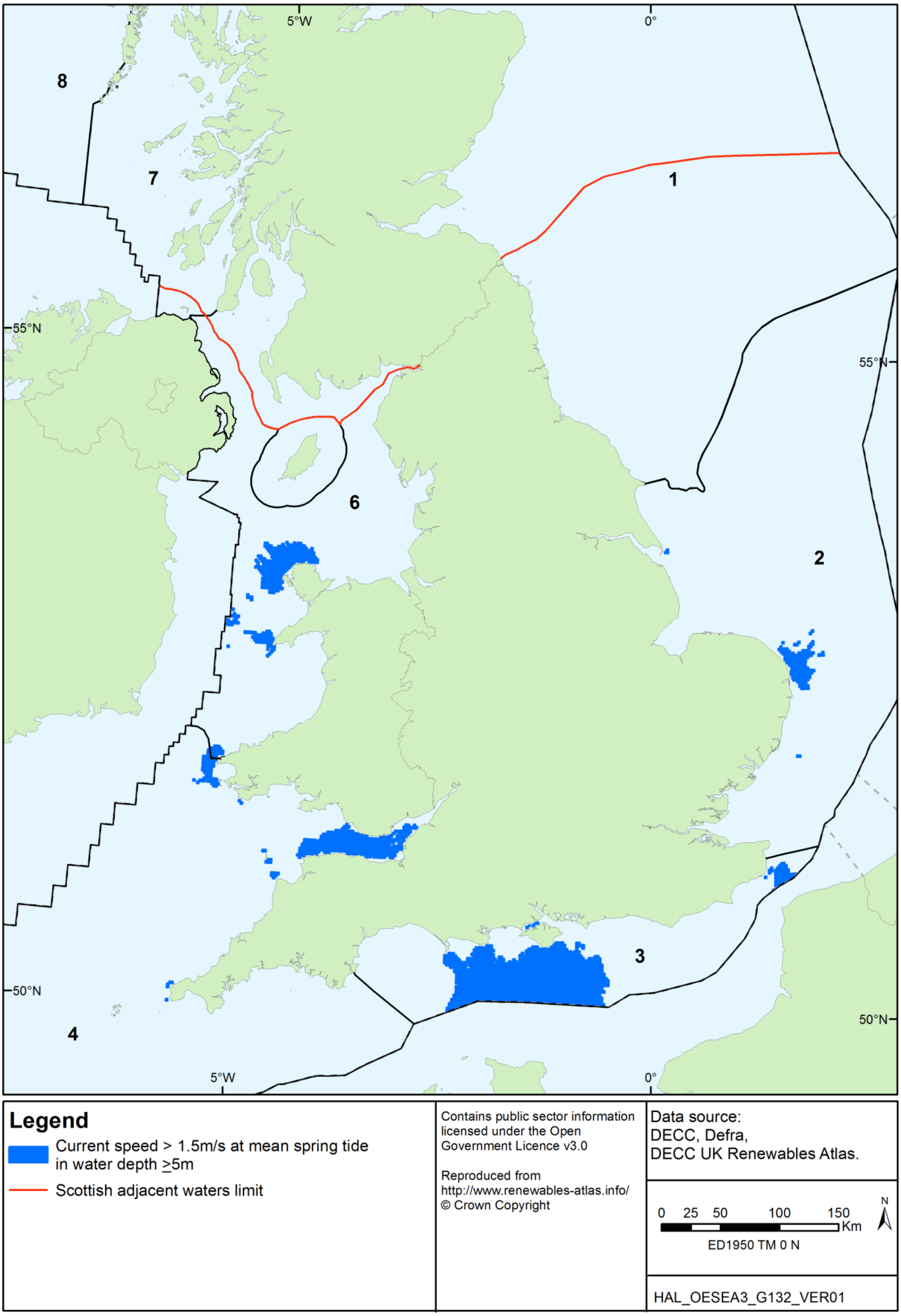


Figure 2.16: Tidal stream resource areas considered in OESEA3



2.8 Characterisation of the potential type and scale of activity

The following table outlines the expected type and scale of activities which could take place in each Regional Sea (RS) derived from the above information.

Table 2.2: Activity by Regional Sea

RS	Oil and Gas	Wind	Wave	Tidal	Gas storage & CCS
1*	Prospectivity is largely for oil in the northern North Sea, Moray Firth and central North Sea Basins. The east Shetland Platform and mid North Sea High areas are comparatively underexploited. The latter has been the subject of an OGA survey to inform a 29th seaward licensing Round. It is likely that further Blocks will be applied for in Regional Sea 1 during the currency of this SEA.	No proposals for commercial scale wind farms have been made to date in the English sector of this Regional Sea. The area is prospective for fixed foundations in nearshore areas, or tethered devices at greater distances. It is possible that further areas may be leased for commercial offshore wind.	No proposals for wave devices have been made in the English sector of this Regional Sea. There is a small area to the north east which falls within the criteria for wave deployment (see above), however the area is distant from the coast.	Tidal ranges and speeds are generally regarded to be too low for commercial exploitation in the English sector of Regional Sea 1.	Existing offshore oil and gas infrastructure in mature fields provides the potential for re-use as storage facilities where structure design life and modifications allow. Proven sealing structures and an abundance of historical geological well and seismic data make Regional Seas 1 and 2 highly prospective for gas storage and CCS projects. A selection of significant emissions sources is also available, particularly to the south of Regional Sea 1 and Regional Sea 2.
2	Prospectivity in the southern North Sea Basin is primarily for gas. A portion of the mid North Sea High area is located in the north east of Regional Sea 2. It is likely that further Blocks will be applied for in Regional Sea 2 during the currency of this SEA.	The southern North Sea contains the bulk of the current UK offshore wind capacity, both in operation and planning. The area remains highly prospective for offshore wind due to its shallow depths and the potential for suitable grid connections. It is possible that further areas may be leased (including by extension) for commercial offshore wind.	Wave energy is generally regarded to be too low for commercial deployment.	Potentially suitable tidal stream locations are found off the Humber and Norfolk coast and are spatially very limited. Prospective areas for tidal range are present between the Humber and Wash. It is possible that areas could be leased for these technologies during the currency of this SEA.	

RS	Oil and Gas	Wind	Wave	Tidal	Gas storage & CCS
3	Prospectivity in the Channel (Anglo-Paris Basin) has historically been for oil, produced by extended reach drilling from shore, however a single gas discover has also been made. It is possible that further Blocks will be applied for during the currency of this SEA.	Comparatively shallow water depths at proximity to shore with good wind resources have made the central and eastern Channel prospective for wind power. One project (Rampion) is currently under construction off the coast of Brighton. Further west, the refusal of consent for the Navitus Bay project is noted. It is possible that further areas (including extensions) may be leased for commercial offshore wind during the currency of this SEA.	Wave energy is generally regarded to be too low for commercial deployment.	Potentially suitable tidal stream locations are found across the central Channel, particularly off Portland, Purbeck and the Isle of Wight. Prospective areas for tidal range are present off the Sussex coastline. A lack of large embayments probably makes lagoon-type technologies more applicable here.	Suitable storage and sealing formations may be present, however potential connectivity to large emitters is more restricted (i.e. Fawley refinery) than in other areas of the UK.
4	No economically exploitable hydrocarbon stores have been discovered to date in the South West Approaches Basin, and the majority of blocks in this area have never been licensed. It is possible that some Blocks may be applied for in Regional Seas 4 and 5 during the currency of this SEA.	Waters have generally proven to be too deep for current foundation technology, however the area is highly prospective for tethered foundation-type technology which could be demonstrated here within the currency of this SEA. Shallower nearshore areas, including the Bristol Channel, have formerly been considered for offshore wind but did not prove viable. It is possible that further areas may be leased for commercial offshore wind during the currency of this SEA.	This area has some of the most prospective waters for offshore wave energy in the UK and contains the only wave demonstration sites in English and Welsh waters.	Tidal stream energy is prospective off western Cornwall, within the Severn Estuary and off Pembrokeshire, with demonstration sites being located in the latter two areas. There has been historically very strong interest in the Severn as a potential source of tidal range energy. Several lagoon development proposals are presently being considered for the Severn.	Comparatively smaller geological understanding make these areas unlikely candidates for gas storage or CCS compared with North Sea and East Irish Sea prospects.
5			Water depths and distances from shore generally make this area not prospective.	Water depths and distances from shore generally make this area not prospective.	

RS	Oil and Gas	Wind	Wave	Tidal	Gas storage & CCS
6*	Prospectivity is largely for gas and has to date been restricted to the East Irish Sea Basin. Oil has been commercially produced in only small quantities. It is likely that further Blocks will be applied for in the East Irish Sea Basin during the currency of this SEA The northern section of the Cardigan Basin has been subject to previous exploration, but without commercial success. It is possible that further Blocks will be applied for in the Cardigan Basin during the currency of this SEA.	The area is relatively shallow and fixed foundation wind turbines are presently more likely to be deployed. Development in this area. Development is most likely in the East Irish Sea. It is possible that further areas may be leased for commercial offshore wind during the currency of this SEA.	Wave power in this area is generally regarded to be too low for commercial exploitation.	Tidal stream energy and related prospectivity is concentrated around the Lleyn Peninsula and Anglesey, with a number of projects having been proposed around the latter. A significant portion of the UK's potential tidal range energy is located along the North Wales and north east English coasts, incorporating coastal areas suited to lagoons and embayments where barriers could theoretically be used. There are a number of proposals for barrages and lagoons in this area.	Existing offshore oil and gas infrastructure in mature fields provides the potential for re-use as storage facilities where structure design life and modifications allow. Proven sealing structures and an abundance of historical geological well and seismic data make the East Irish Sea area highly prospective for gas storage and CCS projects. Large industrial emitters in the Merseyside area also provide significant potential CO_2 sources.
7*	The majority of Regional Sea 7 falls within the bay closing lines subject to landward Regulations. The remaining area has not been commercially exploited to date, however a number of blocks in Northern Irish waters around Rathlin Island were licensed in the 26th seaward round. It is possible that further Blocks will be applied for during the currency of this SEA.	n/a	n/a	n/a	n/a

RS	Oil and Gas	Wind	Wave	Tidal	Gas storage & CCS
8*	The western extent of Regional Sea 8 which is covered by the Rockall Basin is generally under explored, and a single gas discovery has been made in the area. It is possible that further Blocks will be applied for during the currency of this SEA.	n/a	n/a	n/a	A paucity of major CO_2 emitters and comparatively smaller geological understanding make these areas unlikely candidates for gas storage or CCS compared with North Sea and East Irish Sea prospects.
9*	Exploration in this area has been comparatively small compared to the rest of the UK, however a number of significant oil and gas developments have taken place in the West of Shetland Basin. Geological barriers to seismic survey and drilling north of 62˚N has resulted in historically limited exploration.	n/a	n/a	n/a	
10*	The Rockall Basin is generally under explored. The basin within Regional Sea 10 has been the subject of an OGA survey to inform a 29th seaward licensing Round. It is likely that Blocks will be applied for during the currency of this SEA.	n/a	n/a	n/a	
11*	Areas outside of the EEZ are not considered.				

*Notes: *The Scottish Renewable Energy Zone and the territorial waters of Scotland and Northern Ireland are not included in this SEA.*

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.

The OESEA3 scoping specifically aimed to:

- Promote stakeholder awareness of the SEA initiative
- Ensure access to 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

An OESEA3 scoping document was prepared and a formal scoping exercise with the statutory Consultation Bodies/Authorities for Wales, Scotland, England and Northern Ireland and other stakeholders was conducted from 31st July to 4th September 2015. The scoping consultation was undertaken by emailing directly to the statutorily defined Consultation Bodies and Authorities and by also making the scoping document available on the DECC Offshore Energy SEA pages of the gov.uk website[27].

The following consultation questions were asked:

1. Consultees are invited to highlight additional initiatives which they consider are relevant to the draft plan/programme.
2. Consultees are invited to draw attention to and provide (where relevant/possible) additional information and data sets which they consider of potential relevance to this SEA.
3. Do you agree with the choice of Regional Seas used to help describe the environmental baseline?
4. Are there any additional environmental problems you consider to be relevant to the SEA?
5. Are there any additional influences, and supporting data sources, on the likely evolution of the environmental baseline?
6. Are there any objectives that you feel should be included or removed?
7. Are the indicators for each objective suitable? If not please suggest alternatives.

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27 https://www.gov.uk/guidance/offshore-energy-strategic-environmental-assessment-sea-an-overview-of-the-sea-process

8. Do you have any comments on the sources of potentially significant effect for each of the activities covered by the draft plan/programme, including whether they should be scoped in or out of assessment in the Environmental Report?
9. Are there any additional information sources or existing monitoring arrangements which could be used to inform monitoring of the offshore energy draft plan/programme?
10. Do you have any comments on the proposed approach to consultation?

Responses were received from 19 organisations listed below:

- Cadw
- Department of the Environment Northern Ireland (DOENI)
- The Crown Estate (TCE)
- Natural Resources Wales (NRW)
- RenewableUK (RUK)
- Royal Society for the Protection of Birds (RSPB)
- Scottish Natural Heritage (SNH)
- Joint Nature Conservation Committee (JNCC)
- Historic England (HE)
- Natural England (NE)
- Scottish Environment Protection Agency (SEPA)
- Historic Scotland (HS)
- Response on behalf of: Humane Society International UK, Marine Conservation Society and Whale and Dolphin Conservation (WDC et al.)
- Marine Management Organisation (MMO)
- Environment Agency (EA)
- Tidal Lagoon Power (TLP)
- EDF Energy (EDF)
- The Wildlife Trusts (TWT)

A compilation and summary of stakeholder responses is available on the DECC Offshore Energy SEA webpages[28]. 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.

[28] https://www.gov.uk/guidance/offshore-energy-strategic-environmental-assessment-sea-an-overview-of-the-sea-process

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 in 1999, 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, now incorporated in the gov.uk site
- 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 studies and research with results published (website and peer reviewed literature)
- Assessment workshop as part of Environmental Report preparation, involving the steering group and others
- Regional stakeholder workshops
- Sector meetings and 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 is summarised below, but note that certain activities such as information gathering and stakeholder liaison continue throughout the process.

An OESEA3 assessment workshop was held in early December 2015 and is summarised in Appendix 4. This workshop covered: the OESEA3 objectives and indicators (see Section 3.5), amended following scoping; key assumptions in relation to the main elements of the draft plan/programme; alternatives and key issues to be considered in more detail in the Environmental Report.

In addition, three regional stakeholder meetings were held in London, Bristol and Aberdeen in February 2016 at which stakeholders from a wide variety of organisations, sectors and areas participated. The stakeholder input on the information base and other issues of relevance to OESEA3 is summarised in Appendix 4 of the Environmental Report.

The Environmental Report and draft plan/programme are being issued for an 8 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 pages of the gov.uk 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.

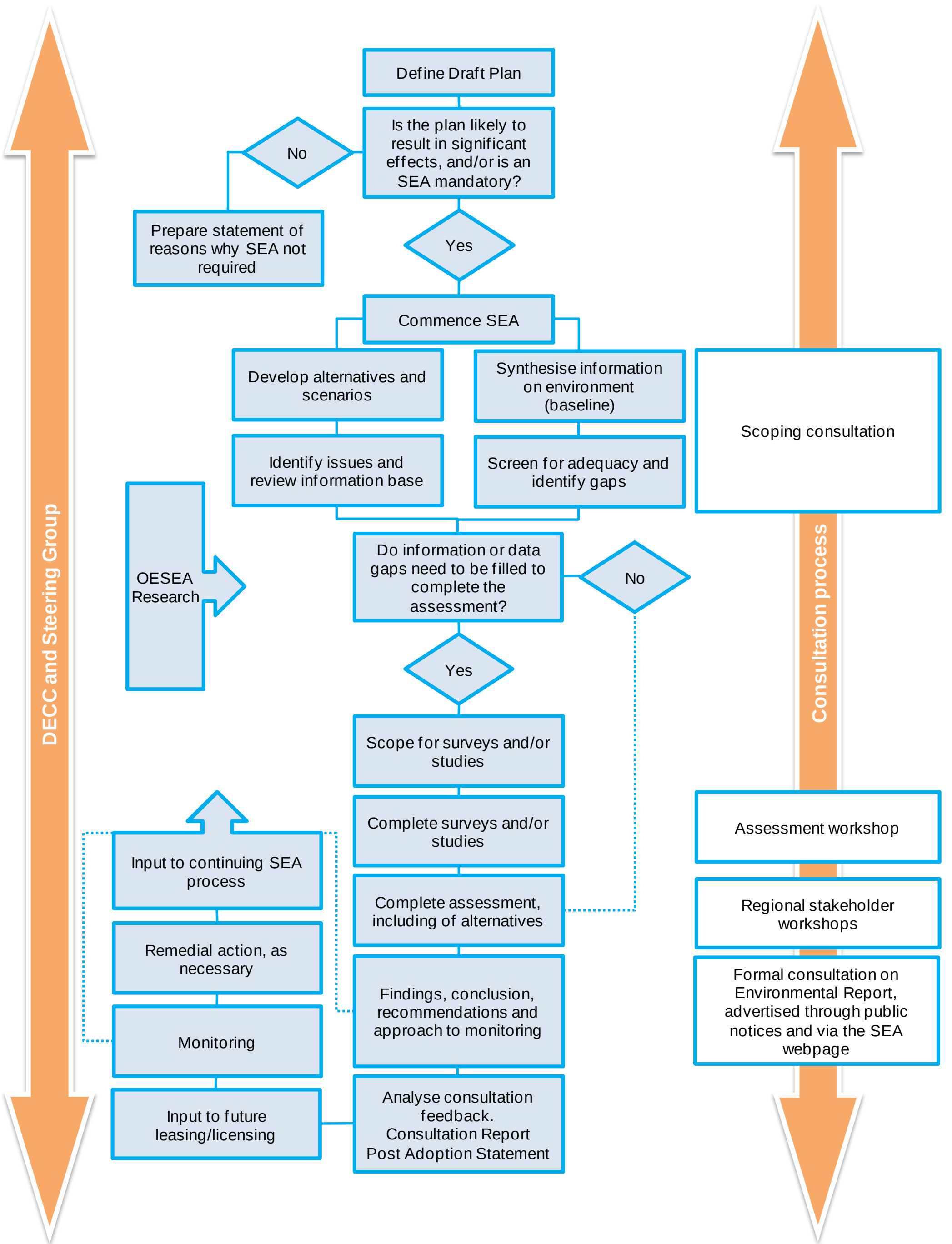
The key stages in the conduct of this SEA are:

1. Instigation of draft plan/programme and identification of alternatives and draft objectives
2. Scoping for field work / longer term studies
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:
    - Environmental baseline
    - Existing environmental problems
    - Potential effects of proposed plan
    - Other relevant initiatives, plans and programmes and their objectives
5. Assessment workshop
6. Assessment of effects including consideration of alternatives
7. Regional stakeholder workshops
8. Sector meetings and/or workshops
9. Production of Environmental Report
10. Public Consultation
11. Post consultation evaluation of feedback (post consultation report) input to decision on the plan (post adoption statement(s))
12. Monitoring plan implementation

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

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.

Figure 3.1: Overview of the SEA process



3.4 Surveys and studies

Since 1999, many studies have been commissioned as part of the DECC SEA programme either to provide expert reviews or data syntheses in areas for which synoptic overviews were not published or readily available. These reports and new studies have been used to inform the current assessment documented in this report and are available from the DECC SEA webpages of the gov.uk website and are also archived by the BGS (http://www.bgs.ac.uk/data/sea/).

3.5 SEA objectives

The development of SEA objectives is a recognised way in which environmental considerations can be described, analysed and compared. The OESEA3 objectives and indicators are presented in Table 3.1 below. These were based on those first developed in OESEA, amended following successive rounds of scoping and discussion including at the Assessment Workshop. The guide phrases are included to assist in interpretation.

Table 3.1: SEA topics, objectives and indicators

SEA Objectives	Guide Phrases	SEA Indicators
Biodiversity, habitats, flora and fauna		
Contributes to conservation of the biodiversity and ecosystems of the United Kingdom and its seas. Avoids significant impact to conservation sites designated at an International, European and National level (e.g. Ramsar, Natura 2000, Marine Conservation Zone, Nature Conservation Marine Protected Area and SSSI). Avoids significant impact to, or disturbance of, protected species and loss of habitat.	*Plan activities do not lead to the loss of biological diversity, the degradation in the quality and occurrence of habitats, and the distribution and abundance of species.* *Plan activities do not cause adverse effects on marine ecosystems/valued ecosystem components.* *Plan activities contribute to the ecological knowledge of the marine and coastal environment through survey and discovery.* *Plan activities do not lead to disruption in habitat and species connectivity.* *Plan activities do not lead to the introduction of noise at levels which adversely affect the marine environment, including by leading to significant effects on conservation sites and sensitive species.* *Plan activities do not lead to the introduction of non-native species at levels which adversely alter marine ecosystems.* *The plan recognises the ecosystem importance of land-sea coupling, for instance its role in species migration.* *The plan promotes the achievement of good ecological/environmental status for water bodies and marine sub-regions as outlined at a European Level.*	For selected 'valued ecosystem components' no loss of diversity or decline in population (measured as % of relevant biogeographic population) attributable to plan related marine activities and promotion of recovery wherever possible. Activities subsequent to licensing/leasing which are on, or potentially affecting designated sites (e.g. Natura 2000, Marine Conservation Zones, Marine Protected Areas), or with the potential to disturb a protected species1, are compliant with the requirements of relevant UK and devolved Regulations2, and consistent with national and regional policy. No adverse change in the environmental status of marine sub-regions, including in relation to the attainment of targets for MSFD descriptors; or in the ecological status of WFD transitional waters and the attainment of good status/potential.
Geology and Soils		
Protects the quality of the seabed and its sediments, and avoids significant effects on seabed morphology and sediment transport processes. Protects the integrity of coastal and estuarine processes.	*Activities arising from the plan do not adversely affect the quality and character of the geology and geomorphology of seabed or coastal sediments.* *Plan activities do not lead to*	No adverse change in quality of seabed sediments, and seabed sediment transport, at a series of regional monitoring stations[29]. No physical damage to designated marine and coastal geological

[29] Including Oil & Gas UK environmental monitoring committee surveys.

SEA Objectives	Guide Phrases	SEA Indicators
Avoids significant damage to geological conservation sites and protects important geological/geomorphological features.	*changes in seafloor integrity which could adversely affect the structure and function of ecosystems.* *Plan activities avoid adverse effects on designated geological and geomorphological sites of international and national importance.*	conservation sites (e.g. GCRs and MCZs).
Landscape/Seascape		
To accord with, and contribute to the delivery of the aims and articles of the European Landscape Convention and minimise significant adverse impact on seascape/landscape including designated and non-designated areas.	*Activities do not adversely affect the character of the landscape/seascape.* *The plan helps to conserve the physical and cultural visual resource associated with the land and sea.*	No significant impact on nationally-designated areas (including the setting of heritage assets). Extent of the visual resource potentially affected by plan activities. Number of areas of landscape sensitivity affected by proposed developments (e.g. offshore wind). Trajectory of change in coastal Character Areas defined at UK constituent country level show no adverse effects arising from plan activities. Change in 'tranquillity' based on national mapping projects.
Water Environment		
Protects estuarine and marine surface waters, and potable and other aquifer resources. Avoid significant impact on flood and coastal risk management activities.	*Plan activities do not result in concentrations of contaminants at levels giving rise to pollution effects.* *Plan activities do not result in permanent alteration of hydrographical conditions which adversely affect coastal and marine ecosystems.* *Plan activities do not result in adverse effects on saline and potable aquifer resources.*	No adverse change in quality of WFD water body status, including in relation to attainment of good ecological status or potential, or good chemical status. UKCS Exploration and Production (E&P) meets OSPAR discharge reduction targets. Number of oil and chemical spills and quantity of material spilled. No adverse impact on flood risk as a result of plan activities.
Air Quality		
Avoids degradation of regional air quality from plan related activities.	*The plan contributes to the achievement of air quality targets for those emissions outlined in the UK Air Quality Strategy.* *Emissions from plan activities do not contribute to, or result in, air quality issues which adversely affect human health or the wider environment.*	Monitoring of local air quality shows no adverse impact. Targets relating to airborne emissions at a regional and UK level are not exceeded.

SEA Objectives	Guide Phrases	SEA Indicators
Climatic Factors		
Minimises greenhouse gas emissions.	*The plan contributes to the achievement of targets relating to greenhouse gases at a national and international level.* *Plan activities contribute to mitigating climate change.*	UKCS E&P greenhouse gas emissions. UK progress towards meeting legally mandated greenhouse reduction targets. UKCP09 projections for the expected currency of the plan/programme, and any updates resulting from new research.
Resilience to climate change	*Plan activities recognise the potential impact of climate change during their lifetime, in relation to their potential impact on coastal change, flood risk, or other climate change adaptation.*	See also; water environment indicators in relation to flood and coastal risk management.
Population and Human Health		
Has no adverse impact on human health and wellbeing.	*Plan activities do not result in, or contribute to the contamination of fish and other seafood for human consumption at levels which exceed those established by Community legislation or other relevant standards.* *Plan activities avoid adverse effects on physical and mental health.*	Progress in achieving OSPAR targets for continued reduction in harmfulness of offshore discharges. Relevant Office for National Statistics wellbeing metrics. Percentage of population in good health.
Avoids disruption, disturbance and nuisance to communities.	*Plan activities avoid adverse nuisance to communities, for instance through noise or vibration.* *Adverse effects on the quality or access to areas used for recreation (e.g. amenity, sailing, surfing), are minimised or avoided.*	Monitoring in relation to Noise Action Plans shows no adverse effects. Relevant Office for National Statistics wellbeing metrics. See also; seascape indicators and those for other users of the sea, material assets.
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.	*Plan activities integrate with the range of other existing uses of the marine environment.* *Plan activities do not result in adverse effects on marine assets and resources.*	Spatial planning capable of addressing changes in technology, policy and prioritisation of site selection. Economic and social impact (both positive and negative).
Safety of Navigation.	*Plan activities avoid adverse effects on, and contribute to the maintenance of, safe navigation, including recognised shipping routes, traffic separation and existing and proposed port operations.*	Increased collision risks and restrictions on pollution prevention methods or Search & Rescue options in the event of an emergency.

SEA Objectives	Guide Phrases	SEA Indicators
Reduces waste.	*Properties and quantities of waste and litter resulting from plan activities do not cause harm to the coastal and marine environment.*	Progress in reducing volumes of waste to landfill from plan activities.
Cultural Heritage		
Protects the historic environment and cultural heritage of the United Kingdom, including its setting.	*Activities avoid adverse effects on the character, quality and integrity of the historic and/or cultural landscape, including those sites which are designated or registered, and areas of potential importance.*	No adverse impact upon the condition of designated sites and features (including impact on their setting) and minimal impact on all other recorded sites and features.
Contributes to archaeological knowledge.	*Plan activities contribute to the archaeological and cultural knowledge of the marine and coastal environment through survey and discovery.*	Number of archaeological finds reported through best practice as a result of plan activities, and their deposit with national curatorial bodies of archaeological studies produced by offshore energy projects.

3.6 SEA scope

The area of study for this Offshore Energy SEA is shown in Figures 1.3 & 1.4.

The main stages of offshore wind and other marine renewable energy development are:

1. Site prospecting/selection including collection of site specific resource and constrain data, and seabed information by geophysical and geotechnical survey
2. Development, including construction of foundations/anchors/structures and any scour protection, device 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 are:

1. Exploration/appraisal including seismic survey and exploration/appraisal drilling with well evaluation and testing
2. Development, including production facility installation, generally with construction of pipeline(s), and the drilling of producer and injector wells
3. Production and export operations, with routine supply, return of wastes to shore, power generation, chemical use, flaring, produced water management/reinjection and reservoir monitoring

4. Maintenance

5. Decommissioning, including cleaning and removal of facilities

The main stages of natural gas offloading and storage are:

1. Exploration/appraisal potentially including seismic survey exploration/appraisal drilling and reservoir/geological formation evaluation
2. Development (depleted hydrocarbon reservoir), including drilling of new or workover of existing wells, installation of storage facility or modification of existing infrastructure, with new or existing import/export pipelines, and potentially offloading facilities
3. Development (salt caverns), including the drilling of wells, construction of storage caverns by dissolution, installation of storage facilities, with new import/export pipelines, and potentially offloading facilities
4. Import, storage and export operations, with routine supply, return of wastes to shore, power generation, chemical use, flaring, produced water management and reservoir/structure monitoring
5. Maintenance
6. Decommissioning, including cleaning and removal of facilities

The main stages of carbon dioxide and storage activity in depleted oil and gas reservoirs and saline aquifers are:

1. Exploration/appraisal including seismic survey and exploration/appraisal drilling and testing
2. Development, including installation of injection facilities, generally with construction of import pipelines, and the drilling of injection wells and potentially aquifer water production wells
3. Import and injection operations, with routine supply, return of wastes to shore, power generation, chemical use, venting, potentially aquifer water production/management and storage 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, semi-continuous or continuous)
- Physical damage or change to the seabed and subsurface
- Other indirect physical effects on seabed and water column
- Ecological effects of presence of structures

- Interactions with other users of the sea
- Visual intrusion
- Chemical and other inputs
- Atmospheric emissions
- Electromagnetic fields
- Waste disposal onshore
- Other effects
- Decommissioning and legacy issues
- Accidental events

All the major stages of offshore renewable energy, oil and gas, gas storage and carbon dioxide storage development, operation and decommissioning are covered by environmental regulations including the requirement for Environmental Impact Assessment at the development stage (see Appendix 3).

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 geomorphology
- 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 analysis shown as output maps and graphics. The assessment considers the implications of the draft plan/programme for relevant existing environmental problems including 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 the plan/programme obtained through consultation with regulators, local authorities, operators/developers and others. The results of the assessment are summarised for each alternative in a receptor based matrix format (Section 5.17).

3.7.1 Habitats Regulations Assessment

As noted in Section 2.6, activity leasing and licensing are split between a number of authorities, and for the purposes of Habitats Regulations Assessment (HRA), The Crown Estate and the Secretary of State are the competent authorities for further renewables leasing and oil and gas licensing respectively at the strategic level. The Crown Estate undertook HRA for Round 3 leasing in 2009, and DECC have undertaken HRA for successive rounds of oil and gas licensing[30]. The Environmental Report considers the potential for effects on conservation sites. In addition, as previously, a strategic HRA will be undertaken as part of the consideration of this draft plan/programme, in advance of award of any licence. The SEA has a wide geographical coverage (the UKCS for some activities) and the potential timing, nature and intensity of activities that could be associated with the adoption of the draft plan/programme is not fully defined. The strategic HRA will therefore be undertaken during each oil and gas licensing Round. The timetable and nature of any future HRA relating to the renewable leasing component of this plan rests with The Crown Estate.

3.8 Alternatives to the draft plan/programme

The SEA Regulations[31] require that the Environmental Report should:

"...identify, describe and evaluate the likely significant effects on the environment of—

(a) implementing the plan or programme; and

(b) reasonable alternatives taking into account the objectives and the geographical scope of the plan or programme"

And:

"...An outline of the reasons for selecting the alternatives dealt with..."

SEA Guidance, including on the selection of alternatives (e.g. ODPM 2005, Partidário 2012, EPA 2015), has been considered as part of the assessment process of the draft plan/programme. The development of reasonable alternatives is made in the context of Article 5.1 of the SEA Directive, which states that, "*Where an environmental assessment is required...an environmental report shall be prepared in which the likely significant effects on the environment of implementing the plan or programme, and reasonable alternatives taking into account the objectives and the geographical scope of the plan or programme, are identified, described and evaluate."*, that is, in the wider context of limitations to the alternatives based on geographical scope, legislative and policy context, including the legal competence of the plan-making authority, which includes the policy context outlined in Section 2.2 (namely enhancing security of energy supply while making progress towards meeting obligations in relation to renewable energy production and carbon emissions reductions).

The alternatives were initially considered using a modified version of the hierarchy in ODPM (2005):

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[30] The latest was for the 28th Round 2014-2015: https://www.gov.uk/guidance/offshore-energy-strategic-environmental-assessment-sea-an-overview-of-the-sea-process#appropriate-assessment
[31] Quoted text is taken from Regulation 12(2) and paragraph 8 of Schedule 2 of the *Environmental Assessment of Plans and Programmes Regulations 2004.*

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 of this consideration are summarised in Table 3.2.

Table 3.2: Consideration of hierarchy of alternatives

In there a need or demand?	Security of supply is a key objective of present energy policy in the UK. Production of domestic oil and gas has been in decline since 1999, with imports exceeding exports for gas and oil since 2004 and 2005 respectively. Whilst the major offshore hydrocarbon basins of the UK are at a mature stage of production, it is estimated that approximately 1,060 million tonnes of oil and 594 billion m^3 of reserves remain in fields in production or development. Central estimates for recoverable resources which are yet to be discovered are 752 million tonnes of oil and 578 million m^3 of gas. Section 9A of the *Petroleum Act 1998* creates an obligation on the Secretary of State (for Energy and Climate Change) to produce a Strategy for achieving the principal objective of maximising the economic recovery of UK hydrocarbons. The draft UK strategy for Maximising Economic Recovery (MER) of Offshore Petroleum is a statutory document which in turn sets out the MER obligations[32] which apply to the Secretary of State, the OGA, petroleum licence holders, operators appointed under those licences, the owners of upstream petroleum infrastructure, and those planning and carrying out the commissioning of upstream petroleum infrastructure[33]. UK gas storage capacity is presently 4.6 billion m^3, with demand for gas in 2014 being 70 billion m^3. The overarching National Policy Statement for Energy (NPS EN-1) recognises that gas storage infrastructure may increase as domestic gas production declines. A number of gas storage and unloading projects have been proposed in recent years and are at various stages of development. 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 (presently ~7%). The means by which this target is to be achieved was set out in the UK Renewable Energy Roadmap. Whilst renewable and other technologies (e.g. new nuclear) have the potential to deliver significant reductions in carbon dioxide emissions from energy production, fossil fuels will continue to constitute the majority of the UK energy mix for the foreseeable future during the decarbonisation of the UK energy supply (e.g. for use in gas fired power stations).

[32] Centrally, "Relevant persons must, in the exercise of their relevant functions, take all steps necessary to secure that the maximum value of economically recoverable petroleum is recovered from the strata beneath relevant UK waters."
[33] provisions in the 2015/16 *Energy Bill* amend Section 9A of the Petroleum Act 1998 to extend this list to cover owners of offshore installations.

	The current decline in domestic hydrocarbon production, the need to enhance security of supply whilst seeking to decarbonise the energy mix, and the statutory obligations placed on DECC and UK Government to maximise the economic production of UK hydrocarbons and meet renewable generation and carbon reduction targets, clearly define a need for further leasing/licensing as defined by the draft plan/programme (Section 2.6).
Mode or process	Within the context of marine energy production, offshore oil and gas exploration and production and offshore wind are considered to be the most mature technologies to deliver the objectives of the plan. CCS, wave and tidal technologies and some wind farm technologies such as tethered turbines are emergent and are unlikely to see large scale commercial deployment during the currency of this SEA, with larger arrays and commercial viability probably achieved closer to 2020. The leasing/licensing authorities and industry representatives have been consulted as part of the SEA process to understand the probable nature of devices likely to be deployed in the currency of the SEA.
Location	The presence of exploitable wind, wave and tidal resources and commercial hydrocarbon resources/gas (including carbon dioxide) storage capacity is variously a function of location, geological history and existing sensitivities and uses which dictate the areas of potential interest. A number of marine planning processes are separately taking place in UK waters, the first completed regional plans being the East Inshore and Offshore plans, covering a southern section of Regional Sea 2 used in this SEA (see Section 2.3). Marine planning in the UK has to date not been spatially prescriptive but has defined the range of offshore uses and potential constraints on certain types of development by location, emphasising priorities and promoting activity co-location where appropriate. The draft plan/programme for future leasing/licensing is not a spatial plan, but has been drafted in the context of knowledge of the potential UK resource and current industry interest, and the policy directions provided by the MPS, Scottish National Marine Plan, and emerging English regional marine plans, and the various current potential constraints arising from other users of the sea and the marine environment (see Section 5.15). Other marine planning processes are ongoing (e.g. in Wales) and any plan related activity would need to take account of their policies in due course.
Timing and detailed implementation (see Section 2.6 for an overview of the leasing/ licensing process)	The plan/programme is needed so that: • Further areas of English and Welsh waters can be leased for offshore wind and other marine renewable technologies. • Further areas on the UKCS can be licensed for hydrocarbon exploration and production in currently unlicensed blocks/unleased areas. • Further relevant areas of the EEZ can be leased/licensed for offshore gas storage (including for carbon dioxide). • Early implementation of the plan would allow potential synergies in terms of use of existing infrastructure (e.g. pipelines) to be taken advantage of (e.g. including for reuse for alternative activities such as natural gas or CO_2 transport and storage). The extent of such synergies will decline if the plan is delayed as infrastructure is decommissioned and removed[34].

The above consideration indicates that the proposed plan/programme has the potential to help deliver a number of UK Government policies and legislative commitments, but that the future location and scale of leasing/licensing is dependent on a number of factors including key resource locations and constraints, and the commercial interest in developing the resources. Previous SEAs have considered three broad alternatives to the draft plan/programme which are considered again for this SEA and have been subject to scoping and discussion with the SEA Steering Group. These alternatives have been selected as reasonable since they reflect the

[34] Note potential changes associated with the MERUK strategy and *Energy Bill* which will place certain obligations on owners of infrastructure subject to decommissioning.

high level nature of the plan, its objectives in relation to the national policy context and uncertainties in the scale and location of the leasing/licensing that could take place on its adoption.

The reasonable alternatives to the plan are shown in Table 3.3 along with a brief overview of the potential outcome of each. The potential effects of the adoption of these options are considered in Section 5.17.

Table 3.3: Overview of reasonable alternatives

Do not proceed with a licensing or leasing round	Proceed with a licensing or leasing round	Proceed with a licensing or leasing round, but restrict these spatially or temporally
This alternative would fail to meet the objectives of the plan/programme and is further restricted by DECC's, and others, legal obligation to pursue recovery of domestic hydrocarbons and to decarbonise the UK energy mix. If the plan were not pursued, this could lead to greater reliance on hydrocarbon imports, a reduction in potential security of supply delivered by enhancing UK gas storage capacity and a reduction in the ability of UK Government to meet its renewable energy and carbon dioxide emissions reduction obligations from domestic marine renewable sources or offshore carbon dioxide storage.	This alternative would allow the plan/programme to contribute to the achievement of a range of UK Government policy goals and legal requirements on security of supply and energy decarbonisation. The scale of any round is contingent on the level of commercial interest and so the potential level of activity which could follow the adoption of the plan/programme under this alternative is not certain, and therefore the individual sectoral contribution to the achievement of Government targets (e.g. renewables, carbon emission reductions) cannot be accurately quantified. Experience of previous rounds of activity can be used to infer the timing and scale of interest for future rounds (Section 2.7).	This alternative is likely to provide a similar outcome as continuing with the leasing/licensing round, but allows for the restriction of activities in certain areas where it can be clearly demonstrated at a strategic level that activity could not take place there, or where levels of uncertainty are such that further evidence or research is required to inform assessment. There is the possibility that this restriction could result in fewer leases/licences being issued.

4 Overview of Environmental Baseline

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 3 is provided in full as Appendix 1. 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 in Section 4.2. Within Section 4.3, summary details are provided for each Regional Sea, with further information and figures available in a series of sub-appendices to Appendix 1 (1a-1j).

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*."

Finally, Section 4.5, 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 2009/147/EC on the conservation of wild birds and the Habitats Directive*."

Throughout Sections 4.2, 4.3 and 4.4, signposts are provided to the locations of further information in the appendices.

4.2 Overview of the 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 >2,400m, 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.

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 1a.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 and other activities. Further information is provided in Appendix 1a.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 and 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 1a.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 circumpolar pattern of occurrence. Spawning and nursery grounds have been identified for many species and 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 (approximately at 60°N), and a distinct species group found in the cold waters of the Faroe-Shetland Channel and Norwegian Sea. Commercially fished species are heavily exploited. Further information is provided in Appendix 1a.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 1a.5.

The bird fauna of the UK is western Palaearctic; 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 nearly 50%, and the Isle of Rum off western Scotland 40%, of the world's breeding population of Manx shearwaters. The largest gannet colony in the world is on Bass Rock in the Firth of Forth, with ~150,000 birds. Further information is provided in Appendix 1a.6.

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 almost 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. Further information is provided in Appendix 1a.7.

Geology substrates and coastal geomorphology (Appendix 1b)

The present geology and substrates of the UKCS reflect a combination of processes taking place over millions of years, most recently influenced by glacial reworking and sedimentation in successive ice ages which is now interacting with Holocene wave and tidal processes. This reworking is very slow for much of the UKCS, but more rapid at shallower depths and in proximity to the shore where wave interaction and strong tidal currents may enhance the rate of change. The speed and nature of such change is also linked to underlying geology, with softer coasts generally eroding and changing much faster, particularly those comprising poorly consolidated rock or sediments. The deep geological history of the UKCS has led to the maturation of hydrocarbons where conditions are favourable (suitable reservoirs at depth and structural traps), and other sedimentary formations such as saline aquifers provide potential opportunities for hydrocarbon gas or carbon dioxide storage.

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. 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 at close proximity to oil and gas infrastructure, with concentrations decreasing with increasing distance from the source. Further information is provided in Appendix 1b.

Landscape/seascape

Landscapes and seascapes, as defined by the European Landscape Convention, include natural, rural, urban and peri-urban areas, land, inland water and marine areas, and includes areas that might be considered outstanding as well as "everyday" or degraded. The coasts and seas of the UK have a diverse character, which has or is being defined through the existing and ongoing identification of landscape and seascape character areas which account for the key characteristics of particular areas. Such characterisation and assessment may be undertaken at the regional and more local scale. The protection of areas regarded to be of particular importance in full or part for their landscape, has to date in the UK been through designation, for example AONB, National Scenic Areas or National Parks, however the wider recognition of landscape in the UK is now also being brought about through national and regional planning policy, including marine planning. Further information is provided in Appendix 1c.

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. A network of marine stations and buoys around the UK provide information on sea surface temperature, salinity, wave and tidal dynamics, alongside nutrient concentrations.

The North Atlantic Current is an important component of the global climate system, bringing warm subtropical water to the UK seas and influencing the climate. Density stratification is well developed in the summer months of most years in the central and northern North Sea, with the relative strength of the thermocline determined by solar heat input and turbulence generated by wind and tides. The UK has one of the highest tidal ranges in the world, peaking at 14.65m within the Severn Estuary and surface tidal streams ranging from <0.25m/s to >3m/s in a number of locations. The western coastline which is exposed to the Atlantic Ocean sees long term mean significant wave heights of 3m, peaking in winter, whilst the shelf region in the Celtic Sea and Faroe-Shetland Channel also experience significant internal wave activity.

River Basin Management Plans for all river basins in the UK were updated in 2015, including estuarine and coastal areas, with the primary objective of achieving good environmental status under the Water Framework Directive (WFD) for all water bodies by 2021. Additional objectives include; preventing the deterioration of the status of the water body, achieving standards and objectives for protected areas and cessation of discharges, emissions and loses of hazardous substances into surface waters. Further information is provided in Appendix 1d.

Air quality

Regular air quality monitoring is carried out by local authorities in coastal areas. The air quality of all local authority areas is generally within national standards set by the UK government's air quality strategy, though several Air Quality Management Areas have been declared to deal with problem areas. Most of these are in urban areas and result from traffic emissions of nitrogen dioxide or particular matter (e.g. PM_{10}). Industrialisation of the coast and inshore area adjacent to certain parts of the central North Sea has led to increased levels of pollutants in these areas which decrease further offshore, though oil and gas platforms provide numerous point sources of atmospheric emissions. Further information is provided in Appendix 1e.

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 extremely likely that the dominant cause of observed global warming since the mid-20th century has been caused by the anthropogenic production of greenhouse gases, which are likely to generate a temperature increase of more than 1.5°C by the end of the century (relative to 1850-1900), or 0.3-0.7°C for the period 2016-2035 (relative to 1986-2005). Related changes include increase in sea-level, possibly more changeable and extreme weather, and alteration to metocean conditions (also covered in relevant topic areas elsewhere). Further information is provided in Appendix 1f.

Population and human health

Population density is highest in England (417 persons/km^2) with over 80% of the UK population, and the English population has also shown the greatest increase over the last 5 years. The population densities in Wales (149 persons/km^2) and Northern Ireland (136 persons/km^2) are comparably lower than that of the UK as a whole; the density in Scotland is the lowest by a considerable margin (69 persons/km^2). General trends observed are lower population densities in coastal areas around much of the south-west of England, west and north Wales, the far north of England, and much of Scotland excluding the central belt. The highest population densities in coastal areas are around much of south-east England, part of north-east England, the Firths of Forth and Clyde, part of north-west England, south Wales and around the Severn Estuary. These areas are typically where conurbations are largest and most numerous.

Throughout the UK, the service sector dominates employment, followed by industry, then a small contribution from agriculture. Compared to England and the UK as a whole, Scotland, Wales and Northern Ireland show slightly higher proportions of employment in the agriculture and industrial sectors, and lower proportions in the service sector.

For the UK as a whole, 18.8% of people described their health for the 12 months prior to the 2011 Census day as “not good”. Values for Scotland and England were below the UK average at 17.8% and 18.5% respectively, with Wales the highest at 22.2%. The proportion of people with a limiting long term illness showed a similar trend, with the lowest proportion in England and highest in Wales. Life expectancy was slightly above the UK average in England and typically slightly below in Wales and Northern Ireland. Scotland showed a notably lower life expectancy at some 2.2 and 1.8 years below the UK average for men and women respectively. See also the National Wellbeing initiative https://www.gov.uk/government/collections/national-wellbeing#wellbeing-policy

Further information is provided in Appendix 1g.

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 1h, with key aspects summarised below.

The UK is heavily reliant on shipping for the import and export of goods, and will remain so for the foreseeable future. Approximately 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. More recently, smaller vessels including recreational craft have started to use AIS. AIS data allow precise tracking of individual vessels, and provide accurate information on important areas, particularly for larger vessel navigation.

Fishing in the UK has a long history and is of major economic and cultural importance. In 2014, there were about 12,000 working fishermen in the UK, operating 6,400 vessels, many of which are smaller inshore boats. These vessels landed 756,000 tonnes of fin- and shellfish in 2014, with a total value of £861 million. On top of this, fish processing provides over 19,000 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 30km radius. A number of other aviation interests also use the UKCS, and these are relevant to the consideration of interactions with aspects of the plan/programme, including helicopter routes to offshore installations and their approaches, and those involved in search and rescue operations. 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 making up the Air Surveillance and Control Systems (ASACS) are present around the coasts of the UK.

Tourism and recreational use of UK coasts and coastal waters is of major importance in many areas. In 2014, the British public made over 23 million overnight trips to the seaside in the UK, spending £4.9 billion, split between England (£3.9 billion), Wales (£0.7 billion) and Scotland (£0.3 billion). Figures for Northern Ireland (collected separately) indicate that 4.5 million overnight trips were made by all visitors in 2014, spending £0.8 billion. Major recreational uses of the sea beyond beaches and coastal paths include yachting, surfing and sea angling, with almost 1.1 million people participating in sea angling in 2012. 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, as offshore mines, telecommunications and other cables, disposal of capital and other dredging wastes, offshore wind farms, surface and subsea oil and gas production, hydrocarbon gas storage and export infrastructure, and most recently for carbon capture and storage. Potential future uses of the sea include further hydrocarbon, gas storage and carbon dioxide storage in geological formations or aquifers, while a number of marine renewable (wave and tidal) projects are in the early stages of development with various demonstration sites around the UK.

Further information is provided in Appendix 1h.

Cultural heritage

The cultural heritage of the UK relevant to OESEA3 includes coastal sites which date to some of the earliest settlements in Britain (potentially to as early as 700-900,000 years ago), and submerged sites in shelf seas which were exposed during previous glacial periods. Later submerged heritage includes a significant shipwreck record and aircraft losses which predominantly relate to previous world wars. 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 led to such a large number of ship and aircraft wrecks. Designated sites are relatively few in number compared to those which are recorded, and those recorded are very few compared to total numbers. With the exception of shipwreck, all designated sites to date are terrestrial, however legislative changes mean that in some areas sites may be designated for a wider range of attributes in the future. Further information is provided in Appendix 1i.

Conservation of sites and species

Designated conservation sites are widespread and abundant around the UK coast and also offshore; 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 Marine Protected Areas (MPAs) (Scotland) and Marine Conservation Zones (MCZs) (England, Wales and Northern Ireland), as well as Sites/Areas of Special Scientific Interest (SSSIs/ASSIs). There has been notable expansion of protected zones in the marine area in recent years. The *Conservation of Habitats and Species Regulations 2010* and *Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007* (as amended) have allowed the designation of SACs and SPAs beyond the 12nm territorial limit. Additionally, the *Marine and Coastal Access Act 2009*, *Marine (Scotland) Act 2010* and *Marine Act (Northern Ireland) 2013* have allowed the designation of MPAs and MCZs in inshore and offshore waters. Consequently, many new designations (MPAs, MCZs, SACs & SPAs) are set entirely in offshore and/or inshore waters, while others, such as some SPAs, are terrestrial with marine components. Progress towards further identification of marine sites is ongoing; a number of marine SACs and SPAs are currently undergoing consultation for designation or extension and work is underway to designate new MPAs (Scotland) and MCZs (England, Wales and Northern Ireland). Detailed listing and descriptions of conservation sites is provided in Appendix 1j.

4.3 Regional Seas

The previous Offshore Energy SEAs used the draft regional sea boundaries defined by JNCC (2004) as a means of considering the broad scale biogeographical regions within UK waters. Iterations to the draft regional seas (e.g. Verling 2009) were underway during the last SEA, and subsequently, a number of other regional subdivisions have been used to delineate the UKCS. These include those used for marine spatial planning, those defined by OSPAR, MSFD sub-regions, and those used in Charting Progress 2 to describe and report on the condition of the UK marine environment. The latter regions were modified from those used in the first Charting Progress on the basis of updated knowledge on the distribution of features, and to align more with WFD water bodies and MSFD sub-regions. This SEA uses a modified version of the Charting Progress 2 boundaries (Figure 4.1) to distinguish several important areas including: the Atlantic South West Approaches (Regional Sea 5), and the Faroe-Shetland Channel (Regional Sea 9), Rockall Trough and Bank (Regional Sea 10), and Atlantic North West Approaches (Regional Sea 11).

4.3.1 Summary of Regional Seas

The text below 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 in the Appendix 1.

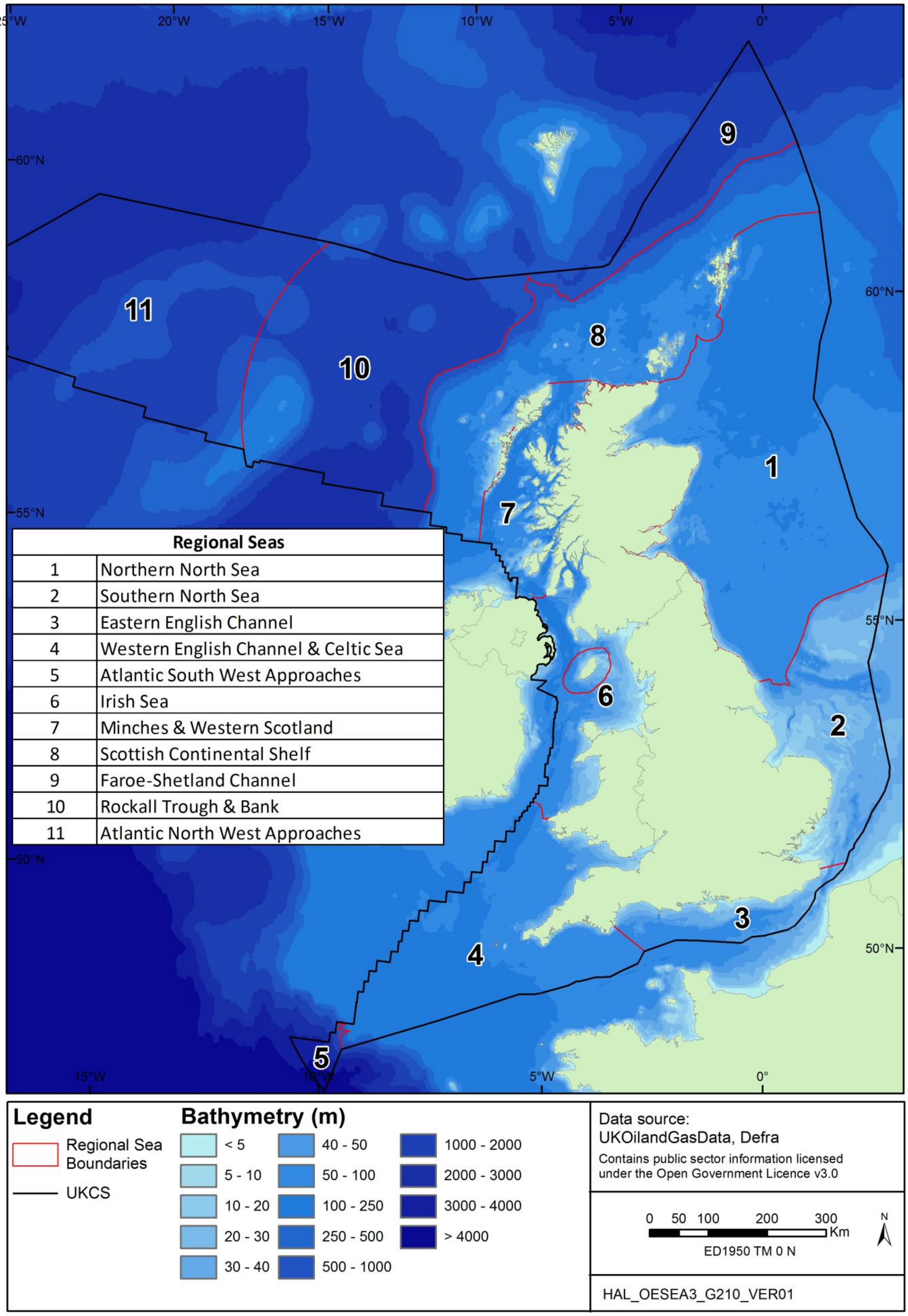
Features of Regional Sea 1

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. Regional Sea 1 supports a high number of coastal and offshore designations encompassing both European (SAC and SPA) and National (MPA and MCZ) sites, and a number of draft or proposed sites for features including seabirds, seabed habitats and marine mammals are presently under consideration.

Oil and gas development is extensive, particularly in the east, and renewables activity is centred on the territorial and offshore waters of the Moray Firth and the Firth of Forth. A number of tidal and wave lease areas have been granted in the territorial waters around Orkney and Shetland.

Figure 4.1: Regional Sea subdivisions used in OESEA3



Features of Regional Sea 2

The southern North Sea extends from the Flamborough front in the north to north of the Dover Strait in the south, with a transition 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 areas which have been designated under the Habitats Directive such as Dogger Bank SCI, the North Norfolk Sandbanks SCI and the Margate and Long Sands SCI. Further seabed features have been designated, or are in the process of being designated, as part of the Marine Conservation Zone project. The western flank of the Dogger Bank also supports high densities of seabirds, with notable colonies on the east coast located at Flamborough Head and Bempton Cliffs, including for kittiwake, gannet, guillemot, razorbill and fulmar. Harbour porpoise are widely distributed throughout much of the area, with apparently variable densities between two 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. Similarly, grey seals are present throughout the area with a notable haulout and breeding site located at Donna Nook on the entrance to the Humber Estuary SAC.

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. Many dredging licence and application areas are present in the region. 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, the Dogger Bank and off Holderness (Hornsea area) and East Anglia. Regional Sea 2 is the most prospective area for carbon dioxide storage due to its underlying geology, and an Agreement for Lease and the first Carbon Dioxide Appraisal and Storage Licence are located to the east of the Yorkshire coast.

Features of Regional Sea 3

The eastern English Channel is bounded by the Dover Strait to the east and extends to the west to a line drawn between Start Point and Cherbourg on the north coast of France. Depths are generally shallow and rarely exceed 60m. There are isolated deeps of 80-100m (e.g. the Northern Palaeovalley) and shallower deeps (60-70m) such as St Catherine’s Deep to the south of the Isle of Wight. Waters are mixed, with strong tidal current velocities in the central channel which decrease to the west and east. 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).

Regional Sea 3 contains a range of coastal SPA sites (e.g. Chesil Beach & The Fleet, Chichester & Langstone Harbours, Pagham Harbour) and one proposed site (Solent & Dorset Coast). Additionally SACs include those with marine components (South Wight Maritime) or entirely offshore sites (Wight-Barfleur Reef SCI), augmented by a large number of MCZs which have either been designated or recommended for designation.

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 and a Round 3 offshore wind farm development has been consented (Rampion).

Features of Regional Sea 4 and 5

The western English Channel and Celtic Sea is a large region west of a line drawn between Start Point 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 (formerly considered as a separate Regional Sea in OESEA and OESEA2), is a region bounded to the east by the shelf break and extends westwards into the northeast Atlantic. As only a very small proportion of this region lies within UK waters, it is therefore grouped with the adjacent Regional Sea 4. 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, 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. 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. Several important seabird colonies are located in this region, including those at Skokholm and Skomer, with areas for wintering birds regularly supporting tens of thousands of birds. 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 SAC. Additional SCI sites containing reef features are located in inshore waters including Start Point to Plymouth Sound and Eddystone SCI, Lizard Point SCI and Lands End and Cape Bank SCI. More recently, Marine Conservation Zones have been designated for features including high to moderate energy circalittoral, infralittoral or intertidal rock, and coarse sediments (Skerries Bank and Surrounds MCZ, Padstow Bay MCZ, East of Haig Fras MCZ, Greater Haig Fras MCZ). Two designated sites are located in the south west Approaches, including The Canyons MCZ (deep sea bed and cold water coral) and the South-West Deeps (subtidal coarse, mixed and sandy sediments, and relict sandbank features). A range of other rMCZ sites are located in the western English Channel, Celtic Sea and Atlantic south west Approaches.

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. To date offshore energy activity has been limited, with no commercial hydrocarbon discoveries and proposals for marine renewables being at demonstrator scale. There have been a number of recent proposals for tidal lagoon developments in the Severn (Swansea Bay, Cardiff and Newport).

Features of 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 the primary reason for the Cardigan Bay SAC and one of the qualifying features of the Lleyn Peninsula and the Sarnau SAC. Shell Flat and Lune Deep SCI is located in inshore waters near Morecambe Bay, and the territorial waters of Northern Ireland contain The Maidens SCI (reefs, sandbanks and grey seal) and Red Bay SCI (sandbanks). A number of designated MCZs are located in Regional Sea 6 (Fylde, West of Walney, Cumbria Coast, Allonby Bay, Strangford Lough), and a number of others are recommended sites which are yet to be consulted upon. In offshore waters, the Croker Carbonate Slabs SCI and Pisces Reef Complex SCI are designated for Annex I submarine structures made by leaking gases and reefs respectively.

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.

Features of 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. 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.

A very large number of designated conservation sites are present along the adjacent coast, including numerous habitat, species and landscape designations, as well as the East Mingulay SCI. Additionally, seven MPAs have been designated, which include the Small Isles and Wester Ross – both have been selected on the basis of supporting a range of habitat and species features, with the former containing the only known aggregation of fan mussels in UK waters, and also marine geodiversity features. Three other significant MPA proposals are located in Regional Sea 7; these are, the Sea of the Hebrides, North-East Lewis and Shiant East Bank. Proposed site features range from seabed habitats and fauna (including fan mussel aggregations, basking shark, sandeel and marine mammals including minke whale and Risso's dolphin). Each site is also proposed for marine geodiversity features.

Features of 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 1,000m 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 (also a designated SCI), 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, and SPA designation for the islands and surrounding waters. Large numbers of breeding seabirds also occur on the adjacent coast of the Outer Hebrides, north mainland and Northern Isles. The region includes two sites designated for reef features (Stanton Banks SAC and Solan Bank SCI), and more recently MPA sites including the West Shetland Shelf, North-west Orkney and part of the Faroe-Shetland Sponge Belt.

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, particularly along the continental shelf edge. 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.

Features of 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 main water masses in the region are oceanic in origin and turbidity is typically low but there are periods with elevated turbidly in near slope areas. 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 SCI, a large area of full salinity stony and bedrock reef. The area also includes part of the Faroe-Shetland Sponge Belt MPA, and the North-East Faroe-Shetland Channel MPA. Amongst other features, both are designated for deep sea sponge aggregations and offshore subtidal sands, and contain representative marine geomorphological features.

Features of Regional Seas 10 and 11

Regional Seas 10 and 11 cover the Rockall Trough and Bank and Atlantic North West Approaches. These are deep-sea regions west of the Scottish continental shelf, bound to the east by the 1,000m depth contour and to the west by the western extent of the UKCS. The seabed supports a different faunal community to that observed at depths less than 1,000m, 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 the Atlantic North West Approaches 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 Atlantic North West Approaches, 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 SCI, and the Darwin Mounds SAC. In the far west of Regional Sea 10 lies the North West Rockall Bank SCI. 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.

4.4 Likely evolution of the baseline

The SEA Directive (Annex I) requires that the Environmental Report provides information on the likely evolution of the relevant aspects of the current state of the environment without implementation of the plan/programme.

4.4.1 Biodiversity, habitats, flora and fauna

4.4.1.1 Plankton

The MSFD requires that the biodiversity, distribution and abundance of species and habitats be in line with prevailing physiographic, geographic and climatic conditions; this is true of the plankton around the British Isles whose biodiversity, abundance and distributions are primarily affected by hydroclimatic forcing as opposed to anthropogenic influences. GES also requires that ecosystems are not adversely affected by eutrophication, contamination, and non-indigenous species introduced through anthropogenic activities. The planktonic ecosystem of the British Isles meets these criteria as, though eutrophication and contamination may occur in some highly localised areas, the majority of plankton are unaffected by nutrient loading or chemical contamination and there is no evidence that non-indigenous organisms have caused negative impacts on the native plankton. Additionally, changes to marine foodwebs caused by alterations in plankton phenology (trophic mismatch) or community composition appear to be related to climatic factors and are not likely to be the direct result of anthropogenic pressures.

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 30 years. There have been widespread changes in the zooplankton community and in the timing of phytoplankton blooms, with wider consequences throughout the ecosystem. Overall, plankton in UK seas are relatively unaffected by direct anthropogenic factors.

The most recent MCCIP report card indicates that confidence in predictions of future changes to plankton from climate change are generally low, however future warming and increased ocean acidification are likely to alter the geographical distribution of primary and secondary plankton production (0-5 yrs), affecting ecosystem services such as oxygen production, carbon sequestration and biogeochemical cycling (20-50 yrs). Such changes have the potential to place additional stress on fish stocks and therefore on mammals and seabird populations which rely on fish as prey species.

4.4.1.2 Benthos

Over recent geological timescales (*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.

Clark & Frid (2001) reviewed long-term changes in the North Sea ecosystem at all trophic levels, and concluded that in the northern, western and central areas of the North Sea, long-term changes are predominantly influenced by climatic fluctuations. Here, primary productivity during a particular year is related to the effect of weather on the timing of stratification and the resulting spring bloom. In the southern and eastern areas of the North Sea, the lack of stratification and the large inputs of nutrients mean that primary productivity is more strongly influenced by variations in anthropogenic nutrient inputs, and is only weakly related to climatic variation. However, the weight of evidence shows that long-term changes in the ecosystem may ultimately be related to long-term changes in either climate or nutrients, although the long-term dynamics of certain taxa and communities do show evidence of being influenced by both anthropogenic factors and/or internal factors such as competition and predation.

The MCCIP Annual Report Card 2013 Scientific Review, shallow and shelf subtidal habitats (Birchenough *et al.* 2013), concluded that:

- There is evidence that climatic processes influence species abundance and community composition in soft-sediment habitats in the North Sea. There is no obvious signal of warming-effects in southern and south-westerly sediments.
- Hard-substrate habitats in southern and south-westerly waters appear to be affected by present day seawater temperature increases, with changes in algal distribution and abundance and the appearance and increased occurrence of a previously unrecorded warm-water barnacle.
- Climate change is likely to impact benthos in future. The changes documented in soft-sediment communities are expected to continue, and probably escalate, in response to the cumulative effects of seawater warming and ocean acidification (e.g. changes in species distribution).
- Future impacts on these habitats are likely to have socio-economic ramifications (e.g. under European legislation and as an important food resource for commercial fish).
- There are knowledge-gaps in a number of areas. We are currently unable to fully assess the scale of benthic species and community responses in relation to climate change, understand how climate interacts with other marine stressors or model future species distributions for many benthic species.

The MSFD requires that benthic biodiversity (descriptor 1) and sea-floor integrity (descriptor 6) are not adversely affected by anthropogenic sources. The UK initial assessment for MSFD indicated that physical damage and loss, particularly from bottom fishing, remains a problem but that depending on the nature of future measures (e.g. in relation to MPA management measures in the wider environment and within MPAs (under national legislation and under the Common Fisheries Policy), such effects are likely to be reduced and therefore some improvement in benthic habitats could be expected. Potential future issues could arise from enhanced coastal squeeze from climate change related sea-level rise, impacts from ocean acidification, and from tidal range devices on intertidal habitats.

4.4.1.3 Cephalopods

The biology and ecology of many cephalopod species remains little known and as a result, the potential effects of a changing climate on cephalopod populations are not easy to predict. However, it is known that for many species, temperature has an important influence on a number of life history processes, including recruitment (through maturation rate and the rate of embryonic development), the timing of migration and the distribution range. As well as this, food availability and predator abundance and distribution are likely to be affected by changes in the marine environment.

4.4.1.4 Fish and Shellfish

The general colonisation of the warming southern North Sea and Celtic Sea regions by Lusitanean demersal species (e.g. sea bass), and a retreat of Boreal species (e.g. cod, whiting) into the deeper parts of UK waters in the northern North Sea is likely to continue. However, variations in habitat preferences and sensitivities to prey and environmental conditions of individual species, the possible role of food web effects, and particularly the extent of future fisheries may complicate this simple picture. For example, while warm-water species have generally increased in abundance off the south-west coast of the UK, consistent with general trends, several warm-water species of commercial importance have declined over the same period (Genner *et al*. 2010). Some pelagic fish species have and are likely to continue to show pronounced latitudinal responses to seasonal sea temperatures (e.g. anchovy, horse mackerel), although predicting their likely distribution is complicated by the important influence of poleward flowing shelf edge currents which carry warm water into high latitudes. Species which are unable to adapt their distributions due to strict habitat association (e.g. lesser sandeels which closely associate with coarse sandy sediments) are likely to be less able to respond to predicted climate changes (Heath *et al*. 2012).

With respect to migratory fish, recent trends may continue with declines in salmon strongly correlated with rising temperatures in oceanic foraging areas, with temperature affecting growth, survival and maturation of salmon at sea. Freshwater temperatures have also increased significantly in the last four decades, with implications for survival of juvenile diadromous fish (e.g. salmon and shad) (Simpson *et al.* 2013).

4.4.1.5 Turtles

Records of marine turtle sightings and strandings in UK waters indicate that they are predominantly of leatherback turtles (e.g. Penrose & Gander 2014), with UK waters likely to represent the northerly limit of routine seasonal leatherback foraging migrations (e.g. McMahon & Hays 2006). Leatherback turtles visit only during the warmer months of the year and it has been suggested that through climate change increased seawater temperature might allow them to utilise UK waters for longer (McMahon & Hays 2006). However, the low numbers of recorded turtles and the quality of recording effort[35] make determining likely future trends very difficult.

4.4.1.6 Birds

Seabird breeding populations in the UK increased in size over much of the last century, but since 1999 some of these populations have shown significant declines. Breeding success has also declined over the same period. Some of the greatest reductions have occurred in the northern North Sea and Scottish Continental Shelf. Climate change is considered to be one of the main drivers of these declines. Warmer winter sea temperatures have resulted in major changes in abundance and species composition of plankton in the North Sea that have contributed to the reduction in abundance and quality of seabird prey species such as sandeels, with knock-on effects for seabirds (Daunt & Mitchell 2013). For example, between 2000 and 2013, declines greater than or equal to 50% have occurred in Arctic skua and kittiwake[36], both of which feed on small shoaling fish such as sandeels. There is also growing evidence that breeding phenology is changing, with seabirds becoming increasingly de-synchronised from their prey. However, regional variations in the impacts of climate change are apparent, with weaker effects on seabird demography in the Irish Sea, Celtic Sea and English Channel (Daunt & Mitchell 2013, Lauria *et al*. 2013).

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[35] http://jncc.defra.gov.uk/pdf/Article17Consult_20131010/S1223_UK.pdf
[36] http://jncc.defra.gov.uk/page-3201

There is increasing evidence that the overwintering distributions of many coastal waders and waterfowl have changed. In recent decades their distributions have shifted north and eastwards out of the UK. This has resulted in declines in usage of the UK's east coast sites by waders, in favour of The Netherlands. These declines may have been partly reversed by the most recent cold winters[37].

4.4.1.7 Marine Mammals

Whilst the ability to detect long-term trends in cetaceans around the UK is limited by the paucity of effort-based sightings data, range shifts appear to have been observed in a number of cetacean species (Evans & Bjørge 2013). For example, short-beaked common dolphin and striped dolphin appear to have extended their shelf sea range further north off western Britain and around into the northern North Sea, and these have been linked to increasing sea temperatures. However, the mechanisms causing those changes remain uncertain, and for some species, it is difficult to differentiate between short-term responses to regional resource variability and longer-term ones driven by climate change. With respect to seals, whilst it is possible that recent demographic changes (increases in most grey seal populations and declines in some harbour seal populations) are linked in some way to climate-mediated changes in food supply, other factors (depletion of food resources from fishing, recovery from epizootics, interspecific competition, density dependent effects) may be more important (SCOS 2008, cited in Evans & Bjørge 2013).

4.4.2 Geology, Substrates and Coastal Geomorphology

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, and energy removal has the potential to result in local or regional changes to sedimentary processes.

Relative sea levels are predicted to rise by 21-68cm for the period 1990-2095 (for London) – note there are regional UK variations in the predicted rate of sea-level rise, including due to glacial isostasy. While these figures are considered to remain valid, they will be updated in due course using new information and data arising from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (e.g. through UKCP18). Coastal erosion is estimated to affect 17% of UK coasts and there are large regional variations connected with coastal rock types – England and Wales have the highest overall erosion rates with 28% of coasts retreating at more than 10cm per year. These rates are expected to rise in the future, corresponding to higher sea levels and possibly also enhanced storminess.

4.4.3 Landscape/Seascape

There are presently 2 offshore wind farms in planning and a further 11 which have been consented, adding to the 27 which are either operational or under construction (England and Wales). A number of these are, or are likely to be, visible from the coast (e.g. those fully or partly in territorial waters) and future leasing rounds for wind and other renewable technologies which could be developed in proximity to the coast, or be coast connected, are possible. There is a likelihood of landscape effects from coastal and terrestrial wind generation projects, other marine energy developments (including tidal range) and continued industrial, port and urban expansion. At the coast, climate change may alter the character of many intertidal areas through coastal squeeze, and in some areas this may lead to significant change in landscape

[37] http://www.mccip.org.uk/media/1301/mccip-arc2013.pdf

character both directly and indirectly through loss of related habitat and species. A linked factor is policies relating to coastal defence and identification of compensatory sites which may also alter areas at a local scale.

4.4.4 Water Environment

Sea-surface temperatures (SST) in UK coastal waters and in the north east Atlantic have risen by between 0.1 and 0.5˚C per decade since the 1980s, being fastest locally in the southern North Sea. The temperature of the upper ocean (0-800m) to the west and north of the UK has been generally rising since the 1970s and 1980s. Superimposed on the underlying upward trend are decadal variations with relative maxima around 1960 and in the 2000s and relative minima in the 1980s and 1990s. However, it remains difficult to fully distinguish natural variations in temperature from those due to anthropogenic influence (including emissions of CO_2) (Dye *et al*. 2013).

There is a history of strong variability in UK wave climate. Inter-annual variability in the modern wave climate is strongest in the winter and can be related to atmospheric modes of variability, most notably the NAO. Rather dramatic increases in wave height occurred between 1960 and 1990, but these are now seen as just one feature within a longer history of variability and there is no clear pattern in results since 1990. There is as yet no consensus on the future storm and wave climate (Woolf & Wolf 2013).

Temperature stratification over the NW European shelf seas is showing evidence of beginning, on average, slightly earlier in the year, although it is very difficult to decipher trends against natural variability (Sharples *et al*. 2013).

4.4.5 Air Quality

Future projections of UK emissions of key air quality pollutants are compiled to inform policy development and to enable comparisons to be made with international commitments. The projections indicate that during the period up to 2025 in which current measures on climate and air quality continue to be implemented then emissions will reduce. However for ammonia, particulate matter (PM_{10}) and non-methane volatile organic compounds (nmVOCs) the longer-term projections are driven by economic growth. Hence, without intervention, emissions are currently projected to be greater in 2030 than 2020. Emissions of nitrogen oxides and sulphur oxides are predicted to continue to decline as energy efficiency measures reduce energy demand and renewable sources of energy replace coal and natural gas combustion.

4.4.6 Climate and Meteorology

It is extremely likely that climate change is influenced and/or generated by the anthropogenic production of greenhouse gases, with globally averaged temperatures having risen by 0.85˚C in the period 1880-2012, and other meteorological parameters such as rainfall also having been affected (e.g. there is high confidence after 1951 that precipitation has increased over mid-latitude land areas of the northern hemisphere). It is also considered likely that further changes in temperature, rainfall and incidence of extreme weather (e.g. heavy precipitation, drought, warm spells/heat waves) will occur in the course of the next century. It is considered virtually certain that the upper ocean has warmed in the period 1971-2010 (globally 0.11˚C per decade for the upper 75m), and very likely that other changes such as in salinity representing alteration in evaporation and precipitation trends have taken place. Future warming is considered to be strongest in tropical and northern hemisphere subtropical regions. Other changes in the 21st century include a weakening of the Atlantic Meridional Overturning Circulation (AMOC) of between 11% and 35% depending on the scenario considered, but there is low confidence in projections beyond the 21st century.

4.4.7 Population and Human Health

In the UK as a whole, population is expected to increase by 3.4 percent to 67.1 million by 2020 compared with the estimated UK population for 2015. Growth is projected to be most significant in England (3.6% growth) and least in Wales (1.99%) over the same period. For the period 2003-2013, the greatest population increase has been in areas adjacent to Regional Seas 2 and 3, and least for areas adjacent to Regional Sea 6, and parts of Regional Sea 1. Continued growth will increase population density. Human health in the UK is unlikely to change considerably in the near future, with life expectancy at birth projected to increase to 84.1 years for males and 87.3 years for females by 2037, an increase of around five years since 2012.

4.4.8 Other Users

Existing marine activities include shipping and port activities, military exercises, fishing, recreational sailing, oil and gas exploration and production, aggregate extraction, aviation and offshore wind farm construction and operation. Port activities and shipping tonnage have a long-term trend of continuous expansion, apart from the 2008 recession which had an accompanying 11% downturn in movement from a 2005 peak. Through-traffic in the North Sea is predicted to increase by 2020. 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 a tidal lagoon has received planning permission and could be installed during the currency of OESEA3, and a number of other proposals are also at a planning or pre-planning stage.

4.4.9 Cultural Heritage

There is an increasing awareness of the submerged archaeological resources of the UKCS, though the speculative nature of their distribution means that they can be vulnerable to offshore operations which disturb the seabed (drilling, piling, cabling), but these activities have in the past also led to significant development-led discoveries. Increasingly sophisticated detection methods, mapping, and underwater excavation, and updated industry guidance and licence conditions (e.g. as attached to deemed marine licences for nationally significant infrastructure projects), means that the recovery of archaeological material or information is increasingly likely.

4.4.10 Conservation of Sites and Species

The number of conservation sites continues to grow as understanding of the marine environment improves. New marine conservation sites established under *The Marine and Coastal Access Act 2009* (and equivalent Acts of the devolved administrations) have the aim of completing an ecologically coherent and well-managed network of MPAs, together with existing and future Natura 2000, OSPAR and other conservation sites. These should also contribute to the achievement of Good Environmental Statues (GES) in relation to the MSFD. It is expected that more marine and coastal sites will be identified and/or designated during the currency of OESEA3.

4.4.11 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. However, coastal habitats are not specifically addressed.

Coastal habitats in the UK, which are variously influenced by physical processes including underlying geology, past and ongoing sedimentary regimes (including aeolian deposition and erosion) are important in terms of their conservation value (e.g. Annex I dune and machair sites, and priority dune machair, coastal vegetated shingle and maritime cliff habitats), and the services which they provide including flood risk reduction. In England, almost a third of international designations are coastal, a proportion of which are intertidal, and over half of AONB designations have a coastal element (Jones *et al.* 2013b).

Many of these coastal habitats are not in favourable condition, being subject to past human intervention through land reclamation (for instance the use of dunes for forestry and golf course development) and the erection of hard defences. This, aligned with projections for future sea-level rise may lead to the further reduction of such areas, particularly where development and hard defences prevent the landward migration of certain habitats (i.e. coastal squeeze), and also where such defences prevent erosion which is a necessary part of the coastal sedimentary system. In other areas, managed realignment is likely to be considered.

Jones *et al.* (2013b) summarises the likely impact that climate change will have on coastal habitats including sand dunes and sandy beaches, machair, saltmarsh, shingle structures and beaches, and hard and soft rock maritime cliffs and slopes which include those with maritime grassland and heath. In addition to sea-level rise, changes in temperature, rainfall, wind speed and direction will affect dune landform development, but the likely results of such changes are uncertain. The range of some plant communities may extend northwards, such as the *Leymus arenarius* and the *Ammophila arenaria-Festuca rubra-Hypnum cupressiforme* subcommunity. Warmer and wetter conditions may be favourable in terms of dune stabilisation and development, but these are likely to be offset by drought periods and storms. Hydrological changes in dune slacks may also lead to changes in dune slack communities. Low-lying machair habitats are similarly affected by sea-level rise and storm events should they increase as a result of climate change. Similarly, saltmarsh environments may be affected by sea-level rise and any increase in storminess, which may further decrease their extent. Their inability in some cases to adjust through inland migration enhances their vulnerability. Regional changes in precipitation could also result in effects such as changes in sediment supply from freshwater runoff, and species distribution could be affected by elevated carbon dioxide levels. Shingle beaches and structures may be affected by changes in wave and tidal energy potentially resulting in the movement of some features out of designated site boundaries. Where movement is not considered acceptable (e.g. in proximity to Dungeness power station), replenishment will be required. There is likely to be landward migration of narrow beaches (coastal squeeze), and coastal defences may be more at risk of being undermined as beach levels lower. Sea-level related impacts to key shingle areas may be disproportionate as they coincide with areas where projected sea-level rise is greatest (i.e. in the south and east). Changes in vegetation of shingle beaches are also likely (for instance the loss of the northern oysterplant in several southern areas is attributed to warmer temperatures, along with assisting the spread invasive garden species which could displace native species. Additionally, more frequent storms could also affect the rate of recolonisation of sparse native vegetation.

Maritime cliffs may erode more rapidly as sea-level and storminess increase, exacerbated by an increase in rainfall which may help promote a greater number of landslips. Such increased disturbance would favour early successional species and may reduce vegetation mosaics important for scarce invertebrates, and warmer temperatures may also favour invasive species.

4.5 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 2009/147/EC and 92/43/EEC (the Birds and Habitats Directives). More recently, the principal problems in UK waters have been reviewed and considered in relation to MSFD descriptors of GES, and set against relevant targets and monitoring programmes with a view to meeting the requirements of the MSFD[38]. These inputs have been reviewed and are considered here in relation to their implications for this SEA. In addition to these, a number of other potential problems of relevance to the SEA not specifically related to conservation of environmental protection are considered, for instance in relation to material assets and cultural heritage. No judgement of importance should be inferred from the position of problems/issues in the section.

4.5.1 Eutrophication

The majority of UK waters do not experience significant eutrophication – the eutrophication problems are restricted to a small number of areas in coastal waters, particularly estuaries and embayments where circulation is restricted. For instance in a limited number of coastal areas in the east, south and north-west of England inputs of nutrients of anthropogenic origin (notably nitrate and phosphate from agriculture and urban waste water sources) have resulted in nutrient enrichment in some small estuaries and bays. Where measures have been taken to reduce nutrient inputs, it may be decades before eutrophication is absent because nutrients can be released from soil and sediments, however the existing programmes for assessing the eutrophication status for coastal and marine waters developed under the WFD and the OSPAR Convention have to a large extent already been applied successfully.

4.5.1.1 Implications for SEA

The SEA must consider the potential implications of the draft plan/programme on attaining good environmental status of both marine and coastal/estuarine waters as determined by the WFD and MSFD. One of the descriptors for determining GES under the MSFD (Descriptor 5) is that human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters. Whilst plan level activities may not directly contribute to or generate eutrophication, any effects which could lead to cumulative effects should be considered.

4.5.2 Hazardous Substances

Environmental concentrations of monitored hazardous substances in the sea have generally fallen, but are still above levels where there is a risk of pollution effects in many coastal areas, especially where there have been historical discharges, emissions and losses from high population densities or heavy industry.

Concentrations of some metals (cadmium, mercury and lead) and persistent organic pollutants are above background in some offshore waters of the North Sea, and unacceptable in some coastal areas. In the Greater North Sea, lead levels, for example, were unacceptable at 40% of locations monitored, while PAHs and PCBs were at unacceptable levels at more than half of the monitoring sites. In the Celtic Seas, heavy metal, PAH and PCB concentrations in sediment, fish and shellfish have fallen, but are still above acceptable levels in some coastal areas, mainly

[38] See Charting Progress 2, Marine Strategy Part 1 and Part 2.

around the Irish Sea. Concentrations of PAHs and PCBs are unacceptable at more than half the sites tested in the Celtic Seas (OSPAR 2010).

The volume of oil accidentally spilled varies widely from year to year and is generally small and of relatively minor significance.

4.5.2.1 Implications for SEA

The SEA must consider international and national scale measures to reduce operational and accidental discharges at sea and from the terrestrial environment in relation to the possible impacts of the draft plan/programme (e.g. operational and accidental discharges from oil and gas exploration and production, and transportation and storage of CO_2), in the context of targets set for the attainment of good environmental status under the MSFD particularly for descriptor 8, including that, "*Concentrations of substances identified within relevant legislation and international obligations are below the concentrations at which adverse effects are likely to occur*" and that "*Occurrence and extent of significant acute pollution effects (e.g. slicks resulting from spills of oil and oil products or spills of chemical) and their impact on biota affected by this pollution should be minimised through appropriate risk based approaches*."

4.5.3 Marine Litter

Amounts of marine litter are a concern, and are considered problematic in all areas where there are systematic surveys of beached litter density. There has only been limited surveying of litter on the seabed and in the water column, which has demonstrated that litter tends to accumulate in certain areas as a result of wind and currents. There is limited information from the northern part of the Celtic Seas sub-region.

In the Greater North Sea over 90% of fulmars have microscopic plastic particles in their stomachs and 45% to 60% have more than the Ecological Quality Objective (EcoQO) set by OSPAR. Beach litter in the southern North Sea is at OSPAR-wide average (around 700 items per 100m of beach), but levels are higher in the northern North Sea. On beaches around the Irish Sea there are unacceptable quantities of litter, reaching over 1,000 litter items per 100m of beach in some areas. This can be dangerous to seabirds, and to turtles and marine mammals when in the sea and also at nesting nests, with plastic and other manmade litter a growing issues at nest sites such as those for gannet on Grassholm. Much of this litter probably comes from sources on land.

4.5.3.1 Implications for SEA

The importance of tackling marine litter has been highlighted in the MSFD, which includes the descriptor that properties and quantities of marine litter do not cause harm to the coastal and marine environment. Whilst information is being collected about the levels of marine litter in UK waters, trend-based targets have been set with a view to more specific targets being available by 2018. The majority (~80%) of marine litter is regarded to come from terrestrial sources. The SEA must consider how marine litter is controlled for the potential activities arising from the plan (e.g. in relation to MARPOL Annex V), and any other potential waste sources and how they are handled (including waste to shore).

4.5.4 Impact of Climate Change

The pace of warming of the sea over the past 30 years has been highest in the southern North Sea and to the west of Scotland, rising at a rate of 0.2-0.4°C a decade. Plankton and fish communities are already changing in response to warming. Fish like sea bass and red mullet are becoming more common further north, while stocks of cold-adapted species in the North

Sea such as cod, haddock and whiting have declined. Additionally, there is a northwards movement of non-native species.

Sea level is rising, increasing the risk to coastal erosion, and from flooding and loss of intertidal habitat due to 'coastal squeeze'. This is a particular concern in the southern North Sea, eastern Channel and Bristol Channel regions due to continued adjustment of the land following the end of the last glaciation, which is resulting is gradual sinking, and the coasts of south-eastern England are low lying. The coasts of the south and east are also generally formed of soft sediments compared to those in the north and west, which are susceptible to erosion and retreat. The southern North Sea and Channel coasts have the highest proportion of coastal defence and flood protection schemes in the UK and further development in response to rising sea level will add to the existing pressure on intertidal sediment habitats. In some areas, shoreline management plan and other coastal policies are directing management towards managed realignment or retreat where further defences may not be economically feasible or else would themselves be environmentally detrimental. A connected issue relates to the challenges involved in identifying and creating areas of potential compensatory habitat (e.g. in relation to flood defence measures and effects on Natura 2000 sites) as mitigation against loss of intertidal areas.

In addition to the direct effects of temperature changes, other effects include those from ocean acidification. 30% of all anthropogenically emitted carbon dioxide has been absorbed by the oceans since the industrial revolution, and the acidification expected to continue to take place, with projections for 2100 in the range 0.06-0.32 pH (a change of approximately 0.1 pH units is regarded to have been connected to anthropogenic carbon dioxide uptake to date). Ecological consequences of reduced pH include changes to the carbonate system which could affect a range of calcifying organisms such as echinoderms, molluscs and corals.

4.5.4.1 Implications for SEA

Activities associated with the draft plan/programme should help to make a net contribution to the reduction of UK CO_2 emissions, as set out in the UK carbon budget, through carbon dioxide storage, or an increase in the proportion of UK energy generated by renewable technologies. As such, adoption of the plan/programme subject to any spatial considerations and recommendations arising from OESEA3 will also contribute to the achievement of the UK's legally binding target of producing 15% of its energy from renewable sources by 2020 – equivalent to ~30% of electricity generation. The longer term UK Government aim, of which the current draft plan/programme is one aspect, is to achieve a sufficient reduction in greenhouse gases (i.e. all of those which contribute to global warming, not just CO_2) to prevent those extreme climate change scenarios (e.g. as projected by IPCC or in UKCP09) and associated social, environmental and economic costs (e.g. Stern 2006).

Climate change has the potential to affect the range of some non-native species, and the SEA should consider the potential for any plan related activities to contribute to their spread in the context of existing measures which are in place for their control, and any new monitoring and control measures arising from targets relating to the MSFD Descriptor on non-native species.

The SEA should also consider relevant UK policy (e.g. MPS and National Planning Policy) and that of devolved administrations with regards to the design and siting of developments, particularly at or near the coast, in terms of resilience to climate change effects including sea-level rise.

4.5.5 Pressures on Fish Stocks

Some important North Sea fish stocks are still outside sustainable limits, while damaging practices have been reduced. The poor status of cod is of particular concern (however some improvement is suggested for the North Sea). By-catch of rays, sharks, porpoises and dolphins in fishing nets is also of concern. While trawl effort has fallen in the Irish Sea and to the west of Scotland, fishing effort is still high. Some beam trawlers have switched to otter trawling or scallop dredging, a fishery without quotas[39]. Several fish stocks are harvested unsustainably. Cod and whiting are depleted to the west of Scotland and in the Irish Sea. To date, recovery plans for cod have not been effective in rebuilding the Irish Sea stock. The amount of fish caught and discarded is still a problem, which is being addressed through the demersal landing obligation as part of the Common Fisheries Policy, currently in the process of being phased in, between 2015 and 2019.

4.5.5.1 Implications for SEA

Activities resulting from implementation of the draft plan/programme may have the potential to improve local fish stocks through the designation of safety zones around structures, and fish attraction to structures, though the corollary to this is fisheries displacement. The SEA should also consider any potential source of effect on fish and shellfish from activities, in the context of the current understanding of fish stocks and pressures on these from other activities, and those targets and indicators set under the MSFD descriptor on populations of commercially exploited fish.

4.5.6 Declines in Bird Numbers

In the northern North Sea, some seabirds have suffered a decade of poor breeding or failure, possibly due to the combined effects of climate change and fishing on key prey species (e.g. sandeel). Additionally, a reduction in fish discards may have resulted in the decline of some scavenging species such as fulmar, with the implementation of the discard ban expected to further impact seabirds – though evidence is still limited for this. Although seabird breeding success was good in 2009, the long-term picture is still one of serious concern, with wider seabird population trends for 2000-2013 showing a general decline in most recorded species[40]. Similar declines in seabird breeding numbers have been observed to the west of Scotland associated with predation by introduced mammals and food supply shortages, although eradication programmes of introduced predators on some islands is providing respite for seabirds vulnerable to predation.

In the southern North Sea, some waterbird populations have declined and this has been linked to reduced food availability possibly due to pressure from shellfisheries. In the Irish Sea, the number of waterbirds, such as waders, has decreased as more birds are now wintering in east coast estuaries, potentially as a result of a changing climate.

4.5.6.1 Implications for SEA

Given that many seabird and waterbird species may be in decline, the SEA should review potential areas which could be licensed/leased for oil and gas, offshore wind, marine renewable or carbon transport and storage activities, and ensure awareness so that potential activities do not exacerbate the risk of surface pollution or significant disturbance to bird populations. Potential activities which may impact on coastal and marine SPAs will be subject to Appropriate Assessment by the relevant Competent Authority. The SEA should consider any potential effect

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[39] See *The Scallop Fishing (England) Order 2012*
[40] http://jncc.defra.gov.uk/page-3201

of plan activities in the context of targets relating to bird abundance and productivity under MSFD descriptors 1 and 4.

4.5.7 Damage to Seabed Habitats

Significant damage has occurred to shallow sediment habitats and reefs as a result of bottom fishing practices especially beam trawling (OSPAR 2010). Around the UK, coastal and offshore seabed sediment habitats such as sands and muds are impacted by a range of activities, however the spatial extent of damage generated by bottom trawling activity, which may damage ecosystem functioning, is considered to the main source of pressure on benthic environments.

4.5.7.1 Implications for SEA

The SEA should review potential areas which could be licensed/leased for oil and gas, offshore wind, marine renewable or carbon transport and storage activities and ensure awareness of existing problems related to the benthos so that potential activities do not exacerbate problem. Safety zones around surface infrastructure will likely locally reduce trawling activities in these areas thereby reducing trawling pressure on benthos. The potential for marine renewable devices to affect sediments and seabed morphology (e.g. through energy removal, changes to tidal regimes) should also be considered. The SEA should consider effects from activities likely to arise from adoption of the plan on benthos in the context of those targets set to achieve good environmental status under MSFD descriptors 1, 4, 6 and 7.

4.5.8 Poor Knowledge of the Status of Marine Mammals

Data on cetaceans' abundance are insufficient to identify population trends with confidence for most species in most regions. There is a greater understanding for the populations of bottlenose dolphins in Cardigan Bay and the Moray Firth and to some extent for harbour porpoise populations; knowledge for several other species is minimal, especially those inhabiting deeper waters off the continental shelf (including beaked whales). A third survey of cetaceans in European Atlantic waters (SCANS-III) is due to take place this summer. Due to the greater ease with which seals can be studied, data on their distribution and abundance are more complete and abundance estimates are of sufficient quality and temporal coverage for larger magnitude changes and trends to be identified and interpreted.

4.5.8.1 Implications for SEA

There is the potential for disturbance of marine mammals from the activities that may result from implementation of the draft plan/programme. Activities will be 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. The SEA should consider such activities in the context of current controls on their occurrence, available mitigation, and implications in relation to monitoring under the MSFD. There is also a collision risk associated with offshore structures (tidal stream turbines) and shipping activity.

4.5.9 Problems associated with the conservation of species and habitats

The OSPAR QSR 2010 (OSPAR 2010) identifies a series of environmental problems in relation to the protection and conservation of biodiversity and ecosystems. These apply to the OSPAR marine area but are equally relevant to UK waters and include:

Pressures such as the removal of species (e.g. by fishing), loss of and damage to habitats, the introduction of non-indigenous species, obstacles to species migration and poor water quality are still present. Some pressures are still increasing in parts of the OSPAR area and all can act in synergy or be exacerbated by climate change. These pressures result in loss of biodiversity, including declines in the abundance and variety of species and habitats. Interruption of ecological processes, such as spawning, migration, and biological communication, may also occur.

The most sensitive features are those that are easily damaged and slow to recover. Reefs of the cold-water coral *Lophelia pertusa* and individuals of the fan mussel *Atrina fragilis* are slow-growing and delicate and can be severely damaged by bottom trawl fisheries.

Coastal waters contain feeding grounds, spawning and nursery areas, and feature on migration routes for seabirds and some fish species. These areas also host intense and varied human activities, which exert a wide range of pressures and can lead to the damage or loss of key habitats in estuaries and intertidal areas. Salt marshes and seagrass beds, which are highly productive and act as natural carbon sinks, are under pressure from relative sea-level rise and coastal development. Key areas of the shelf seas, including offshore banks and reefs, and frontal zones between different water masses, play important roles in pelagic productivity. Fishing is recognised as a key pressure on species and habitats in the shelf seas and there continues to be a need for information about ecologically important areas to guide improvements in management.

With reference to habitats and species protected under the Habitats Directive, JNCC have assessed their conservation status. This assessment of conservation status does not only relate to that component of the habitat area or species population to be found in Special Areas of Conservation, but to the totality of the habitats and species throughout the United Kingdom. The 2013 Article 17 report (JNCC website – http://jncc.defra.gov.uk/page-6563) prepared under the Habitats Directive is the third six year report.

When assessing the conservation status of habitats, four parameters were considered. These were: range, area, structure and function (referred to as habitat condition) and future prospects. For species, the parameters are: range, population, habitat (extent and condition) and future prospects. Each of these parameters was assessed as being in one of the following conditions: Favourable, Unfavourable-inadequate, Unfavourable-Bad, or Unknown. An overall assessment was determined by reference to the conclusions for the individual parameters, and, in general, reflects the least favourable of the individual parameter conclusions.

The overall UK assessments for seven Annex I marine habitats assessed included: 3 which were determined to be in ‘bad and deteriorating’ condition (estuaries; mudflats and sandflats not covered by seawater at low tide; large shallow inlets and bays); 3 in ‘inadequate’ condition (sandbanks which are slightly covered by seawater all the time; coastal lagoons; reefs), and 1 in ‘unknown’ condition (submarine structures made by leaking gases).

Of the 22 Annex II marine species assessed: 2 were considered in ‘bad’ condition (allis shad; harbour seal), 1 in ‘inadequate’ condition (Atlantic salmon), 2 in ‘inadequate but improving’ condition (river lamprey; twaite shad), 10 in ‘favourable’ condition (brook lamprey; bottlenose dolphin; common dolphin; harbour porpoise; grey seal; Atlantic white-sided dolphin; white-beaked dolphin; minke whale; fin whale; otter), and 8 in ‘unknown’ condition (sea lamprey; killer whale; long-finned pilot whale; Risso's dolphin; sperm whale; leatherback turtle; maerl).

Hayhow *et al*. (2015) provide information on trends in abundance and breeding success of seabird and waterbird species, many of which are protected by SPA designations.

4.5.9.1 Implications for SEA

The SEA should consider the implications of the draft plan/programme and its alternatives on the wider marine environment, in relation to the features of conservation sites of European and national importance, and those areas for which designations are proposed. The SEA will need to draw attention to the current location of these sites and the species or habitats for which they are designated, and any sites which are currently being considered for designation, in addition to characterising the present baseline condition and issues relating more generally to the marine environment. At this more general level, the SEA must consider the potential implications of the draft plan/programme on attaining good environmental status of both marine and coastal/estuarine waters as determined by the WFD and MSFD.

4.5.10 Changes to landscape and seascape

Prior to the development of offshore renewables, 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 generally in the form of cable and pipe landfall and associated infrastructure, and also helicopter, port activity and vessel traffic. Drilling activity and production platforms have in the most part been too far from shore to be visible, notable exceptions being Beatrice in the Moray Firth, exploration well sites off Dorset and Cardigan Bay, structures in the east Irish sea and those associated with the Cromarty Firth rig support industry. The more recent development of offshore renewables, namely offshore wind farms, has led to a greater consideration of landscape/seascape issues as most have been restricted on technical and economic grounds to water depths of up to 60m (i.e. primarily in nearshore waters). Cost reduction and technical advances (including future tethered turbines) has led to deployment progressively moving offshore in most European countries, and with Round 3, now also the UK. Pressures from changes to landscape and seascape also involve those onshore, including continued urban expansion and the development of the onshore renewables industry.

4.5.10.1 Implications for SEA

The SEA should consider the potential scale and location of activities which could arise from the adoption of the plan in relation to seascape (including historic seascape) character, in the context of existing and proposed developments, and relevant landscape planning policy as contained in National Policy Statements, the MPS and national and regional marine plans of the UK and devolved administrations.

4.5.11 Impact of air quality on human health and the environment

Though the UK's terrestrial air quality is generally 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 but appear to have a considerable impact. Estimates of the fraction of mortality attributable to long-term exposure to current levels of anthropogenic particulate air pollution ranged from around 2.5% in some local authorities in rural areas of Scotland and Northern Ireland, to over 6% in some local authorities in the east and south east of England.

4.5.11.1 Implications for SEA

Consider potential scale of plan activities in relation to current air quality problems and in the context of the range of emissions controls there are for plan activities.

4.5.12 Possible disturbance 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 and even the specific location of known sites are sometimes not precise. These include former occupied landscapes (palaeolandscapes) and any potential associated material, in addition to more recent maritime archaeology. These areas and sites are vulnerable to offshore operations which disturb the seabed (e.g. drilling, piling, cabling, and trawling), though development-led studies, for instance associated with the aggregates industry, have added considerably to knowledge in this area.

4.5.12.1 Implications for SEA

The SEA should consider the potential effects of plan activities in relation to current understanding of submerged cultural heritage in the context of international and national protection measures and planning policy. The SEA should raise awareness of available industry guidance (e.g. Gribble & Leather 2011) on marine cultural heritage.

4.5.13 Coastal erosion and flooding

A large proportion of the UK coastline is suffering from erosion (*ca*. 17% in the UK) with England (*ca*. 30%) and Wales (*ca*. 23%) having the greatest proportion of eroding coast, particularly the Yorkshire and Humber region. The coastline of England is also the most protected with *ca*. 46% of its length lined with coastal defence works (seawalls, groins) or fronted by artificial beaches. Estimates of the number of properties at risk from flooding and/or coastal erosion in England indicate that almost 3,000 dwellings are at risk for the period (2010-2025). Implementation of the respective Shoreline Management Plans (SMPs) was predicted to reduce this number to about 170.

4.5.13.1 Implications for SEA

The SEA should consider the potential scale and location of activities in particular tidal range schemes which could arise from the adoption of the plan, with respect to their potential impact on coastal erosion and flooding, and relevant SMP policies

5 Assessment

5.1 Assessment approach and methodology

OESEA3 covers a very large marine area comprising all UK waters with water depths ranging from the intertidal to more than 2,400m. The draft plan/programme includes the licensing/leasing of offshore oil and gas activities, the storage of gas and CO_2, offshore wind farms and marine renewables. The assessment has to address complex issues and multiple interrelationships, where a score based matrix assessment on its own would be inadequate. The assessment is therefore supported by an evidence based consideration presented in the sections which follow. In addition, significant use has been made of Geographical Information System (GIS) tools to collate, process, analyse and present spatial information both in the following assessment and baseline presented in Appendix 1.

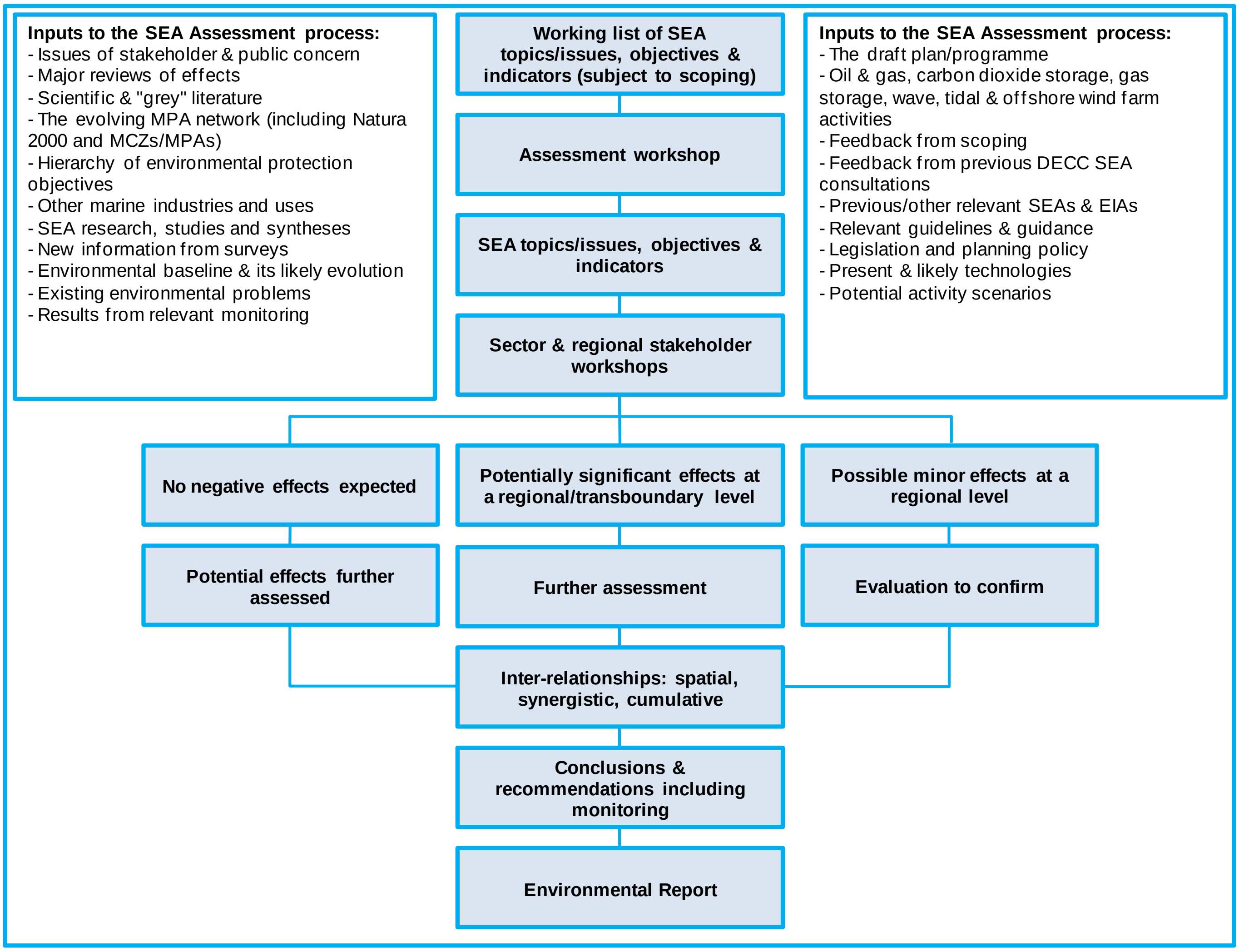
The assessment for this SEA is a staged process (Figure 5.1) incorporating inputs from a variety of sources:

- Baseline understanding of the relevant receptors (including other users) grouped according to the SEA Directive (see Appendix 1 *Environmental baseline* and Section 4 *Environmental information* and the range of studies undertaken through 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 3).
- The evolving regulatory framework.
- The evolution of technology.
- The SEA objectives (see Section 3.5).
- The evidence base regarding the relative risks and potential for significant effects from offshore wind farm, wave, tidal stream and tidal range developments, offshore oil and gas exploration and production, carbon dioxide storage 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 meetings, and other meetings and communications – see Appendix 4.

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.

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 significant effect

Previous SEAs have been informed by activity/effect matrices (e.g. Marlin), which have sought to link human activities with effects on the marine environment. Significant additional work has been undertaken in this field in recent years (e.g. Tillin *et al.* 2010) resulting in agreed lists of pressures at a UK and international level (the OSPAR Intercessional Correspondence Group on Cumulative Effects (ICG-C), see Tillin & Tyler-Walters 2015). ABPmer and Cefas (2015) were commissioned to develop an evidence base for the latest pressures-activity matrix produced by JNCC (2013). Each pressure is augmented by a benchmark which describes the intensity of the pressure, which for the latest sensitivity matrix (Tillin & Tyler-Walters 2015) is defined as the medium pressure level. These are intended to be representative of the intensity of pressures from a defined set of activities, with the magnitude, extent or duration qualified or quantified in some way (e.g. spatial footprints, noise source levels) and represent the likely effects on marine species and habitats.

In addition to the potentially significant effects identified (see Box 5.1 below) for the draft plan/programme which is the subject of this SEA (and subject to scoping and variously discussed with the SEA Steering Group and stakeholders – see Appendix 4), the matrices referred to above (e.g. Tillin & Tyler-Walters 2015, Defra 2015) were reviewed to ensure that all sources of effect have been identified for plan related activities. Note that Defra (2015) identifies a number of relevant activities (energy generation) and sub-activities (construction, operation) and links these to pressure themes (e.g. as defined by ICG-C) and relates these to whether the resulting pressure may be below or above the benchmark. Whilst the broad sources of effect for certain activities correspond with that already understood for activities which may arise from the draft plan/programme, and the evidence provided for the potential scale of some individual sub-activities is informative, certain other aspects are difficult to apply, particularly the benchmarks. For example, the assessment could indicate the potential for a particular activity or activities to generate effects which could be above a particular baseline, but it is not clear that the information this provides to the assessment significantly adds to the evidence base which has already been collected for each topic (i.e. on activity scale and research undertaken on key sources of effect), and how spatial and technological uncertainties in the potential future leasing/licensing of plan activities, and gaps in the environmental baseline, are considered in the context of these benchmarks.

Potential sources of effects from the activities which could follow adoption of the draft plan/programme in terms of the likely significant effects on the environment, identified by SEA topic, are listed in Box 5.1 below. A question mark indicates uncertainty of potential for effect. The sources of potentially significant effect identified in Box 5.1 have been categorised by Assessment Topic (left hand column, see key below) which forms the basis of the subsequent assessment sections. The potentially significant effects identified in Box 5.1 represent potential issues for further consideration in the assessment (relevant assessment section is signposted in the right hand column).

Key to Assessment Topics

Noise
Physical damage to features and habitats (includes energy removal)
Physical presence
Landscape/seascape
Waste
Marine discharges
Air quality
Climatic factors
Accidental events

Assessment Topic	Box 5.1:Potentially significant effect	Oil & Gas	Gas Storage	Carbon Dioxide Storage	Offshore Wind	Tidal Stream	Tidal Range	Wave	Assessment Section
	Biodiversity, habitats, flora and fauna								
	Physical damage to biotopes from infrastructure construction, vessel/rig anchoring etc (direct effects on the physical environment)	X	X	X	X	X	X	X	5.4
	Behavioural and physiological effects on marine mammals, birds and fish from seismic surveys	X	X	X					5.3
	Behavioural and physiological effects on marine mammals, birds and fish from other geophysical surveys	X	X	X	X	X	X	X	5.3
	Behavioural and physiological effects on marine mammals, birds and fish associated with construction phase noise[41]	X	X	X	X	X	X	X	5.3
	Behavioural and physiological effects on marine mammals, birds and fish associated with operational noise	X	X	X	X	X	X	X	5.3
	Behavioural and physiological effects on marine mammals, birds and fish associated with decommissioning noise	X	X	X	X	X	X	X	5.3
	The introduction and spread of non-native species	X	X	X	X	X	X	X	5.6, 5.9
	Behavioural disturbance to fish, birds and marine mammals etc from physical presence of infrastructure and support activities	X	X	X	X	X	X	X	5.6
	Collision risks to birds				X	X	X	X	5.6
	Collision risks to bats				X				5.6
	Collision risks to water column megafauna (e.g. fish, marine mammals).					X	X	X	5.6
	Barriers to movement of birds				X	X	X		5.6
	Barriers to movement of fish and marine mammals					X	X	X	5.6
	Changes/loss of habitats from major alteration of hydrography or sedimentation (indirect effects on the physical environment)				X	?	X	?	5.6
	Potential for effects on flora and fauna of produced or treated water and drilling discharges	X	X	X	X	X	?	X	5.9
	EMF effects on electrosensitive species				X	X	X	X	5.6

[41] May include piling noise, and the detonation of unexploded ordnance (UXO).

Assessment Topic	Box 5.1:Potentially significant effect	Oil & Gas	Gas Storage	Carbon Dioxide Storage	Offshore Wind	Tidal Stream	Tidal Range	Wave	Assessment Section
	The nature and use of antifouling materials				?	X	?	X	5.9
	Accidental events – major oil or chemical spill	X	?	?	?	?	?	?	5.13
	Accidental events – major release of carbon dioxide			X					5.13
Geology and Soils									
	Physical effects of anchoring and infrastructure construction (including pipelines and cables) on seabed sediments and geomorphological features (including scour)	X	X	X	X	X	X	X	5.4
	Sediment modification and contamination by particulate discharges from drilling etc or resuspension of contaminated sediment	X	X	X	X	X	X	X	5.4
	Effects of reinjection of produced water and/or cuttings and carbon dioxide	X	X	X					5.4
	Onshore disposal of returned wastes – requirement for landfill	X	X	X					5.10
	Post-decommissioning (legacy) effects – cuttings piles, footings, foundations, *in situ* cabling etc	X	X	X	X	X	X	X	5.4
	Changes to sedimentation regime and associated physical effects					X	X	X	5.4
	Accidental events – risk of sediment contamination from oil spills	X	?	?	?	?	?	?	5.13
	Accidental events – blow out impacts on seabed	X	X	X					5.13
	Offshore disposal of seabed dredged material	X	X	X	X	X	X	X	5.4
Landscape/Seascape									
	Potential effects of development on seascape including change to character (interactions between people (and their activities) and places (and the natural and cultural processes that shape them))	X	X	X	X	X	X	X	5.8
Water Environment									
	Contamination by soluble and dispersed discharges including produced water, saline discharges (aquifer water and halite dissolution), and drilling discharges from wells and foundation construction	X	X	X	X	X	?	X	5.9
	Changes in seawater or estuarine salinity, turbidity and temperature from discharges (such as aquifer water and halite dissolution) and impoundment		X	X			X		5.9
	Energy removal downstream of wet renewable devices					X	X	X	5.5

Assessment Topic	Box 5.1:Potentially significant effect	Oil & Gas	Gas Storage	Carbon Dioxide Storage	Offshore Wind	Tidal Stream	Tidal Range	Wave	Assessment Section
	Accidental events - contamination of the water column by dissolved and dispersed materials from oil and chemical spills or gas releases	X	X	X	?	?	?	?	5.13
Air Quality									
	Local air quality effects resulting from exhaust emissions, flaring and venting	X	X	X	X	X	X	X	5.11
	Air quality effects of a major gas release or volatile oil spill	X	X	X					5.11
Climatic Factors									
	Contributions to net greenhouse gas emissions	X	X						5.12
	Reduction in net greenhouse gas emissions			X	X	X	X	X	5.12
	Population and Human Health								
	Potential for effects on human health associated with reduced local air quality resulting from atmospheric emissions associated with plan activities	X	X	X					5.11
	Potential for effects on human health associated with discharges of naturally occurring radioactive material in produced water	X	X	?					5.9
	Accidental events – potential food chain or other effects of major oil or chemical spills or gas release	X	X	X	?	?	?	?	5.13
Other users of the sea, material assets (infrastructure, and natural resources)									
	Positive socio-economic effects of reducing climate change			X	X	X	X	X	5.12
	Interactions with fishing activities (exclusion, displacement, seismic, gear interactions, “sanctuary effects”)	X	X	X	X	X	X	X	5.7
	Other interactions with shipping, military, potential other marine renewables and other human uses of the offshore environment	X	X	X	X	X	X	X	5.7, 5.15
	Accidental events – socio-economic consequences of oil or chemical spills and gas releases	X	X	X	?	?	?	?	5.13
Cultural Heritage									
	Physical damage to submerged heritage/archaeological contexts from infrastructure construction, vessel/rig anchoring etc. and impacts on the setting of coastal historic environmental assets and loss of access.	X	X	X	X	X	X	X	5.4, 5.8

5.3 Noise

Assessment Topic	Potentially Significant Effect	Oil & Gas	Gas Storage	Carbon Dioxide Storage	Offshore Wind	Tidal Stream	Tidal Range	Wave	Assessment Section
	Behavioural and physiological effects on marine mammals, birds and fish from seismic surveys	X	X	X					5.3.2.3 5.3.3
	Behavioural and physiological effects on marine mammals, birds and fish from other geophysical surveys	X	X	X	X	X	X	X	5.3.2.3 5.3.3
	Behavioural and physiological effects on marine mammals, birds and fish associated with construction phase noise[42]	X	X	X	X	X	X	X	5.3.2.1 5.3.3
	Behavioural and physiological effects on marine mammals, birds and fish associated with operational noise	X	X	X	X	X	X	X	5.3.2 5.3.3
	Behavioural and physiological effects on marine mammals, birds and fish associated with decommissioning noise	X	X	X	X	X	X	X	5.3.2.3 5.3.3

5.3.1 Introduction

The study of ocean noise is a relatively new discipline and the number of peer- reviewed papers has increased exponentially in the last two decades. The focus of research has broadened from naval applications and studies of physical acoustics to investigations on the ecological impacts of a variety of anthropogenic sources with respect to marine mammals, fish and other organisms (Williams *et al.* 2015).

Sound is generated in the marine environment by a number of natural processes with a physical (e.g. wind, waves, rain, lightning, earthquakes) or biological origin (e.g. communication and behaviour) as well as being ubiquitous to all human activities either as their by-product (e.g. shipping, fishing, construction) or as the key element of the activity itself (e.g. sonar and geophysical exploration). The potential effects of sound on marine organisms depend on the characteristics of the sound (e.g. type, intensity, spectra, duty cycle, duration), the physical characteristics of the environment in which sound propagates, the acoustic sensitivity of the receiver, and their interaction in space and time. Potential effects range from masking biological communication and causing small behavioural reactions, to chronic disturbance, injury and mortality (e.g. OSPAR 2009) and these are described in Section 5.3.3.

Sound is a disturbance in pressure that propagates through water via particle vibration. The most common quantity used to describe a sound wave is pressure, as it is readily measurable (e.g. hydrophone responds to pressure change) but overall sound is a complex entity to measure and to report. A plurality of methodologies and acoustic metrics are used across different disciplines (e.g. acoustical oceanography, geophysical exploration, offshore engineering, physiology) and to counteract this, international standards for underwater acoustics are being developed. While awaiting their publication, this SEA supports consistency with national efforts at standardisation (Robinson *et al.* 2014) and with the EU Marine Strategy Framework Directive Technical Sub-group on Noise (EU TSG 2014a, 2014b, 2014c); readers are referred to these publications and references therein for further details.

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[42] May include piling noise, and the detonation of unexploded ordnance (UXO).

The unit of pressure is the Pascal (Pa) and by convention, sound levels are expressed in decibels (dB) relative to a fixed reference pressure (the reference value for sound in water[43] is 1µPa). The decibel scale is a logarithmic scale (to base 10) which has been historically adopted as a scale compression method to deal with the very wide range of pressures encountered (from µPa to MPa). Commonly used metrics and their quantities expressed in levels are given in Boxes 5.2 and 5.3.

The other fundamental characteristic of a sound wave is its frequency, measured in Hertz (Hz) where 1 Hz represents one wave per second. Frequency is inversely related to the wavelength (the distance between two peaks) for a constant speed of sound within a medium: a low frequency sound wave has a long wavelength, while a high frequency wave has a short wavelength. Any complex acoustic waveform contains several frequencies which can be represented by its spectrum (amplitude as a function of frequency). Detailed spectra can be obtained (e.g. using Fourier analysis) to represent the signature of a sound; however, since amplitudes can vary rapidly with frequency, detailed spectra are difficult to use in comparisons. More commonly, levels are calculated within third-octave bands which represent a standard set of frequency bands[44].

Sound broadly falls into two types (Southall *et al.* 2007, Robinson *et al.* 2014) (see figures in Box 2). Impulsive (pulse) sound is characterised by a short burst of acoustic energy of finite duration; it is transient in nature, with rapid rise in amplitude, wide bandwidth and short duration (<1 sec). With relevance to offshore energy developments, pulses are generated from explosions, impact pile-driving, seismic air-guns and sub-bottom profilers. Continuous sound occurs when the acoustic energy is spread over a significant time (several seconds to hours); it may contain broadband noise and/or tonal (narrowband) noise at specific frequencies and its amplitude may vary. Relevant examples include shipping, drilling, dredging and operational noise. The distinction of pulsed sound from continuous sound is important because pulses generally have a different potential to cause effects, particularly on mammalian hearing with respect to injury (e.g. Ward 1997). However, pulses lose their impulsive character as sound propagates from source; in the case of impulsive sounds repeated at intervals (duty cycle), such repetition may become diffuse with distance and will become indistinguishable from continuous noise at a distance of several kilometres (Southall *et al.* 2007, EU TSG Noise 2014b).

[43] The reference value in air is 20 µPa so comparisons of sound levels in air and water are not straightforward.
[44] An octave represents a doubling in frequency and each octave contains three third-octave bands; each third octave band is a frequency ratio corresponding to a ratio of $2^{1/3} \approx 1.2599$. An alternative expression for “third-octave” is the ‘deci-decade’ which is defined as one tenth of a decade or $10^{0.1} \approx 1.2589$ (smaller than one third of an octave by 0.08%). The former is favoured in Robinson *et al.* 2014 while the latter is the convention used in EU TSG Noise (2014c). The nominal central frequencies of each band are practically the same as listed in IEC 61260:1995.

Box 5.2 - Relevant acoustic metrics

sound pressure (or "instantaneous sound pressure"): the difference between instantaneous total pressure and pressure that would exist in the absence of sound. This is in effect the quantity represented when a sound pressure waveform is plotted as illustrated below.

peak sound pressure (or zero-to-peak sound pressure), p_{peak}: the maximum sound pressure during a stated time interval. A peak sound pressure may arise from a positive or negative sound pressure.

peak to peak sound pressure, p_{pp}: the sum of the peak compressional pressure and the peak rarefactional pressure during a stated time interval.

root mean square (RMS) sound pressure: the square root of the mean square pressure, where the mean square pressure is the time integral of squared sound pressure over a specified time interval divided by the duration of the time interval. The RMS sound pressure is calculated by first squaring the values of sound pressure, averaging over the specified time interval, and then taking the square root.

sound exposure, E: the integral of the square of the sound pressure over a stated time interval or event (such as an acoustic pulse). The quantity is sometimes taken as a proxy for the energy content of the sound wave. When applied to an acoustic pulse, the integration time is the pulse duration and the quantity is sometimes called "single pulse sound exposure". Pulse duration is commonly defined as the time occupied by the central portion of the pulse, where 90% of the pulse energy occurs. This is useful because it can be difficult to determine the exact start and end of the pulse when the waveform contains noise; as illustrated below. When applied to an extended period or sequence of pulses/events, it is called "cumulative sound exposure" and it is important to specify any other relevant information such number of pulses, total time duration, duty cycle of any sampling.

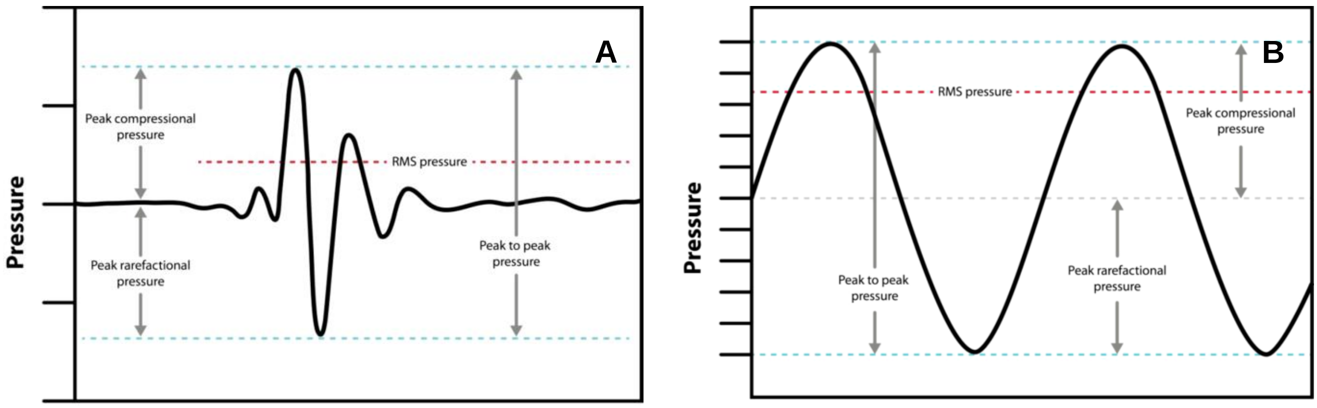
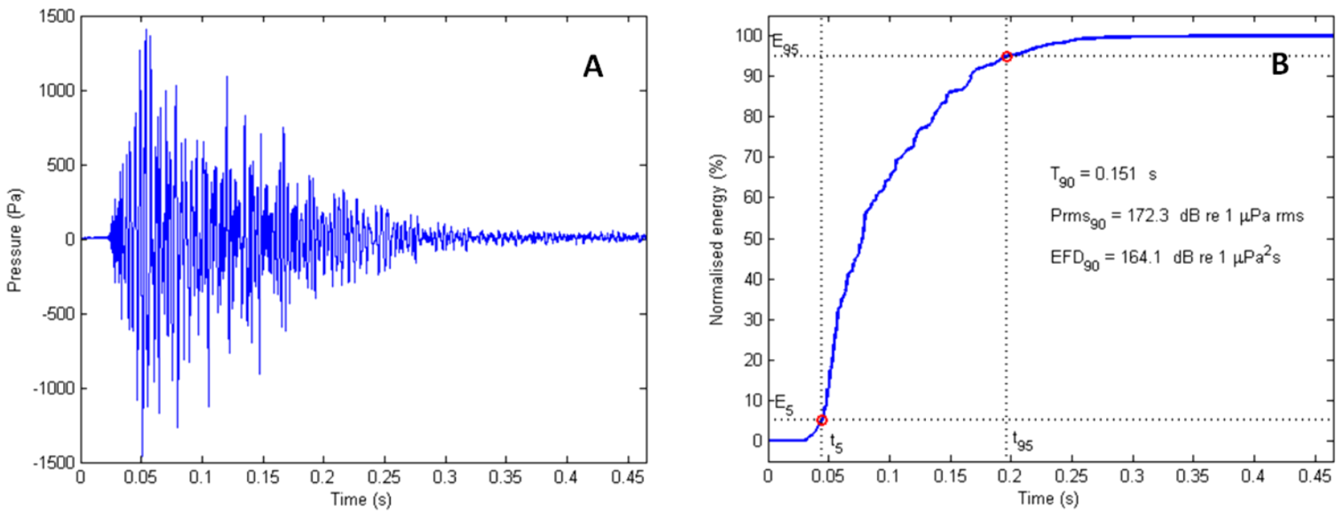


Illustration of metrics for sound pressure illustrated for a sound pulse (A) and for a periodic form (B)



illustrative examples of pulsed waveform from a measurement of marine pile driving (A) and calculation of pulse duration (B).

Source: Robinson et al. 2014

Box 5.3 - Relevant acoustic quantities expressed as levels

peak sound pressure level (or zero-to-peak sound pressure level), L_{peak}**:**

$$L_{peak} = 20\log_{10}\left[\frac{P_{peak}}{P_0}\right]$$

where p_{peak} is the peak sound pressure and p_0 is the reference value, of 1 µPa in water. Units are dB re 1 µPa

It was common use to abbreviate peak sound pressure level to "peak SPL"[45]. However, since SPL generally refers to a time-averaged quantity, the meaning was ambiguous - it could be interpreted at "peak sound pressure expressed as a level", or as the "peak (or maximum) of the SPL". It is now recommended that peak sound pressure level is not abbreviated to "peak SPL".

peak to peak sound pressure level, L_{pp}**:**

$$L_{pp} = 20\log_{10}\left[\frac{P_{pp}}{P_0}\right]$$

where p_{pp} is the peak to peak sound pressure and p_0 is the reference value, of 1 µPa in water.
Units are dB re 1 µPa.

sound exposure level, SEL:

$$SEL = 10\log_{10}\left[\frac{E}{E_0}\right]$$

where E is the sound exposure and E_0 is the reference value, of 1 µPa^{2}s in water. Units are dB re 1 µPa^{2}s.

Note that the sound exposure level is a useful measure of the exposure of a receptor to a sound field, and a frequency weighting is commonly applied. If a frequency weighting is applied, this should be indicated by appropriate subscripts.

sound pressure level, *SPL*:

$$\boldsymbol{SPL = 10\log_{10}\left[\frac{\hat{p}^2}{p_0^2}\right] = 20\log_{10}\left[\frac{\hat{p}}{p_0}\right]}$$

where $\hat{p}$ is the root mean square (RMS) sound pressure and p_0 is the reference value, of 1 µPa in water.
Units are dB re 1 µPa. Note that the time interval used in the calculation of SPL must be stated.

Source: Robinson et al. 2014

Sound is altered as it radiates away from its source. The amplitude of the wave generally declines with distance from source with several factors at play, including geometrical spreading, absorption, reflection, refraction, scattering and reverberation (see Box 5.4). With the exception of geometrical spreading, the factors that influence propagation are frequency (wavelength) dependent and as a consequence the spectral component of sound is also altered with distance. Variations in seabed topography (depth, aspect, slope) across space are among the key characteristics of the environment that influence sound propagation; for example the presence of sand banks and shallow coastal areas can significantly reduce transmission, increase pulse duration and affect frequency content. In very shallow water, the tidal cycle may have an important influence on sound propagation. Within the water column, the presence of stratification (e.g. caused offshore by increased surface temperature during the summer or by low salinity at the mouth of rivers) may result in the formation of sound ducts and enhance propagation (see Box 5.4). Seabed sediment type can affect sound propagation, with sand for example being more reflective of sound than clay or mud. Different wind conditions (sea state) will also have an influence.

Overall, modelling sound propagation is a complex endeavour and its complexity depends on the required accuracy as well as the environmental conditions encountered. Several modelling approaches have been developed, each with its own assumptions, strengths and weaknesses

[45] For example in Southall *et al.* 2007

(Etter 2013, Spiga 2015). Models based entirely on geometric spreading laws are commonly used and computationally simple. They may offer a suitable approximation in some situations but their limitations must be carefully considered (Robinson *et al.* 2014, Ainslie *et al.* 2014). Especially in the case of heterogeneous shallow environments, these models may introduce substantial errors because they assume that sound levels decrease at a constant rate with range and do not take into account spatial variability in the environment and frequency-dependent effects (Fracas *et al.* 2016). More computational complex models use various mathematical approaches such as ray theory, normal modes and parabolic equations; originally limited to the research community, they are now commonly applied. No single model is applicable to all environmental conditions and acoustic frequencies, and care should be taken in choosing the model most suitable to the task; in particular, range dependent models should be considered when propagating sound over significantly changing bathymetry and models capable of coping with frequency dependence should be investigated when accuracy over considerable distances is required. More complex models require more input data and at times the limiting factor is not the model but the availability of suitable environmental data at the appropriate scale. In all cases, models require validation against experimental data to ensure accurate predictions.

A common use of sound modelling in environmental impact assessment is to predict how much noise generated by a particular activity will be received by marine organisms at one or more locations in the surrounding area. For this, the source level of the activity must be known. In underwater acoustics the source level has been used traditionally as a measure of the output of a transducer; the pressure in the far-field of the source is measured under free field conditions (i.e. large body of water to minimise reflections) and back calculated to 1m range assuming spherical spreading. It has been quoted as dB re 1 µPa @1m (or more recently as dB re 1 µPa.m) but the reference to 1m does not imply a measurement was made at 1m or indeed that the value is expected to be accurate at 1m. Such an approach to determine source level has also been applied to large sound sources such as from a seismic array or during impact pile-driving; caution should always be applied when interpreting these results as they represent only a modelled hypothetical level, higher than what can be encountered in practice (see Section 5.3.2.3.1 for seismic array example). The reasons for this discrepancy are several but all relate to the fact that spherical spreading back-calculations ignore the complexity of sound propagation in the near-field. These include the distributed and complex nature of the sound source (not the infinitely small point source assumed in the propagation model), the presence of reflections at the sea surface and at the seabed, spatial heterogeneity of physical parameters that influence sound propagation. Such estimated source level is appropriate as input to modelling when the focus is in the far-field. However, when the aim is to accurately predict the sound field close to the source, more sophisticated near-field models should be used, ideally benchmarked with near-field measurements.

Finally, ambient noise, also referred to as ‘background noise’, is the sound field against which signals must be detected (Hildebrand 2009). Ambient noise is a complex combination of several natural and anthropogenic contributing sources, influenced by sound propagation laws (see Appendix Section A1d.2.10). There is relatively large spatial and temporal variability in UK waters which affects signal to noise ratio and hence the range at which a sound may be audible to a receiver may vary significantly (e.g. EU TSG 2014c).

In the next section, sources of noise associated with each element of the draft plan/programme are described. For each element, the potential for noise generation of each main stage of development is considered.

Box 5.4 - Factors influencing propagation

The term **geometric spreading** is used to describe the decrease in intensity and apparent weakening of the signal due to the spreading of the energy as it gets farther from the source. From a point source, the sound wave propagates as spherical waves of increasingly larger diameter and its pressure will decay at a rate proportional to the inverse of the distance (e.g. spherical spreading). In shallow water, the initial spherical propagation may continue as cylindrical spreading once the physical boundaries of surface and seabed have been encountered.

Absorption of sound is caused by both viscosity (where some energy is converted to heat) and a number of chemical relaxation processes due to dissolved salts; the rate of absorption increases with frequency (high frequency sound will travel shorter distances before being reduced to the level of background noise). Absorption is relatively low for low frequency sound; for example at 1kHz absorption is less than 0.1 dB per kilometre.

Reflection of sound waves occurs at physical boundaries such as the sea surface (known to act as a very good 'mirror' for sound waves) and the seabed; multiple reflections may occur as the sound reflects alternatively from the sea surface and the bottom. The result is that a sound may be received at a distance not just from the direct path between source and receiver, but also as multiple signals from the additional reflections. The sea surface is known to act as a very good 'mirror' for sound waves. At the seabed, different sediment types (e.g. clay, gravel) reflect sound to different extents. Depending on a variety of factors, constructive or destructive interferences may be created between signals, reducing or enhancing the decay of sound (e.g. Lloyd mirror effect, 'ghost' reflections). Further signal distortions are introduced through **scattering** when boundaries are rough rather than smooth surfaces (e.g. surface with waves or complex bathymetry) and through **reverberation** depending on the angle at which sound encounters the boundary. Reflection may occur also within the water column, at the boundary between water masses with different physical characteristics.

The path of a sound wave in the ocean follows a straight line only when conditions are constant, allowing the speed of sound to remain the same. However, the sound speed depends on density which in seawater is mainly a function of temperature, salinity and pressure. If any of these variables change, the sound will be refracted and the path will bend towards the area of minimum sound speed. The sound speed is such an important oceanographic parameter that it is routinely measured as a function of depth, either directly or indirectly calculated using a CTD probe. In certain conditions, **refraction** allows so called 'shadow zones' and 'sound channels' to exist in the ocean. 'Shadow zones' are areas where sound from a particular source does not penetrate. Conversely, 'sound channels' act like ducts that tend to focus sound energy, allowing more efficient propagation over that from simple geometrical spreading. The global example is the Deep Sound Channel (or SOund Fixing And Ranging channel), first discovered in the 1940s as part of submarine warfare efforts, where low-frequency sounds have been recorded across entire ocean basins. It is centred at the depth where sound speed is at its minimum, due to a combination of temperature decrease and pressure increase with depth (it occurs between 600 and 1200m at low and middle latitudes but becomes progressively shallower at higher latitudes and reaches the surface in the polar oceans). Smaller sound channels can develop at varying depths but due to mode-stripping, not all frequencies will be transmitted equally; each channel has a cut-off frequency which depends on its thickness and propagation only of frequencies above that cut-off will be enhanced.

Sources: OGP 406, Robinson et al. 2014, Bradley and Stern 2008, Buckingham 1992.

5.3.2 Sources of potentially significant effect

Sources of potentially significant effect are grouped by the element of the draft plan/programme that they are more directly or historically associated with even though it is recognised that many noise generating activities (e.g. vessel traffic, geophysical surveys) are common across all elements. Noise generated during pile-driving and disposal of UXO are described under 'offshore wind farms' together with operational wind farm noise. Operational noise generated by wave and tidal energy devices is the focus of 'wave and tidal power'. Noise from seismic surveys, other geophysical surveys, production platforms, drilling, pipe laying, helicopters, support vessels and decommissioning are under 'Oil & Gas'.

5.3.2.1 Offshore wind farms

5.3.2.1.1 PILE-DRIVING

Wind farms constructed in the UKCS to date have relied on monopole technology and percussive methods for installation of turbine foundations, i.e. hammering a steel cylinder into the seabed, known as "pile-driving" (Elmes *et al.* 2013). Other techniques, generating less sound may also be available or in development and these are described in Section 5.3.4.

The body of evidence for understanding sound generated by impact pile-driving is growing (Nedwell *et al.* 2003, Nedwell & Howell 2004, Madsen *et al.* 2006a, Nedwell *et al.* 2007, Thomsen *et al.* 2006, Lüdemann & Koschinski 2013) and modelled predictions are increasingly in good agreement with acoustic measurements, even in topographically complex coastal environments (e.g. Schecklman *et al.* 2015). Pile-driving of monopole foundations generates a pulsed sound, qualitatively similar to pile-driving resulting from harbour works, bridge construction and oil and gas platform installations. The primary source of underwater sound is associated with the compression of the pile by the hammer strike; as the compressional wave travels through the pile, sound radiates across air, water and sediment and back into the water column with the direct water path being the dominant one (Nedwell *et al.* 2003, OSPAR, 2014). The sound pulse produced with each strike lasts between 50 and 100ms and a common rate of hammering involves 30-60 strikes per minute; it usually takes between 1-2 hours to drive one pile into the seabed (Thomsen *et al.* 2006).

The single pulse has very high energy; in a review of measurements from earlier UK constructions, Nedwell *et al.* (2007) indicated source levels (peak to peak sound pressure level, L_{pp}) to range between 189 and 257 dB re 1µPa @1m mainly as a function of pile diameter (0.5 to 4.7m). It is important to bear in mind the difficulties with extrapolating far-field sound measurements back to the concept of 'source' (see Ainslie *et al.* 2010) and while very high source levels have been reported (e.g. L_{pp} > 270 dB re 1µPa @1m) these should be interpreted with care (e.g. Norro *et al.* 2010). More recently, using the energy source level (SL_E) as the metric to describe the sound, Ainslie *et al.* (2010) obtained values ranging between 204.5-213.5 and 215-220 dB re µPa^{2}m^{2}s for a 2m pile at a UK site and a 4m diameter pile at a Dutch site, respectively. Pile diameter is largely dictated by the type of foundation required, with monopole foundations relying on single large diameter piles (>3.5m) while jacket foundations commonly use 3 or 4 smaller piles. There are several other factors which influence the levels of underwater sound generated during piling; these include blow energy, size of the hydraulic hammer and sediment type so that considerable variability in sound levels are reported from installation of comparably sized piles (DECC 2011). In terms of frequency spectrum, sound generated from impact pile-driving ranges from less than 20 Hz to more than 20 kHz but most energy is concentrated between 100-500 Hz (e.g. Thomsen *et al.* 2006, Ainslie *et al.* 2010).

Given the high levels, noise from piling can be detected above ambient noise to a range of 25km – 100km, with the latter being characteristic of quiet background conditions (see Nedwell *et al.* 2007 and references therein, Bailey *et al.* 2010).

5.3.2.1.2 OPERATIONAL NOISE

Underwater noise during operation of wind turbines is generated mainly by mechanical vibrations in the gear-box and generator inside the nacelle; these vibrations are coupled to the water column and the seabed through the turbine foundations. Noise is also produced in air by the air flow and turbulence from the blades but this is almost completely reflected at the water surface and does not contribute to underwater noise. Sound emitted by turbines in operation is continuous, relatively low in amplitude, broadband and characterised by a series of tonals mostly below 700 Hz The frequency content of the tones is a function of the mechanical properties of each turbine; since turbines are maintained at a constant rate of revolution independent of wind speed, only the height of the peaks and not their location on the frequency axis is affected by increased wind speed (Madsen *et al.* 2006a; Tougaard *et al.* 2009, Marmo *et al.* 2013). Foundation type influences the amplitude and frequency of operational noise; a modelling comparison concluded that monopile foundations have higher acoustic output than gravity or jacket foundations in all wind conditions (Marmo *et al.* 2013).

A review of earlier recordings from operational turbines in Denmark, Sweden and Germany reported considerable variations, especially in the tonal content, but overall received levels dropped to <120 dB re 1 µPa (SPL_{RMS}) at a distance of 100m even in the case with the highest recorded tonal (Whalberg & Westerberg 2005; Madsen *et al.* 2006a). Nedwell *et al.* (2007) reported from operational wind farms in the UK; 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 underwater noise dominated over the background noise only 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 lower than that measured outside. Similar results were obtained by Tougaard *et al.* (2009) undertaking recordings from different types of wind turbines (450 kW – 2 MW), under different wind conditions in three offshore wind farms; turbine noise was clearly identifiable above background noise at distance where measurements were undertaken (14-40m). Absolute noise levels (SPL_{RMS}) were low, ranging between 109 and 127 dB re 1 µPa; in terms of frequency, turbine noise above ambient was recorded across the 1/3-octave bands between 12.5 and 500 Hz.

As part of a modelling study to predict the large-scale consequences of offshore wind turbine array development (van der Molen *et al.* 2014), an acoustic energy flux model was constructed; large turbines (5 MW) with an equivalent broadband source level energy of 167.6 dB re 1 µPa.m (SPL_{RMS}) resulted in broadband noise levels reaching 113 dB re 1 µPa (SPL_{RMS}) between turbines (800m spacing) and dropping down to 102 dB re 1 µPa (SPL_{RMS}) between farms (5km spacing). Notwithstanding uncertainties and constraints inherent in the model, it was concluded that large arrays of farms of many thousands of turbines offer the potential to make relatively small (a few dB) increases in average ambient noise over large areas.

Airborne operational noise from wind energy developments in the terrestrial environment has received considerable attention in relation to issues of disturbance to nearby residents, particularly where turbines are located in rural areas with low ambient noise levels. Noise assessment criteria (*ETSU-R-97*[46]) provide guidance on the assessment and mitigation of such effects from wind farm developments. Noise emissions from turbines are dominated by aerodynamic noise caused by the interaction of the turbine blade with the turbulence produced both adjacent to it and in its near wake. This is of low frequency and broad band in nature, i.e. it does not contain a distinguishable note or tone. The dominant character of aerodynamic noise is perceived as a ‘swish’ and fluctuates at the rate at which the blades pass a fixed point (typically about 1 blade pass per second); these fluctuations are known as Amplitude Modulation of aerodynamic noise (AM). In some situations, AM can become a source of unacceptable annoyance for neighbouring residents. Airborne operational noise from offshore wind farms is not widely documented, and is currently not considered to be a major source for concern for wind farms located well offshore as the distance between turbines and coastal settlements will allow for sound attenuation between source and receptor.

5.3.2.1.3 UXO

Large amounts of legacy unexploded ordnance (UXO) are present in UK waters (see Appendix Section A1h.13.2). Sources of the munitions vary, ranging from munitions dumps, wrecks/crashes, weapon firing ranges or mines, torpedoes and depth charges dating from WWI and WWII. Most reported UXO are detonated in a controlled way out of concern for the safety of fishers and other users of the sea.

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[46] ETSU-R-97: The assessment and rating of noise from wind farms. http://webarchive.nationalarchives.gov.uk/+/http:/www.berr.gov.uk/files/file20433.pdf

UXO detonations have the potential to cause significant injury or death and project developers are bound by health and safety legislation to manage and reduce this risk. For example, in early 2014 three WWII bombs found during development of the Gwynt y Môr offshore wind farm led to a 250m exclusion zone until they were destroyed by controlled explosion (Appleyard 2015) involving the attachment of a small explosive charge to the munition.

In-water explosions create spherical shock waves that travel at faster than the speed of sound in water. Immediately around the source there is a pressure rise followed by an exponential decay and a large oscillating gas bubble is also produced that radiates sound. The explosion itself generates low-frequency shock waves and subsequent pulsations of the bubble sphere at high pressure which propagate over long distances. Water depth affects the sound propagation characteristics, particularly of low frequency sound. Actual recording of noise levels from underwater explosions are sparse but Hildebrand (2009) states that a MK-46 torpedo detonation with 44kg (of TNT equivalent) explosive would produce a total source level of 289 dB re 1 μPa at 1m (including the initial shock and bubble pulse), with an almost constant frequency content between 10 and 200 Hz.

In the southern North Sea mainly within the Dutch Continental Shelf, controlled explosions of UXOs carried out by the Royal Netherlands Navy during 2010 and 2011 were examined by von Benda-Beckmann *et al.* (2015). It was found that there was a distinct seasonal pattern to the explosions, with a peak in March of 49 explosions and smaller peaks in August and November. The peak in March coincides with a peak of fishing activity, and therefore an increase in encounter rate of UXO. Explosive charge masses reported ranged from 10 to 1,000kg, with most between 125 and 250kg. Large variations in received levels were measured during explosions, at different depths in the water; the minimum SEL measured within 2km was 191 dB re 1 μPa^{2}s and SEL levels of 179[47] dB re 1 μPa^{2}s were estimated to vary between hundreds of metres and 15km.

5.3.2.2 Wave and tidal power

The available information on underwater noise associated with wave and tidal energy devices remains limited; this is partly due to the relatively early stage of development and deployment and partly to the wide variety of technical designs, each potentially providing unique sources of noise (Copping *et al.* 2013, Robinson & Lepper 2013).

The construction phase may include several activities that generate underwater sound, including dredging, vessel traffic, cable laying, drilling and/or piling during device installation; none of these are unique to this industry and are discussed in Sections 5.3.2.1 and 5.3.2.3. Among them, impact piling represents the noise source of most concern, but in practice this is unlikely to occur extensively. Most tidal stream devices are deployed in areas with rocky seabed and as a consequence, they are commonly fixed to the seabed by drilling rather than by piling; offshore wave developments may be installed by drilling on rocky seabed or may use gravity based anchors in areas of sediments (Robinson & Lepper, 2013). When pile installation is necessary, smaller diameter piles (e.g. 1m pin-pile) tend to be used, thus resulting in lower sound levels than commonly associated with the offshore wind industry (Copping *et al.* 2013).

During operation, sound generation will depend on the design of the device as well as on operating conditions (i.e. wave height and/or tidal state). The overall sound output will be a combination of several sources including noise generated by the device itself (e.g. rotating machinery, joints etc.) and by its interaction with water (e.g. turbulence, vortex shedding); many

[47] Updated injury criteria for harbour porpoise

of these mechanisms are not yet well characterised and more direct measurements are required. However, accurate measurements of the acoustic environment are technically difficult to achieve within fast flowing conditions, such as tidal streams, and novel measurement techniques may need to be explored (Robinson & Lepper, 2013). In addition, wave and tidal energy devices have the potential to generate complex particle velocity fields in the near-field; while this is of relevance to many organisms, particle velocity is not typically measured (Robinson & Lepper, 2013).

The SeaGen 1.2MW tidal energy convertor was installed in the Narrows of Strangford Lough in April 2008; a comprehensive Environmental Monitoring Plan covering all phases of this demonstrator project was implemented as part of the licence conditions (Royal Haskoning, 2011). Noise associated with SeaGen was first reported by Nedwell & Brooker (2007) and summarised in a biological noise assessment by SMRU (2010). Noise measurements of SeaGen carried out with high-precision instruments from a drifting boat showed that it produces narrowband, tonal components as well as broadband noise. The main narrowband components are tones at frequencies of 110-120Hz, 750Hz and 1500Hz. The maximum measured power spectral density at 49m distance was 153dB re 1 µPa/Hz2 and originates from the 750Hz tone. At close ranges, the power spectral density of the broadband noise is generally 40dB below that of the tones. The 'source level' of SeaGen was back-calculated from field measurements using a simple geometric propagation model and estimated to be 174dB re 1µPa. Ambient noise levels were also characterised at the site under different environmental conditions; measurements at slack tide and low sea state appear to be less than 80dB re 1 $\mu Pa/Hz^2$ at frequencies higher than 20-30Hz, but in conditions with strong tidal currents and slightly higher sea state, ambient noise levels increase by 15-20dB in a frequency range between 0.1kHz and 10kHz and remain high even at frequencies above 10kHz, most likely the result of moving stones on the seafloor (Nedwell & Brooker 2007).

As part of The Crown Estate's Pentland Firth and Orkney Waters Enabling Actions programme, Robinson & Lepper (2013) reviewed available evidence on noise radiated by wave and tidal stream energy devices. Information was obtained from publicly available resources as well as directly from manufacturers, developers, regulators and their advisers. Broadband 'Effective Radiated Noise Level' obtained for tidal energy converters ranged between 166 and 174 dB re 1 µPa referred to 1m. Measurements of operational noise for wave energy converters showed a range in broadband source level between 120 and 180 dB re 1 µPa2/Hz between low and high sea state and received levels SPL at 10-20m were 126-129 dB re 1 µPa. While an accurate comparison was difficult because of the use of different acoustic output metrics, the authors concluded that noise radiated during operation is comparable to that of a modest size vessel at moderate speed (e.g. a trailing suction hopper dredger during operation). Of key relevance to assessing impact, noise radiated during operation is likely to be below ambient noise levels beyond a limited range from the device (a few hundred metres to a few kilometres). This may occur both at low and high sea states as a strong correlation is likely between operational and ambient noise, for example in the case of wave energy converters, a high sea state will result in both an increase in operational noise and ambient noise (Robinson & Lepper 2013).

Noise recorded from the Wavestar wave energy converter installed on the Danish North Sea coast indicated noise levels at 25m from the converter were 1-2 dV above ambient in the range 125-250 Hz but undetectable at other frequencies. These results may not be directly transferable to all wave energy converters as the low emissions recorded here are most likely due to the specific construction design used, where all moving parts, except for the absorbers, are placed above water on a jack-up rig (Tougaard 2015).

5.3.2.3 Oil & gas

5.3.2.3.1 SEISMIC

Seismic surveys are commonly used during the exploration, development and production of oil & gas to map hydrocarbon bearing formations and their geologic context. The technique is based on the determinations of the time interval between the initiation of a seismic wave and the arrival of reflected or refracted impulses at detectors. The most common seismic source is the air-gun, typically used in tuned arrays; the receivers are usually hydrophones, detecting the reflected sound waves as pressure fluctuations in water. A brief summary of categories of seismic survey operations common in the UKCS are given below and a detailed overview can be found in OGP (2011).

- A two dimensional (2D) seismic survey involves a survey vessel towing a single airgun array and a single streamer, containing several hydrophones along its length. Streamers are typically 3-8km long (up to 12km). Repeated parallel lines are run at intervals of several kilometres (minimum 0.5km) and a second set of lines at right angles to the first is used to form a grid pattern.
- In a three dimensional (3D) seismic survey, a vessel tows two or more airgun arrays and several streamers (up to 16). Because the streamers are close to each other (typically 25-75m), data density is much improved with respect to 2D. These surveys may take several months to complete and cover areas of 300-3,000km^2.
- When a 3D survey is planned to be repeated over time (e.g. for reservoir management), it is referred to as a 4D seismic survey.
- Site surveys are carried out to obtain high resolution maps of the seabed surface and near subsurface. To achieve such high resolution, a similar technique to 2D seismic is used but crucially, a much smaller seismic source (a four air-gun cluster of 160 in^3 is typical or alternatively a mini-gun, ‘sparker’ or ‘boomer’ device) and receiving streamer (600-1200m in length) are deployed. Typically the area covered is 2-3km^2 and the survey lasts four or five days. Site surveys once a platform is in place may require the use of ‘undershooting’ whereby the sub-surface beneath an obstruction can be imaged by deploying the source and the receiver on separate vessels.
- Vertical Seismic Profiling (VPS) is employed to assist with well evaluation, by linking rock strata encountered in drilling to seismic survey data. A number of geophones are lowered into a well while the airgun array is deployed from either the rig itself, or from a vessel which may be stationary or moving. Sound source volumes are typically around 500 in^3, with a maximum of 1200 in^3 (Stone 2015b). Survey duration is short (one or two days at most).
- Ocean bottom seismic techniques, including ocean bottom seismometers (OBS), two-component (2C) and four component (4C) techniques, rely on acquisition of information by sensors placed directly on the seabed (either within cables or within sensor nodes). In addition to hydrophones, ground motion sensors (geophone or accelerometer) are used in 2C and 4C. The seismic source is deployed as in 2D or 3D surveys. This type of survey is favoured to accurately monitor reservoir depletion.

Airguns are among the highest energy anthropogenic sound sources in the sea (Richardson *et al.* 1995); when an airgun fires, part of the energy is converted to sound and generates a seismic signal that travels into the earth’s subsurface. Single airguns may be used but only in specific instances (e.g. site surveys); to achieve the required high amplitude and low frequency ideal seismic wavelet (perfect impulse) airguns are combined into arrays i.e. strings of multiple airguns supported by towed floating tubes (Dragoset 2000). Tuned airgun arrays consist of many guns of different, carefully selected volumes fired simultaneously; sound pressure is proportional to the cube root of the volume so that several small guns are more effective than a few large ones. The volume of a single air-gun varies between 30 and 800 in^3, while whole arrays, typically involving 12-48 guns (up to 100 are used), have a volume of 3000-8000 in^3. In the UKCS for the period 1998-2010 Stone (2015a) reported a yearly mean array volume between 2000-4000 in^3 and maximum volumes between 4000-7000 in^3, with the largest volume of 10,170in^3 used on a 2D survey in 2006. Airgun arrays are towed generally at 6m (5-10m) below the surface. During normal operations guns are fired every 10-15s at a typical operating pressure of 2000 psi.

Several array geometries can be deployed, with horizontal arrays of 3-6 sub-arrays being common. Thus an array is not a point source but spans a small area (e.g. 15x16m, 30x15m) (Caldwell & Dragoset 2000). From a test measurement, energy output can be back-calculated assuming that the array is a point source; these values are commonly presented as 'nominal peak source level' but they do not accurately resemble energy at a short distance from the array (i.e. 'near-field'). While each airgun is an omnidirectional sound source, an airgun array does not behave as a point source; in the near-field, the horizontal configuration of the guns in the array is such that the outputs of each gun interfere destructively with one another, so that peak pressures are significantly lower than the output of the largest individual gun. This is done purposefully to concentrate the radiation pattern downwards; hence amplitude levels emitted vertically below the array tend to be at least 15-24 dB larger than levels emitted horizontally (Cadwell & Dragonet 2000). Back-calculated sound levels measured in the far-field from arrays have exceeded >260 dB (e.g. Wyatt 2008 and references therein) but for reasons given above, these values are only theoretical and should not be confused with the true maximum amplitude. More sophisticated modelling is used by the industry to accurately model array output; Cadwell & Dragonet (2000) estimated that despite the myriad array geometries deployed, overall output levels (RMS peak-to-peak amplitudes) tended to be 240-246 dB re 1 µPa vertically downward and 220-230 dB re 1 µPa in the horizontal plane. Differences in the horizontal plane have also been observed (Breitzke *et al.* 2008); likely due to a shadowing effect of the vessel, levels recorded during vessel approach were lower than during departure from the hydrophone.

Given the high source level and low frequency dominance, seismic sound can propagate large distances and ensonify areas on scales of ecological importance. The exact propagation is case specific but representative studies are informative; peak sound pressure levels are commonly reported to have decreased below 200 dB re 1 µPa at a range of 100-1000m and below 160 at a range of 10-11km (e.g. Breitzke *et al.* 2008, Kongsberg 2010). Acoustic detection of seismic survey noise above ambient occurs regularly at distances of hundreds or even thousands of kilometres from the location where firing is taking place (Nieukirk *et al.* 2012); during surveys, average ambient levels in the low-frequency 20-50 Hz band most important to whales can be raised by 10-25 dB over large areas (e.g. 7500nm^2) as reported by Clark & Gagnon (2006).

Frequency influences how far sound may travel and only low frequencies can penetrate the seabed to the depths (several kilometres) required in many oil & gas activities. Airguns produce most of their energy in the low frequency, centred around 50Hz and mainly below 200Hz but nonetheless a very broad frequency spectrum is produced and energy up to at least 15kHz has been recorded (Goold & Fish, 1998; Madsen *et al.* 2006b); while amplitude at higher frequencies is low relative to that at the peak frequency, it may still be loud in absolute terms given the overall high energy generated. In addition, the spectral signature of sound changes as it propagates away from source, depending on the environmental conditions encountered; for example in shallow coastal water low frequencies propagate poorly. This has been recently confirmed by Hermannsen *et al.* (2015); the authors studied characteristics and propagation of airgun pulses and made recordings (10Hz up to 120kHz) from single air-guns (10-40 in^3) in a sandy area with a uniform depth of 15m at different distances (up to 1300m). While most of the signal energy was found at frequencies below 1kHz, high frequency components were also present (up to 10kHz at 1300m) and crucially the ratio between high and low frequency noise changed with distance. The peak frequency increased with range as did the noise energy above 1kHz relative to the total broadband energy. Another instance when environmental conditions combine to proportionally increase the high-frequency content of airgun signals is surface ducting. This was observed by De Ruiter *et al.* (2006) modelling acoustic propagation of airgun array pulses recorded on tagged sperm whales in the Gulf of Mexico. Some arrivals recorded near the surface had energy predominantly above 500 Hz at the time and location when sound speed profile indicated the presence of a surface duct in the water column.

Waves degrade the seismic signal because the geometry of the array becomes less stable and because rough seas spread out the reflection of the sound (i.e. the ghost reflection) producing a composite smoothed pulse with much reduced amplitude (OGP 2011). Weather appears to be less of an operational constraint on VSP and OBC surveys than 2D and 3D surveys; in practice in the UKCS, Stone (2015b) observed a clear seasonal pattern in 2D and 3D surveys with more activity in summer, but not in VSP.

Seismic interference from other surveys reduces productivity and is therefore avoided (OGP 2011).

5.3.2.3.2 OTHER GEOPHYSICAL SURVEYS

In addition to airguns, there are a variety of other equipment and sound sources used in geophysical surveys, including echosounders, side-scan sonars and sub-bottom profilers (pingers, boomers, chirp, sparkers). In comparison to airguns, such equipment use higher frequency sound and focus on surface or shallow seabed imaging (see Zykov 2013, DECC 2011b). Most information of noise exposure during these surveys is modelled and direct measurements are limited. Sub-bottom profilers generate sound from about 500Hz to 10-300 kHz; their use by industry requires regulatory consent and is monitored through the UK Marine Noise Registry. There are several different types of echosounders, resulting in a variety of outputs in terms of power, frequency and directionality (single to complex beam patterns) but for those most commonly used on site surveys, the expectation is that sound levels drop off very quickly with distance due to a combination of high frequency (>10kHz) and high directionality. Side-scan sonar are also characterised by very high frequency output (>100kHz). Echosounders and side-scan sonars are activites that require only notification under the current regulations and do not require inclusion into the UK Marine Noise Registry[48], with the exceptions of multi-beam echosounder system (MBES) of less than or equal to 12kHz.

5.3.2.3.3 DRILLING

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 but the overall acoustic output depends on the type of operation (Wyatt 2008). When drilling from semi-submersible rigs, noise is transmitted from the rig to the water column through submerged parts of the drilling unit hull, risers and mooring cables, and (to a much smaller extent) across

[48] Draft Marine Noise Registry document (version Dec 2015) from JNCC (soon to be publicly available from http://jncc.defra.gov.uk/page-7070).

the air-water interface. If position is maintained by dynamic positioning, noise from thrusters may dominate the lower frequency band (Wyatt 2008). Noise transmission from jack-up drilling units used in shallower water is less because of reduced surface area contact between the water column and submerged parts of the rig. Sound pressure levels of 120dB re 1µPa in the frequency range 2-1400Hz (Todd & White 2012) are probably typical of drilling from a jack-up rig and is of the same order and dominant frequency range as that from large merchant vessels (e.g. McCauley 1994). Drilling duration may range from a few weeks for an exploration well, to several years in the case of a large development programme.

5.3.2.3.4 PIPE LAYING

The overall source levels resulting from pipe laying operations on the UKCS are not typically measured; however, near-field cumulative sound levels associated with pipe lay for the Clair project were predicted to be a maximum of 177dB (Lawson *et al.* 2001), with a duration of weeks or months. Pipelines can either be laid directly on the seabed or trenched and buried. Noise levels will likely be dominated by the vessel noise associated with installation (Genesis 2011). A pipeline installation which includes trenching and backfilling activities, is likely to be comparable to dredging activities, particularly cutter trailing dredgers and trailing suction hopper dredgers (Genesis 2011). Dredging generates underwater sound during sediment excavation, transportation and placement. This can originate through a variety of sources including movement of material, engine and mechanical sound, propellers, pumps, cutting and digging of material. Underwater sound caused by dredging activities is typically of low frequency, with strongest sound below 1 kHz (de Jong *et al.* 2010). However, relatively high source levels can be generated above 1 kHz (Robinson *et al.* 2011). Sound source levels typically range from 168 to 186 dB re 1 µPa (Genesis 2011). The levels and frequencies generated depend on the type of dredger, operational status and sediment type. Robinson *et al.* (2011) found that source levels were approximately 5 dB higher during dredging of gravel compared with sand.

5.3.2.3.5 PRODUCTION PLATFORM

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.

5.3.2.3.6 HELICOPTERS

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.

5.3.2.3.7 SUPPORT VESSELS

Noise from marine vessels represent numerous, widespread and relatively loud individual sources which combine to form by far the dominant anthropogenic source of continuous low frequency sound in the marine environment. Several factors play a role in determining the exact characteristics of radiated vessel noise, including vessel type, size, age, mode of propulsion and speed (OSPAR 2009). For example, Abrahamsen (2012) found dominant noise radiation from low powered vessels to be from on-board machinery, such as hydraulic systems, gears and compressors. Propellers and/or thrusters were the strongest noise source for many vessels, particularly high powered or high speed vessels. Noise was measured from a survey vessel at two different operating conditions; machinery noise dominated at a speed of 8 knots and propeller noise dominated at 13 knots (Abrahamsen 2012). Peak amplitude of machinery noise was found to be generated by the gears. Most support vessels are medium-size ship (50-100m length); typical broadband source levels are within the 165-180 dB re 1 µPa range and although there is considerable variability in associated frequency spectra, they tend to be similar to large vessels with dominant frequency below 1kHz (OSPAR 2009). Support vessels may be stationary for large periods of time, either at anchor or through dynamic positioning (DP) thrusters. Noise generated from DP is not well documented but it likely to be less than that generated during transit.

5.3.2.3.8 DECOMMISSIONING

Noise will be generated during decommissioning works and potential effects will depend on the type and duration of activities undertaken. In many instances, decommissioning requires a similar set of activities and associated noise emissions to construction and installation, with the exception of an absence of extensive seismic surveys and pile-driving activities. The main sources of noise are rigs and vessels as well as mechanical cutting techniques. Underwater noise emissions from cutting tools (operated by divers or remotely) are unlikely to result in sufficient levels of noise to cause significant disturbance to marine life. The use of explosive cutting methods may produce high intensity impulsive noise, although such activities are infrequent and would be subject to activity-specific assessment and regulation, with alternative cutting methods sought where possible.

5.3.2.4 Carbon dioxide storage

Noise characteristics of potential carbon dioxide storage developments are likely to be very similar to existing oil and gas developments. Geophysical surveys, in particular 4D seismic surveys (i.e. repeated, high resolution 3D surveys), may be necessary to monitor CO_2 plume spread within the reservoir. This may involve the deployment of permanent seabed geophone arrays. The frequency and cumulative acoustic disturbance associated with geophysical monitoring of carbon dioxide storage is not clear.

5.3.2.5 Gas storage

As with carbon dioxide storage, noise associated with gas storage in depleted reservoirs or salt caverns is predicted to be very similar to the survey, drilling and operational phases of conventional gas exploration and production.

5.3.3 Consideration of the evidence

Given the variety of sounds to which marine organisms may be exposed, potential effects are wide ranging, involving both physiology and behaviour (Kight & Swaddle 2011). In addition to direct effects on a receptor, indirect effects may also occur for example via potential changes to prey species.

The most acute effects can be lethal, involving the direct physical damage of body tissues and air filled cavities from rapid pressure change (i.e. barotrauma); these effects are spatially restricted to the immediate proximity of very high amplitude impulsive sounds (e.g. explosions) and are relatively well understood in part thanks to the interest in establishing safe levels for humans working underwater (Richardson *et al.* 1995, Parvin *et al.* 2007). In marine mammals, there is also a risk of nitrogen bubbles being formed, which may result in physiological effects similar to decompression sickness in humans. Although evidence on the exact mechanism remains equivocal, bubble formation has been suggested as causal mechanism between certain sound exposure (e.g. military sonar) and stranding events in beaked whales and other species (Southall *et al.* 2007).

The auditory system is most sensitive to sound and can be damaged by elevated sound (e.g. through damage and death of sensory hair cells in the ear). Depending on the exposure (e.g. sound type, amplitude, duration, kurtosis, duty cycle, frequency), damage may result in an irreversible loss of hearing functions (i.e. a permanent shift in hearing thresholds or PTS) or in a temporal loss of hearing functions (i.e. a temporal shift in hearing thresholds, or TTS) also called auditory fatigue, from which recovery is possible (e.g. Southall *et al.* 2007). Although not immediately fatal, the consequences of auditory damage are of concern given the importance of sound for marine organisms across a spectrum of activities, including communication, orientation, predator avoidance and foraging (e.g. OSPAR 2009).

There is also the potential for a pervasive role of noise as a chronic stressor given that in humans a variety of consequences on health, including cardiovascular disease, cognitive impairment and sleep disturbance have been identified (WHO 2011).

In addition to physiological impacts, behavioural changes can be induced in response to sound, resulting in disruption of normal activity. All types of behaviour may be affected including locomotion, communication, foraging and reproduction and while short-term effects are likely to have little ecological consequences, prolonged effects may be significant; the main concern is whether individual vital rates and ultimately population viability can be affected. Behavioural responses can be difficult to measure, interpret and predict; most importantly in relation to impact assessment, behavioural responses have been found to be strongly context specific depending on an individual's internal state, its perceived risks and habitat quality (Bejder *et al.* 2009, Gill *et al.* 2001). For example, avoidance of low-quality habitats may take place more readily because the immediate consequences to an individual are likely to be negligible.

Anthropogenic noise may mask important acoustic cues (Richardson *et al.* 1995); masking occurs whenever the presence of a sound reduces the animal's ability to hear a second sound (i.e. threshold of hearing for a second sound is increased). In the case of vocal communication involving a sender and a receiver, both may have their performance reduced through acoustic interference from anthropogenic noise. Masking is more effective the greater the overlap in frequency between signal and noise; temporal overlap also plays a role but the relative potential of continuous and pulsed sounds is currently still unclear (EU TSG Noise 2014c). The levels of sound involved in masking can be relatively low and as a consequence the spatial footprint can be very large; this rationale led to the development of the MSFD indicator 11.2.1 (Tasker *et al.* 2010).

As discussed above, the relationship between the type of effect elicited and sound level (or distance from source) is far from straightforward but nonetheless in many cases, it can be used as a valid approximation. The 'zone of influence model' of Richardson *et al.* (1995) was the first approach to assessing noise impacts on marine mammals largely on the basis of distance between source and receiver; four zones of influence were identified, each centred on the source and each of increasing size, determined by sound thresholds of decreasing amplitude: (1) zone of hearing loss, discomfort or injury, (2) zone of masking, (3) zone of responsiveness and (4) zone of audibility.

More recent developments establishing criteria for impacts have followed this original approach; efforts have focused on reviewing available evidence and establishing thresholds were meaningful to do so. For management, threshold criteria can be a useful and relatively simple tool to apply because they reduce the complexity of judging impact to whether sound produced exceeds a given level. However, in so doing, the complexity is shifted on to the process of establishing criteria. Since the acoustic sensitivity and the behaviour of the receiver play a very important role in how sound may affect marine organisms, impact criteria are specific to each receptor and are introduced in the relevant sections below.

5.3.3.1 Marine mammals

Marine mammals emit and hear sound across a very wide frequency bandwidth spanning from the low frequency calls of baleen whales to the high frequency echolocating clicks of dolphins. Hearing sensitivity is expressed in the form of a hearing curve (i.e. audiogram) where the lowest sound level detected is plotted as a function of frequency; an audiogram commonly exhibits a U-shaped form with greater sensitivity (lower sounds detected) in the middle of a specific bandwidth. In marine mammals, audiograms have been obtained for several species of odontocetes and pinnipeds using either behavioural or electrophysiological (AEP) methods, mainly with captive individuals but more recently also with wild animals temporarily captured and restrained (see Castellote *et al.* 2014, Finneran 2015 and references therein). No measurement has yet been made for any baleen whale and their sensitivity is derived from knowledge of the acoustic properties of emitted signals and anatomical features. Southall *et al.* (2007) considered the differences and similarities in auditory capabilities between species and grouped marine mammals into functional groups; cetaceans were divided into low-, mid- and high- frequency while pinnipeds were treated differently with respect to whether they were in water or air. These groups are currently considered relevant to noise impact assessment in UKCS and provided for reference in Table 5.1.

Table 5.1: Functional marine mammal hearing groups, auditory bandwidth and relevant species regularly present in UK waters.

Functional hearing group	Estimated auditory bandwidth	Species in UK waters
Low-frequency cetaceans	7 Hz to 22 kHz[49]	Minke whale *Balaenoptera acutorostrata* Fin whale *Balaenoptera physalus* Humpback whale *Megaptera novaeangliae* Sei whale *Balaenoptera borealis* Blue whale *Balaenoptera musculus*
Mid-frequency cetaceans	150 Hz to 160 kHz	Bottlenose dolphin *Tursiops truncatus* Common dolphin *Delphinus delphi* White-beaked dolphin *Lagenorhynchus albirostris* Atlantic white sided dolphin *Lagenorhynchus acutus* Risso's dolphin *Grampus griseus* Striped dolphin *Stenella coeruleoalba* Long-finned pilot whales *Globicephala melas* Beaked whales *Mesoplodon spp., Ziphius spp. Hyperodon spp.* Killer whale *Orcinus orca* Sperm whale *Physeter macrocephalus*
High-frequency cetaceans	200 Hz to 180 kHz	Harbour porpoise *Phocoena phocoena*
Pinnipeds in air	75 Hz to 75 kHz	Grey seal *Halichoerus grypus* Harbour seal *Phoca vitulina*
Pinnipeds in water	75 Hz to 30 kHz	Grey seal *Halichoerus grypus* Harbour seal *Phoca vitulina*

The most significant contribution to the development of threshold criteria for the management of noise-generating activities with respect to marine mammals was provided by Southall *et al.* (2007). They reviewed available science on the impact of noise on the hearing of cetaceans and pinnipeds and proposed noise exposure criteria which are now the most commonly used in

[49] As part of the NOAA process to update thresholds and revise guidance for assessing effects of anthropogenic sound on marine mammal species (http://www.nmfs.noaa.gov/pr/acoustics/guidelines.htm), evidence has been identified to suggest that the low-frequency cetacean hearing group may be extended up to 25kHz.

the UK[50]. Another approach used in environmental statements in the UK was proposed by Nedwell *et al.* (2007); because of its wider application with respect to fish it is described in Section 5.3.3.2.

Southall *et al.* (2007) distinguished anthropogenic sound sources according to their acoustic and operational features into 'single pulse', 'multiple pulses' and 'non-pulses' and established criteria for each. With regard to metrics, since damage to auditory capabilities can occur from instantaneous exposure to a very intensive sound as well as to cumulative exposure over time of sound of lesser relative intensity, they proposed a dual-criterion approach based on both pressure and energy (i.e. the relevant threshold in any one case is the first one to be exceeded). The chosen metrics were zero-to-peak sound pressure level, L_{peak}[51] and cumulative sound exposure level, SEL_{cum}. The former being best suited to single pulses and for all sounds which include intense peak pressure components while the latter is favoured when assessing cumulative exposure as it allows sounds of different durations to be compared in terms of total energy. SEL_{cum} is the cumulative exposure over a 24h period calculated by simple summation of multiple exposures (assuming no recovery of hearing). To compensate quantitatively for the differential frequency response between functional groups, Southall *et al.* (2007) proposed frequency weighting functions (M-functions) to be applied in the calculation of SEL. These were derived following the approach of C-functions[52] for human hearing.

Table 5.2: Marine mammal injury criteria

Functional hearing group	Dual-criteria	Single pulse	Multiple pulses	Non-pulsed
Low-frequency cetaceans	sound pressure level L_{peak} dB re 1 µPa	230	230	230
	sound exposure level SEL_{cum} dB re 1 µPa^{2}s	198	198	215
Mid-frequency cetaceans	sound pressure level L_{peak} dB re 1 µPa	230	230	230
	sound exposure level SEL_{cum} dB re 1 µPa^{2}s	198	198	215
High-frequency cetaceans	sound pressure level L_{peak} dB re 1 µPa	230	230	230
	sound exposure level SEL_{cum} dB re 1 µPa^{2}s	198	198	215
Pinnipeds in water	sound pressure level L_{peak} dB re 1 µPa	218	218	218
	sound exposure level SEL_{cum} dB re 1 µPa^{2}s	186	186	203

Source: Southall et al. (2007)

The authors recognised that injury and behavioural disturbance as very different effects and chose to deal with them separately. Data with respect to non-auditory injury (e.g. gas bubble growth) was insufficient to allow formulation of quantitative criteria, so the focus of injury criteria is on auditory injury. Injury criteria are given in Table 5.2; they are the received level of sound which corresponds to the estimated onset of PTS. Since PTS has not been measured directly

[50] These criteria have been recommended in the guidance for the protection of marine European Protected Species from injury and disturbance (JNCC, NE & CCW 2010, Marine Scotland 2014)
[51] Southall *et al.* (2007) used to abbreviate zero-to-peak sound pressure level to SPL_{peak} but L_{peak} is now preferred.
[52] The C-weighting function is based on equal loudness contours and used in human audiology to quantify the loudness of more intense sounds.

in any experiment on marine mammals, but only extrapolated from TTS measurements, the process of developing these criteria relied on several assumptions. Inevitably choices with respect of which evidence to use were made at several steps in the process and the authors purposefully and consistently erred on the conservative side. The following aspects are highlighted by way of example:

- SEL is calculated over a 24hr period assuming no recovery between sounds, even when large intervals may occur. This is a practical approach to deal with the difficult issue of interval and hearing recovery but it is flawed as recovery during intervals between sounds plays a crucial role in the growth of TTS; depending upon the temporal pattern of the activity, this assumption may have a potentially minor or large consequence in overestimating the potential for injury (e.g. Hastie et al. 2015).
- SEL is calculated assuming the Equal Energy Hypothesis to be valid and yet as more evidence becomes available it is clear that this is not always the case; fatiguing sounds induce different TTS depending not just on total amount of energy but on the interaction between level, duration of exposure, rate of repetition and frequency (Kastelein et al. 2012, 2014; 2016, Popov et al. 2014). The concept of 'effective quiet' is also ignored i.e. the maximum sound pressure level that will fail to produce any significant threshold shift despite duration of exposure and amount of accumulation.
- SEL is frequency weighted to account for species differences when evaluating impact; the choice of weighting curve can have important consequences on SEL calculations and there are concerns that the M-weighting curve adopted by Southall et al. 2007 may not be the most appropriate (Tougaard et al. 2015, NOAA 2015, Houser & Moore 2014).

It follows that these injury thresholds are precautionary and should be interpreted as the sound levels above which a risk of PTS occurring becomes increasingly likely and below which there is no scientific basis for expecting auditory injury to occur; it would be an over- simplification of their report to state that PTS is induced as soon as thresholds for injury are reached.

Southall *et al.* (2007) describe their process in detail and present their criteria as 'preliminary', being well aware of the fast pace of current research and the need to improve and update these criteria as soon as new evidence becomes available. Since 2007, much of the evidence on TTS in mid-frequency cetaceans and harbour seals has tended to corroborate earlier findings. On the contrary, recent research on harbour porpoise warrants a revision of thresholds for high-frequency cetaceans. The early suggestion that harbour porpoises were more sensitive to noise than other cetaceans (as reported by Southall *et al.* (2007) in light of preliminary results by Lucke *et al*. (2007)), has been corroborated. Lucke *et al.* (2009) measured the auditory evoked potentials of an adult male harbour porpoise exposed to single airgun pulses and recognised the onset of TTS to occur at received sound pressure level (L_{pp}) of 199.7 dB re 1 µPa and a sound exposure level (SEL) of 145 dB re 1 µPa^{2}s. Kastelein *et al.* (2010, 2012a, 2013b, 2014) carried out several tests, also on an adult male harbour porpoise, to quantify TTS and hearing recovery after exposure to fatiguing continuous sound (octave band white noise centred at 4kHz); TTS was observed across a range of SEL 151-175, depending on SPL, duration and interval between exposures. While differences in sound types and methodologies make comparison between these studies difficult, there is now agreement that harbour porpoises are more sensitive to sound than other species previously tested.

Thresholds for this species should be revised; this is particularly important for assessing potential noise impacts of human activities in a large proportion of UK waters, where harbour porpoises are the most common cetacean. A recent report commissioned by SNH on sensitivity of cetaceans and seals to acoustic deterrents (Lepper *et al.* 2014), applied the procedure proposed by Southall *et al.* (2007) to the results obtained by Lucke *et al.* (2009) and revised injury thresholds for harbour porpoise accordingly for continuous and pulsed sounds. (Table 5.3).

Table 5.3: Revised injury criteria for harbour porpoise

Dual-criteria	Multiple pulses	Non-pulsed
sound pressure level L_{peak} dB re 1 µPa	200	200
sound exposure level SEL_{cum} dB re 1 $\mu Pa^2 s$	179	184

Source: Lepper et al. (2014) based on the threshold for TTS onset reported in Lucke et al. (2009)

The US National Oceanographic and Atmospheric Administration (NOAA) are currently in the final stages of a process to update acoustic threshold levels as part of publishing 'acoustic guidance for assessing the effects of anthropogenic sound on marine mammal species'[53]. Until then, the acoustic threshold levels that were first established in 1995 by the National Marine Fisheries Service are still applied. The latest draft of the guidance (July 2015) proposes criteria for injury based on an approach similar to that of Southall *et al.* (2007) and incorporating recent research results. In addition to high-frequency cetaceans being recognised as a particularly sensitive group, the main innovation is a new set of marine mammal auditory functions constructed by Finneran (2015)[54].

With respect to behavioural effects, criteria based on exposure alone have been much more difficult to extrapolate, mainly because behavioural responses are often affected by individual history and exposure context. For single pulses, Southall *et al.* (2007) assumed that significant behavioural disturbance could occur if noise exposure was sufficient to elicit a measurable transient effect on hearing or TTS-onset. However, for multiple pulses (e.g. seismic survey) and continuous sounds, behaviour was assumed to be affected at sound levels below TTS onset. A systematic assessment of available behavioural disturbance studies was carried out by assigning severity scores to the relevant received sound level, on the basis of a simple 'behavioural response severity scale', ranging from minor behaviours with negligible and brief effects (scores 0-3) to those affecting vital rates (scores 7-9). Due to various statistical and methodological problems, much of the data were not considered to provide sufficient scientific credence for establishment of exposure criteria. The results suggested the presence of dose-response relationships between noise exposure and behaviour but the very high variability observed meant that no single threshold could be reasonably justified. Instead 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). Overall, caution was recommended in the application of the severity analyses and careful consideration of 'the overall context of exposure relative to that shown in the studies reviewed'. Further empirical evidence has been collected over the last ten years providing a stronger basis for comparison; key studies are presented below. In the UK, European Protected Species Guidance (JNCC 2010) recommends that disturbance as described in Regulations 39(1),

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[53] http://www.nmfs.noaa.gov/pr/acoustics/guidelines.htm

[54] The shape of the function has changed from the M-weighting function (resembling the human dB(C) approach) to a function based on a generic band-pass filter that resembles the much more commonly applied human dB(A). Function parameters are derived for each hearing functional group from available data including behavioural audiograms, equal latency contours, TTS measurements and predicted audiograms from anatomically based models.

39(1)(b) and 39(1A)(a) of the HR and OMR is interpreted as sustained or chronic disruption of behaviour scoring 5 or more in the Southall *et al.* (2007) behavioural response severity scale.

The behaviour of marine mammals introduces uncertainty and complexity not just in terms of response but also in the calculation of exposure. The position in the water column and the movement of an animal with respect to the direction (and movement) of a sound source influences its overall exposure. To cope with large uncertainties in these respects, a comparison of predictions based on different expected behaviour (e.g. static, transiting and fleeing animals) is often included in noise assessments. More complex models are capable of including specific details for both source and receiver (speed, direction, diving pattern, expected response to sound) and simulate relative source and receiver movement.

Taking all of the above in consideration, the EU MSFD Technical Subgroup (TSG Noise) under the Working Group on Good Environmental Status has developed an indicator (Indicator 11.1.1) on low- and mid- frequency impulsive sounds defined as: "*The proportion of days and their distribution within a calendar year, over geographical locations whose shape and area are to be determined, and their spatial distribution in which source level or suitable proxy of anthropogenic sound sources, measured over the frequency band 10 Hz to 10 kHz, exceeds a value that is likely to entail significant impact on marine animals.*"

This indicator aims to address the cumulative impact of impulsive sound generating activities in terms of 'considerable' displacement, described as 'the displacement of a significant proportion of individuals over a relevant time period and spatial scale' (EU TSG Noise 2014a). To make the indicator operational, Member States have been instructed to establish a Registry of the occurrence of all relevant low- and mid-frequency impulsive sounds. Minimum noise thresholds were established as a basis for including sources in the Register and are shown in Table 5.4 (EU TSG Noise 2014a). These thresholds were purposefully low; the aim being to ensure that all sources that have the potential for significant population level effect are included in the Register and only sources unlikely to have significant impact are excluded. As a consequence the sources included vary widely in their potential for impact.

Table 5.4: Sound level thresholds for inclusion into the MSFD Noise Register

Sound type	Activity	Sound level threshold for inclusion into Register	Proxy threshold for inclusion into Register (if relevant)
Non-pulse	Sonar	SL = 176 dB re:1 μPa	
Non-pulse	Acoustic deterrent	SL = 176 dB re:1 μPa	
Multiple impulsive	Impact pile driving	SL_E = 186 dB re:1 μPa^{2}s	E_{hammer} = 1.1 kJ [55]
Multiple impulsive	Seismic survey (airgun array)	SL_E = 186 dB re:1 μPa^{2}s	SL_{zp} = 209 dB re:1 μPa m
Single impulsive	Explosions	SL_E = 210.3 dB re:1 μPa^{2}s	m_{TNTeq} = 8 g

Source: EU TSG Noise 2014a

Thresholds for inclusion into the Register were formulated as a combination of sound level and spatial range across which the sound level was exceeded; this was done to ensure that the effect of displacement elicited by the sound generating activity could be considered 'significant' from an ecological perspective. A range of 1000m was agreed thus the threshold proposed corresponded to the sound at source that would exceed the level identified for displacement over a range of at least 1000m.

[55] The hammer energy threshold for pile driving is much less than what is routinely used in construction therefore no minimum threshold is valid and all pile-driving activities need to be registered.

5.3.3.1.1 Offshore wind farms – construction and operation

Several empirical studies of marine mammal behaviour have been carried out during construction and operation of offshore wind farms in the North and Baltic Seas; piling sounds during construction have also been used for playback studies in wild and laboratory conditions. It is important to note in the following review that mitigation measures in Denmark and Germany promote the use of harassment devices (pingers and seal scarers) prior to impact piling; while studies have focused on the effect of piling, harassment devices may partly confound the results by contributing, at least close to the piling site, to influencing animal responses.

Tougaard *et al.* (2009b) measured the acoustic activity of harbour porpoises at Horns Rev using passive acoustic monitoring devices (T-PODs) and found clear evidence for a negative effect of pile driving. Waiting time between echolocation events increased significantly from an average of 5.9h during the construction period as a whole to an average of 7.5h between the first and second encounters after piling. No difference was observed in later inter-encounter intervals, suggesting the negative effect of piling was of limited duration. In terms of spatial extent however, the study concluded that the entire area was affected; this is because T-POD location (within the 4x4km^2 of the windfarm, at 7.5km east and at 21.5km west of the wind farm) did not have any effect on the outcome of the analysis. However, given the relatively small sample size, it might be possible that the analyses did not have enough power to detect a gradient.

A decrease in acoustic activity associated with pile-driving was reported also by Carstensen *et al.* (2006) at the Nysted wind farm; the interval between echolocation encounters increased from 6 hours in the baseline period to 3 days during the construction period within the wind farm area, but not at the reference area (10km east of the wind farm). A further construction activity involving prolonged ramming and vibration of steel sheet piles into the seabed for stabilisation was associated with an effect in both construction and reference areas. Measurements made 6-7 years after construction showed that echolocation activity had not yet fully recovered to pre-construction levels within the wind farm, while the reference area had remained unaffected (Teilmann & Carstensen. 2011). This is the only record available so far of a negative long-term effect and contrasted at the time of writing with the experience at Horns Rev and Egmond aan Zee; several differences exist between sites (e.g. turbine type, ship traffic) but a possible explanation put forward by the authors is that the area at Nysted is a less important habitat to harbour porpoises, consistent with the lower density observed.

Also in the Moray Firth, Thompson *et al.* (2010) found some evidence that harbour porpoises responded to disturbance from installation activities; in July and August 2006, the period in which the main installation work was carried out, porpoises were detected for significantly fewer hours per day when compared with a similar period in 2007, whereas similar comparisons for the adjacent months of June, September and October did not show significant differences in porpoise detections. Analysis of a different variable, the waiting time until the next porpoise detection, showed variable results, with waiting times within the typical distribution for the piling of the first sub-structure, and an extreme outlier of zero porpoise detections during piling of the second structure. Several factors, mainly small sample size and high variability between areas, limited the power of this study to draw firm conclusions; however, the experience was pivotal in proposing improvements on experimental design, such as the use of a gradient design to look for an effect of impact instead of relying on a BACI comparison. The latter is particularly difficult to establish whenever temporal/spatial variability is high and whenever 'control' sites may differ in several characteristics other than just the lack of impact as it's often the case in marine mammal field studies.

The gradient approach was successfully adopted in two recent studies at Horns Rev II (Brandt *et al.* 2011) and Alpha Ventus (Dähne *et al.* 2013). At Horns Rev II, T-PODs were deployed at 6 positions along a gradient ranging from 2.5 to 21.2km from the centre of the windfarm.

Porpoise activity was found to be negatively affected by pile driving out to a distance of 17.8km; at the closest T-POD site the effect was stronger (reduced by 100% during 1 h after piling) and stayed below normal levels for longer (24-72h); with increasing distance, the duration of this effect gradually decreased. In contrast, activity at the furthest location was found to be higher than elsewhere (up to 30 h after piling). Overall, out to a distance of 4.7km, recovery time was longer than pauses between piling so that the end result was a reduction in activity throughout the construction period. At Alpha Ventus, C-PODs were deployed at 12 locations, extending up to 50km from the construction area, and information on acoustic activity was combined with sighting data from aerial surveys. Overall, harbour porpoise densities were found to be lower during construction period; a comparison of distribution patterns obtained on two aerial surveys three weeks before and exactly during pile-driving shows a strong avoidance response within 20km from the noise source. Analyses of acoustic detections using generalised additive modelling, identified a reduction in detection rate within 11km and an increase at the positions further away (25 and 50km); it was also noted that duration of pile-driving had a large impact, with longer pile-driving durations leading to a longer displacement.

A controlled exposure study was carried out by Tougaard *et al.* (2012) within a coastal area frequented by harbour porpoises where visual tracking by theodolite is possible from a nearby cliff top. Pile-driving sounds were played back from underwater loudspeakers and porpoises were clearly observed to avoid the area up to about 200m from the speaker. At that distance, received levels were on average 140 dB re 1 uPa (peak-peak).

Most recently, Kastelein *et al.* (2015) have used pile-driving playbacks to test hearing frequency thresholds on a captive harbour porpoise using a well established psychoacoustic technique. Total exposure of 180 SEL_{cum} (146 SEL per pulse over 60 mins) resulted in a statistically significant TTS at 4 and 8 kHz but not at any of the other frequency tested, including no effect on the high frequencies used in echolocation. The magnitude of the effect was small (<4 dB) and full recovery was achieved within 48mins. In addition, the behaviour of the experimental porpoise was affected by the 60mins exposure: there were changes in swimming patterns, increased swimming speed and surfacing rate resulting in effects on the level of exertion and anxiousness. The carefully controlled and particularly quiet conditions of the test pool were important in being able to measure such a small TTS; the response may differ within an open water situation.

In the Moray Firth, the original focus of the study by Thompson *et al.* (2010) was to assess the response of bottlenose dolphins to piling since the turbine site lies 25km from a SAC designated for their protection. However, this turned out not to be feasible; knowledge of their distribution in the offshore Moray Firth was limited at the time and indeed it was only during the study that it became clear that bottlenose dolphins rarely visit the Beatrice area, rendering the ‘impact’ site ineffective and concluding that the population was at low risk from near-field effects.

In summary, all studies have shown clear evidence for displacement of harbour porpoises in response to pile-driving. Some variation between studies was observed regarding the magnitude of the effect, its spatial extent and its duration once construction was completed. This is not surprising given the number of factors at play when drawing such comparisons: site conditions (sound propagation characteristics, ambient noise, vessel traffic but also ecological importance of the area), use of different mitigation measures (soft-start, acoustic deterrents), experimental protocols (BACI, gradient design) and sample size.

Low relative abundance of cetaceans other than harbour porpoises has limited the opportunity to study responses of other species, but studies have been conducted on harbour seals.

At Horns Rev wind farm (Tougaard *et al.* 2006) a study using satellite telemetry showed that harbour seals were still transiting the farm during periods of piling but no conclusive results could be obtained from analysis of habitat use with regard to a change in response to piling. Evidence of a response was obtained by Eden *et al.* (2004) at a haul-out site 10km away from the Nysted windfarm; during piling, numbers hauling out were reduced by 10-60% but the effect was only of short duration since the overall number of seals increased slightly during the whole construction phase. Hastie *et al*. (2015) reported the results from a large satellite telemetry tracking effort to elucidate the potential for sound exposure of harbour seals during the construction of the Lincs Offshore windfarm. All seals (n=24) were observed to spend time offshore during at least one pile driving event but none of the tagged seals were observed any closer than 4.7km.

Empirical observations with respect to operational turbines are limited but the available evidence suggests that harbour porpoises and harbour seals routinely enter wind farms and in some cases show attraction and behaviours consistent with foraging. In particular, Scheidat *et al.* (2011) studied acoustic activity of harbour porpoise in the area of the Dutch wind farm Egmond aan Zee and were able to compare patterns collected before construction with a later period when the farm was fully operational, both within the farm and at two reference sites, 10km north and south of the farm. No data were collected during construction. There was an overall increase in harbour porpoise acoustic activity from baseline to operation in line with the increase observed in this southern region of the North Sea; however, the increase was significantly higher within the operating wind farm than at the reference sites; the exclusion of most ship traffic from the farm, including fishing vessels, and the potential for the farm to act as an area of increase food availability are suggested as a reasonable explanations. For harbour seals, satellite telemetry tracking data has provided the clearest proof yet of individual seals not only regularly entering operational windfarms but concentrating their foraging activity at individual turbines, following a grid-like pattern to move between turbines (Russell *et al.* 2014).

Underwater detonations have the potential to cause lethal injury to marine mammals as well as a range of physiological and behavioural effects. Acoustic impairment or behavioural response to a series of underwater explosions was linked to a recent mass stranding event of long-finned pilot whales in Scotland (Brownlow *et al.* 2015). The potential impact of explosive clearance activities of historical UXO has recently been addressed in a study on harbour porpoises in the Southern North Sea (von Benda-Beckmann *et al.* 2015). For recorded explosion events, impact areas were modelled and the number of animals likely to have suffered injury (PTS) was estimated using injury thresholds and aerial survey-based estimates of concurrent abundance. It was estimated that the 88 explosions between March 2010 and March 2011 were very likely to have injured 1,280 and possibly up to 5,450 animals. Uncertainties in these predictions were acknowledged, such as difficulty of predicting underwater shock waves in shallow water, lack of data on the response of harbour porpoise to explosion shock and lack of knowledge on habitat use and movement patterns; nonetheless, the study identifies the need to consider this activity as part of cumulative assessments for the harbour porpoise in the North Sea.

5.3.3.1.2 *Oil & Gas – exploration (seismic surveys and other geophysical surveys)*

Research on the potential effects of seismic airgun pulses focused initially on baleen whales, because of their greater acoustic sensitivity to low frequency sounds. Most early studies relied on visual observations and in several instances evidence for localised avoidance was obtained for species such as grey, bowhead and humpback whales (e.g. Richardson 1995). For example, in a comprehensive study of reactions of gray whales to seismic noise along their migration route off the Californian coast, Malme *et al.* (1983) found definite avoidance reactions by gray whales within a range of 5km from seismic array source; off Western Australia, McCauley *et al.* (2000) observed localised avoidance (approx. 3km) by migrating humpback and a more pronounced response (avoidance at 7-12km range) for pods with cows involved in resting behaviour in key habitats (McCauley *et al.* 2000). In contrast, recent marine mammal observations during seismic surveys off Angola, concluded that the effects were small or negligible for humpback whales (Weir 2008); encounter rate (sightings/h) of humpback whales did not differ significantly according to airgun operational status; mean distance to humpback whale sightings was greater during full-array operations than during guns off, but this difference was not significant; no evidence for prolonged or large-scale displacement from the region during the 10-month survey duration was found.

Overall, the magnitude of response has been found to vary between studies, with several factors likely to be at play including species, actual received sound exposure levels, biological and social status of individuals (e.g. age, sex, single males vs. mother-calf units) and behavioural state and activity (e.g. migrating, foraging, resting) (e.g. Richardson 2002, McCauley *et al.* 2000). In addition, the behaviour of the sound source may also influence response; in a study to determine the short-term behavioural responses of bowheads to various industrial activities in the Canadian Beaufort Sea, Richardson *et al.* (1985) found no obvious reaction by the whales to seismic vessels operating as close as 6km to them but observed much stronger behavioural reactions to rapidly changing situations, including approaching boat, aircraft and a brief playback experiment. A recent analysis of bowhead behavioural data collected in the Beaufort Sea from 1980-2000, demonstrated seismic operations to have an effect on surfacing and dive durations but these changes in behaviour were found to be largely dependent on both circumstances and whale activity (Robertson *et al.* 2013).

Evidence of changes in vocalisation in response to seismic noise has been obtained from passive acoustic monitoring studies in several baleen whale species. Numbers of singing humpback whales (breeding displays) were found to decrease with increasing received levels off the coast of Northern Angola (Cerchio *et al.* 2014). In bowhead whales during the westward autumn migration in the Alaskan Beaufort Sea, calling rate is known to decrease in proximity (41-45km) to seismic operations (Blackwell *et al.* 2013); a more detailed study was able to differentiate between an initial increase in calling rate as soon as airgun pulses became detectable and decreased calling rates as exposure levels increased until all whales were virtually silent (Blackwell *et al.*2015). Extreme sensitivity has been suggested in sperm whales in the Southern Ocean, where vocalisation was observed to cease in some cases when a seismic survey vessel at range >370km was heard firing (Bowles *et al.* 1994). Other studies on this species have shown much greater tolerance both in terms of avoidance and acoustic behaviour (Madsen *et al.* 2002; Miller *et al.* 2009).

Within the UKCS, the observations obtained from Marine Mammal Observers during seismic surveys are particularly valuable to infer potential effects on relevant species and a recent analysis has been conducted on all data between 1994 and 2010 (Stone 2015). Among baleen whales, minke and fin whales were the only two species with sufficient observations for statistical analyses. Significant differences were measured on surveys with 'large' seismic arrays (i.e. 500 or more cubic inches) when periods of air-gun firing were compared to non-firing; when firing, minke whales were detected less but behaviourally, they were more often recorded avoiding vessels (e.g. travelling away), swimming 'fast' and surfacing frequently. Also fin whales were recorded avoiding vessels more often during firing periods.

The effects of seismic surveys on odontocetes and pinnipeds have been less thoroughly investigated but recent studies are addressing the gap, with several relevant to species in the UKCS. In the Moray Firth, plans for 2D seismic surveys instigated a large research effort funded by industry and regulators, to improve baseline data and provide evidence for the assessment of potential effects on bottlenose dolphins and harbour porpoises (Thompson *et al.* 2013a). The 2D seismic survey took place over 10 days (in September 2011) exposing a 200km^2 area with regular noise throughout that period; source levels were estimated to be peak-to-peak source levels 242–253 dB re 1 μPa at 1m and received levels within 5-10km from the source were estimated to be received peak-to-peak SPLs varied from 165 to 172 dB re 1 μPa, whereas SELs for a single pulse were 145–151 dB re 1 $\mu Pa^2 s$, and rms. levels were 148–155 dB re 1 μPa.

Changes in the behaviour of harbour porpoises were measured (Thompson *et al.* 2013a). Observed waiting times derived from passive acoustic monitoring increased following the start of the survey; this effect diminished with distance from source and with time (suggesting some degree of habituation) but it was short-lived as porpoises returned to impacted areas within 19h. Detection rates from digital aerial surveys showed a decrease during the survey period within 10km of the vessel and an increase at greater distance; this supports the assumption that changes in acoustic detections corresponded to changes in abundance. Further analyses of acoustic recordings (occurrence and type of inter-click intervals or ICIs) provided more evidence regarding sub-lethal effects, such as possible disruption of social or foraging activities (Pirotta *et al.* 2015); porpoises remaining in the impact area reduced their buzzing activity by 15% during the seismic survey and the probability of detecting buzz ICIs increased with distance from the source vessel. In addition, Thompson *et al.* 2013 explored the potential for broad-scale displacement by comparing control and impact sites between 2010 and 2011 (BACI design); statistically, a significant effect was identified but the effect size was small and entirely within seasonal and inter-annual variability. The authors concluded that while short-term disturbance was induced, this seismic survey did not lead to long-term or broad-scale displacement.

Bottlenose dolphins are more commonly observed in the inner Moray Firth and along the southern Moray Firth coast and occurred only rarely in the impact area, creating a challenge for analyses. Passive acoustic monitoring provided evidence of short-term behavioural responses in the part of their range closest to the seismic survey. The occurrence of dolphins at PAM sites in the southern Moray Firth increased during the survey, most likely the result of animals being displaced inshore, away from the survey vessel (Thompson *et al.* 2013b). However, there was no evidence for an overall reduction in dolphin occurrence and photo-identification estimates of the number of dolphins using the SAC remained similar throughout the period 2009-2012.

Common dolphins off the coast of Wales were monitored acoustically during a three month period before, during and after a 2D seismic survey; results from this study suggested localised avoidance but overall tolerance to the sound exposure outside a 1km radius of the guns (Goold 1996).

The analyses by Stone (2015) on MMO data, provides evidence of effects of airgun firing also on odontocetes and pinnipeds. The species which demonstrated a degree of avoidance during firing of ‘large arrays’ were long-finned pilot whale, killer whale, harbour porpoise, white-beaked dolphin, Atlantic white-sided dolphin, bottlenose dolphin and grey seals; metrics used to compare avoidance between period of firing and non-firing were sighting rates, distance of approach and changes in direction or vessel avoidance. Changes in swimming behaviour (i.e. increased swimming speed) were also detected in bottlenose dolphins, white-beaked dolphins and short-beaked common dolphins.

Beaked whales were also included in the analysis, although sample sizes were low and all species of beaked whale had to be combined; detection rates of beaked whales were significantly lower when ‘large arrays’ were active. Beaked whales, for which so little information is available, are a particular concern because of the high sensitivity they display to another anthropogenic underwater source, military sonar (de Soto *et al*. 2016). Although no causal link has yet been established between seismic surveys and strandings (of beaked whales or other species), the possibility has been raised (Castellote & Llorens, 2016).

Controlled experimental studies have also been conducted to establish dose-response functions or at least thresholds with respect to auditory damage from airguns. Some studies have exposed captive odontocetes to airgun impulses and measured the effect on auditory thresholds. TTS was induced in a harbour porpoise after exposure to single impulses by Lucke *et al.* (2009); the onset of TTS was estimated at SEL = 162 dB re 1 lPa2 s and peak SPL = 196 dB re 1 lPa. Exposure to single pulses resulted in significant TTS also in a beluga whale (Finneran *et al.* 2002), while a study on bottlenose dolphins exposed to a sequence of 10 pulses showed a much more limited response, even though maximum cumulative SELs were higher (193-195 193 to 195 dB re 1 lPa2 s) (Finneran *et al.* 2015).

Potential effects from exploratory sound sources other than airguns have received limited attention. DiIorio and Clark (2010) reported on a study to investigate vocal behavioural response of blue whales to a low-energy sparker source during a seismic reflection survey; increased call production was detected on days with sparkers in operation even though exposure was relatively low and estimated at , 131 dB re 1 µPa (peak to peak) (30–500 Hz) with a mean sound exposure level of 114 dB re 1 $\mu Pa^2 s$.

A high-powered 12Hz multi-beam echosounder system (MBES) has been implicated as the only plausible behavioural trigger of a highly unusual mass stranding of melon-headed whales that occurred in Madagascar in 2008 (Southall *et al.* 2013).

5.3.3.1.3 Oil & Gas – drilling and production

Evidence is relatively limited with regard to the effects of noise during production, but observations at installations in the North Sea have shown harbour porpoises regularly frequenting and actively foraging around platforms (Todd *et al.* 2009), implying that noise during production is either negligible or not a sufficient deterrent given the foraging opportunities provided.

There is evidence that vessel traffic may influence marine mammals in several ways, reported responses include avoidance, changes in swimming and surfacing patterns, alteration of the intensity and frequency of calls and increases in stress-related hormones (Veirs *et al.* 2016, Rolland *et al.* 2012, Dyndo *et al.* 2015). In UK waters, results of a modelling study indicated a negative relationship between the number of ships and the distribution of harbour porpoises in the Celtic/Irish Sea and the North Sea (Heinänen & Skov, 2015).

5.3.3.1.4 Wave and tidal power

Potential biological effects of noise produced by the SeaGen 1.2MW tidal energy convertor in Strangford Lough were initially assessed by SMRU (2010). Monitoring for effects included shore based surveys, passive acoustic monitoring (using TPODs) of harbour porpoises, harbour seal tracking by telemetry (for more details see also Royal Haskoning 2011). During the short installation of the turbine (drilling), a large and rapid decline in acoustic activity was observed at short-range (i.e. within the Narrows but not in the inner Lough). This was short-lived and levels of activity recovered immediately after installation; it is unclear if the cause was the noise during drilling or the increased vessel activity.

SMRU (2010) used underwater sound propagation models to predict potential exposure of animals at increasing distance from SeaGen; these were combined with information on marine mammal hearing abilities and likely behavioural responses to predict potential effects as a series of influence zones (audibility, behavioural response). During strong tidal flow when ambient noise and turbine activity are highest, noise from SeaGen was predicted to be audible to marine mammals up to 1.5km. Two models were developed to evaluate the potential behavioural effects of the different components of the operational noise (tonal peaks and broadband) on marine mammals; together these results suggested that behavioural responses would most likely occur within a zone between 77m and 610m from SeaGen but could potentially extend up to several kilometres. These predictions must be viewed in the context of the actual observed behaviour of marine mammals around the turbine. Land-based observations, telemetry derived data on seal movements and TPOD detections of harbour porpoise echolocation all indicated that seals and porpoises continued to frequent the Narrows and the inner Lough throughout the operational phase within the distances within which they were predicted to display behavioural avoidance responses (Savidge *et al.* 2014). The use of harbour seal haul-out sites was not affected by SeaGen, nor was there any evidence to suggest a barrier effect or a significant displacement of seals and porpoises. The only changes detected in any of the metrics monitored were of a small magnitude relative to the natural variation explained by tidal cycle, time of day and season. Overall the observations are suggestive of small-scale local redistribution (250m) in relation to the SeaGen presence and operation with the likelihood of little ecological significance (Savidge *et al.* 2014).

Conclusions with regard to the likely impact of operational noise from wave and tidal stream developments were drawn by Robinson & Lepper (2013) and by Copping *et al.* (2013). The risk of injury to marine mammals is highly unlikely from operational noise even in close proximity to the device. Behavioural responses may be induced but significant behavioural effects are also unlikely at long-ranges from the development site.

Among the gaps in knowledge identified, Robinson & Lepper (2013) stressed the importance of improving understanding of the potential influence of changes in radiated noise relative to background noise on the risk of impact; the relative signal-to-noise ratio will influence perception capability, on one hand minimising behavioural responses but on the other potentially increasing the risk of collision with the devices. Finally, because current understanding is limited to experience with single devices or small arrays, there is still high uncertainty with respect to effects of large scale arrays.

Efforts are on-going to improve knowledge base; for example, at the four test sites of the European Marine Energy Centre Ltd (EMEC) in the Orkney Islands the potential for displacement effects by wave and tidal stream devices is being monitored and results are expected to be reported upon shortly (http://www.gov.scot/Topics/marine/science/MSInteractive/Themes/EMEC-Wildlife).

5.3.3.2 Fish

Fish exhibit large variation in their ability to emit and detect sound, largely dependent on great diversity in anatomical features, hearing physiology and behaviour. The otolithic organs of all fishes respond to particle motion but in addition some fish have adaptations that make them sensitive also to sound pressure; these are gas-filled structures near the ear or connected to it and extensions of the swim bladder able to functionally influence the ear. It follows that understanding the effects of sound on fish requires measurements of particle motion and not only pressure; however, technology to make measurements of particle motion is still in development and while some devices are available, field measurements are very limited (Hawkins *et al.* 2015, Cefas 2015).

Hearing sensitivity is expressed using audiograms as the lowest level (either as particle acceleration or sound pressure) detected as a function of frequency. Species sensitive to both particle motion and pressure show an increased hearing sensitivity and wider hearing bandwidth than species which rely exclusively on particle motion but overall, variability among species is high and difficult to predict from anatomical knowledge alone. Most species are sensitive to sound from below 50Hz to 500Hz, with most pressure-sensitive species detecting up to 2kHz but a few exceptions have been identified with some species of herring-like fishes capable of detecting sounds above 20kHz. However, the number of species for which accurate data are available is still small and measuring the hearing abilities for a wider range of species has been recommended as high research priority (Hawkins *et al.* 2015).

The susceptibility of fish to barotrauma (i.e. physiological trauma in response to sudden change in pressure) is also much greater in species with a swim bladder and other gas chambers.

A metric for the assessment of auditory and behavioural effects of underwater sound was first developed by Nedwell *et al.* (2007) together with relevant criteria. The aim of this work was to provide industry and regulators in the UK with an objective quantitative metric that would be simple to apply in practice, while accounting for the intrinsic complexity of the effects of different types of sounds across a range of species with widely different hearing abilities.

The metric proposed was dB_{ht} and corresponds to the amount of sound received above the hearing threshold; it is analogous to the dB(A) scale commonly used in human noise tests. It is not an absolute sound level unit, rather a 'prediction of the perceived loudness of the sound to the animal'. Since hearing threshold varies with frequency, dB_{ht} is calculated as an integral over frequency using a species-specific frequency dependent weighting obtained from good quality audiograms. Since different species have different hearing abilities, a given sound will have a different level on this scale for each species, hence the need to append the species name to the level e.g. dB_{ht}(*Species*). Validation of the metric and criteria combined evidence from three different sources; a re-evaluation of existing data from acoustic fish deflection systems, a set of laboratory reaction experiments to identify the onset of avoidance responses and re-interpretation of relevant literature including observations in the field during seismic surveys and studies on the onset of permanent threshold shift. On the basis of the information reviewed, criteria were suggested relative to specific effects (Table 5.5).

Table 5.5: Criteria developed by Nedwell *et al.* (2007)

Level in dB_{ht}(*Species*)	Effect
< 0	None
0-50	Mild reaction in minority of individuals, probably not sustained
50-90	Stronger reaction by majority of individuals, but habituation may limit effect
90 and above	Strong avoidance reaction by virtually all individuals
Above 110	Tolerance limit of sound; unbearably loud
Above 130	Possibility of traumatic hearing damage from single event

Several limitations with this approach have constraint its broad application in noise risk assessments; Nedwell *et al.* 2007 used audiograms expressed only in terms of sound pressure so that validation with respect to particle motion is lacking; at present the quality of audiograms for many species is not satisfactory for calculation of dB_{ht}(*Species*) levels; reliance on audiograms may be appropriate for behavioural effects but should be considered with caution in respect to injury as also inaudible sounds can cause damage to tissues.

More recent efforts to establish broadly applicable sound exposure criteria for fishes along the lines of those by Southall *et al.*, (2007) for marine mammals have resulted in publication of guidance by Popper *et al.* (2014). Fish were classified depending as:

- Fishes without a swim bladder or other gas chamber (particle motion detection), e.g. elasmobranchs (sharks, skates and rays), jawless fishes, some flatfish, some gobies, some tuna and other pelagic and deep-sea species

- Fishes where swim bladder is present but not involved in hearing (particle motion detection and barotrauma), e.g. Atlantic salmon
- Fishes where swim bladder or other gas chamber is present and involved in hearing (particle motion detection, sound pressure detection and barotrauma), e.g. Atlantic cod, herring and relatives.
- Fish eggs and larvae

Sound from explosions, pile driving, seismic airguns, sonar and continuous sources were considered in turn. Potential effects were divided into: mortality and mortal injury, impairment effect (including recoverable injuries, TTS and masking) and behavioural effects (interpreted as substantial change in behaviour for a large portion of animals exposed). Exposure levels for the onset of any given effect are given either quantitatively (expressed in appropriate metrics) or qualitatively as a relative likelihood of effect occurring. These sound exposure guidelines should be treated as interim values and refined with the results from new research, which is strongly recommended (Popper *et al.* 2014). Guidelines for pile-driving are the more conservative ones and reported in Table 5.6 for reference.

Table 5.6: Sound exposure guidelines for pile-driving

Type of animal	Mortality and potential mortal injury	Recoverable injury	TTS	Masking	Behaviour
Fish: no swim bladder	>219 dB SELcum or >213 dB peak	>219 dB SELcum or >213 dB peak	>>186 dB SELcum	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: swim bladder not involved in hearing	210 dB SELcum or >207 dB peak	203 dB SELcum or >207 dB peak	>186 dB SELcum	(N) Moderate (I) Low (F) Low	((N) High (I) Moderate (F) Low
Fish: swim bladder involved in hearing	207 dB SELcum or >207 dB peak	203 dB SELcum or >207 dB peak	186 dB SELcum	(N) High (I) High (F) Moderate	(N) High (I) High (F) Moderate
Eggs and larvae	>210 dB SELcum or >207 dB peak	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low

Notes: peak sound pressure levels dB re 1 µPa; SEL dB re 1 $\mu Pa^2 s$. All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist. Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I) and far (F).
Source: Popper et al. (2014).

It is well established that underwater explosions can injure and kill fish; 'dynamite fishing' is practised (albeit illegally) in many parts of the world (McManus 1997) and several studies have reported on the effects (see Popper *et al.* 2014 and references therein). Models for predicting lethal impacts are considered to be robust for large juvenile and adult fish and are being further developed for larvae and young juveniles; evidence suggests larvae and juveniles are more vulnerable (Govoni *et al.* 2008).

Several studies have explored the effect of pile-driving on adult fish and demonstrated the potential for lethal injury on several species including Chinook salmon, (*Oncorhyncus tshawytscha*); these were reviewed by Popper *et al.* (2014) and used to set the guidelines discussed above. The extent of injury has been shown to increase with sound exposure level and duration (e.g. Halvorsen *et al.* 2012) but the lowest level found to induce injury (207 dB SEL cum) is relatively high and likely to be experienced only within a limited range of the source (<100m). Lethal effects on larvae have been examined by Bolle *et al.* (2012) in the common sole (*Solea solea*); sole larvae at different developmental stages were exposed to various levels and durations of exposure but no significant difference in mortality was observed between treatment and control groups. The highest cumulative sound exposure level applied was 206 dB re 1µPa^{2}s corresponding to 100 strikes at 100m from a typical North Sea pile-driving site.

Behavioural responses to pile-driving operations have been investigated as part of a COWRIE study (Mueller-Blenkle *et al.* 2010). Pile-driving noise was played back to cod and sole held in two large pens located in a quiet bay on the west coast of Scotland, with received SPL and particle motion measurements taken and the movements of fish analysed using a novel acoustic tracking system. There was a significant movement response to the pile-driving stimulus in both cod and sole at relatively low received SPL (sole: 144-156dB re 1µPa peak; cod: 140-161dB re 1 µPa peak, particle motion between 6.51x10-3 and 8.62x10-4ms^{-2}). Sole showed a significant increase in swimming speed during the playback period compared to before and after playback. Cod exhibited a similar reaction, yet results were not significant, although cod did show a significant freezing response at onset and cessation of playback. There were indications of directional movements away from the sound source in both species. Some observations suggested a level of habituation to the noise source but overall high variability across individuals was observed. Mueller-Blenkle *et al.* (2010) describe that their results further imply a relatively large zone of behavioural response to pile-driving sounds in marine fish, although note that it is difficult to explain the nature and biological significance of these responses. Many responses observed suggest avoidance reactions, although it was noted that in a wild marine environment a wider demographic of animals will be present, and there will be other ecological drivers (e.g. food, reproduction) at play, both of which will influence the nature of reactions.

Studies investigating fish mortality and organ damage from noise generated during seismic surveys are very limited and results are highly variable (Popper *et al.* 2014). One study showed long-term damage to the epithelial cells of the pink snapper (*Pagrus aurata*), (McCauley *et al.* 2003) while a similar experiment conducted in several species of riverine fish by Popper *et al.* (2005) found that the limited hearing loss incurred had recovered with 24 hours, with no apparent damage to hair cells. Popper *et al.* 2016 found no mortality or tissue damage in response to single airgun shot exposure even at high level (SPL 231 dB re 1µPa or SEL single shot of 205 dB re 1µPa^{2}s). On the other hand, behavioural responses and effects on fishing success ("catchability") have been reported following seismic surveys (Pearson *et al.* 1992, Skalski *et al.* 1992, Engås *et al.* 1996, Wardle *et al.* 2001). 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".

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. Guidance on sensitive periods for fish spawning is available to developers, and may be incorporated into licence conditions, including prohibitions of some activities in certain months.

Less intense sounds that are of longer duration and potentially affect much larger areas need also considering. 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 (Fujii 2015) and other production platforms (MMS 2004). Similarly, it has been suggested that wind farms and other renewable energy installations can act as artificial reefs once in operation (Inger *et al.* 2009). In addition to studies on masking, several recent experimental studies are improving the evidence base with regard to effects induced by low-level increases of ambient noise, such as from increased vessel traffic; changes to the behaviour of adults including effects on startle response, anti-predator response, ventilation rate and swimming speed, as well as changes to the behaviour, growth and development of larvae have been documented (Neo *et al.* 2014, Nedelec *et al.*, 2015, Bruintjes *et al.* 2016). Nonetheless it is still difficult to interpret many of these results, extrapolate to natural situations and place them within the context of potential population effects.

Potential effect on migratory species of conservation importance is also an area of significant interest for which empirical evidence is still needed (Gill & Bartlett 2010). Swim bladder in salmonids and eels is not involved in hearing (particle motion sensitive). Laboratory experiments carried out by Simpson *et al.* (2015) found that predator avoidance by juvenile European eels migrating to the continent from the Sargasso Sea was significantly impaired by the noise of vessel traffic in harbours. The migration route of older eels back to spawning grounds does not appear to be affected by noise generated by offshore wind farms in the southern Baltic Sea (Andersson *et al.* 2012). Gaps in knowledge with respect to Atlantic salmon are the focus of current research as part of Marine Scotland Science National Research and Monitoring Strategy for Diadromous Fish[56].

5.3.3.3 Other receptors

Aquatic birds are exposed to a variety of man-made noise sources, depending on their habitat. Offshore foraging species are those more likely to be exposed to noise from offshore energy development and shipping while inshore species may be exposed more often to recreational boating, coastal construction and even traffic noise if close to highly populated areas (Crowell *et al.* 2015). Increased ambient (in air) noise levels on birds have been linked to a variety of effects including masking communication signals, spatial avoidance, decrease reproductive success and increase physiological stress and the hearing sensitivity of a species is thought to determine the magnitude of the effect (Crowell *et al.* 2015). Physical damage from high amplitude underwater noise, specifically during impact piling or seismic surveys, is theoretically possible, especially for diving birds but evidence is limited. Hearing sensitivity for species measured so far peaks between 1 and 3kHz, with a steep roll-off after 4kHz (Crowell *et al.* 2015). However, direct observations during extensive seismic and piling operations in the North Sea and elsewhere have not reported mortality. 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 thickbilled murre (Brünnich's guillemot). 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. It is therefore considered unlikely that offshore impulsive noise will result in significant injury or behavioural disturbance to seabirds.

Interest in assessing the potential effects of anthropogenic sounds on marine turtles has recently come to the fore (Popper *et al.* 2014). Nonetheless, available information is very

[56] http://www.gov.scot/Topics/marine/marineenergy/Research/NatStrat/Theme1

limited. A recent systematic review identified 29 references that provided information on marine turtles and their response to sound in comparison to 414 for marine mammals and 187 for fish (Nelms *et al.* 2016). Behavioural and auditory evoked potential studies have indicated the hearing range of cheloniid species is between 50-2000 Hz, with highest sensitivity below 400 Hz (Ridgway *et al.* 1969, Martin *et al.* 2012, Lavender *et al.* 2012, all in Popper *et al.* 2014). Morphologically, sea turtles have a typical reptilian ear with few underwater modifications and they are able to detect sound pressure (see in Popper *et al.* 2014). Injury and death of turtles has been linked to the use of explosives, avoidance behaviour has been elicited by airgun exposures in experimental conditions but evidence is lacking during seismic surveys observations and no data on the effects of pile driving or sonar have yet been obtained (Popper *et al.* 2014). Concern of the potential impact of seismic surveys to turtle populations is not limited to the effect of sound but to entanglement in equipment during both towed or seabed deployed operations (Weir, 2007). In summary, there is potential for anthropogenic sounds to affect marine turtles but the extent to which this may result in impact still remains to be clarified. 'Interim' sound exposure guidelines have been published (Popper *et al.* 2014). Where turtle encounters are common (i.e. not the UK), time-area closures designed to avoid critical habitats at times of aggregations have been favoured as mitigation measures while those based on direct observations (e.g. shut-down of operations if turtle is encountered) are thought to be ineffective due to difficulty in turtle detection (Nelms *et al.* 2016).

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 but data are very limited. Cephalopods, with a well developed nervous system and complex behavioural responses, are a possible exception. Their primary sound detection organs are the statocysts (balance organs), although peripheral hair cells may also play a role in detecting local water movements. Cephalopods appear to detect the acceleration and particle motion component of the sound field, rather than pressure and are most sensitivity to low frequency (<400 Hz) sounds; thus their hearing ability has been described as comparable to those of elasmobranch and teleost fish that lack auditory specialisations. Hu *et al.* (2009) suggested that the octopus *Octopus vulgaris* and the squid *Sepia lessoniana* may detect sounds at higher frequencies (400-1000Hz and 400-1500Hz respectively) but a recent study by Mooney *et al.* (2010) challenged that result, suggesting it might have been an artefact of the experimental procedure. Mooney *et al.* (2010) carried out a carefully controlled experiment to quantify the acoustic sensitivity of the longfin squid *Loligo pealeii* using auditory evoked potentials (AEPs); the responses to near-filed acoustic as well as shaker-generated stimuli were found to be limited within 30 - 500 Hz with highest sensitivity between 100 and 200 Hz. Of relevance to impact assessment, controlled exposure experiments have demonstrated that statocysts of several species can be damaged after exposure to low-frequency sound (Andre' *et al.* 2011; Solé *et al.* 2013a, b). Specific thresholds could not be extrapolated during these studies because of tank effects and lack of particle motion measurement. A link between seismic surveys and increased reports of stranded giant squids in Spain has been suggested (Guerra *et al.* 2004), while experimentally Fewtrell & McCauley (2012) showed that exposure to noise from a single airgun could elicit alarm responses of squid with increasing occurrence as noise levels increased. Behavioural responses of cuttlefish (*Sepia officinalis*) to pure-tone pips within a range of sound pressure levels and particle accelerations have been studied by Samson *et al.* (2015). Responses observed included escape (inking and jetting), changes in body patterns and fin movements; type and intensity of response was dependent on stimulus amplitude and frequency (e.g. inking observed only between frequencies of 80 and 300 Hz and at sound levels above 140 dB and 0.74 ms^{-2}).

For all other invertebrate taxa, studies are too few to reach conclusions even though several examples of effects have been obtained (Hawkins *et al.* 2015). For example, recent laboratory experiments on scallop larvae have shown that noise exposure to playbacks of seismic sounds can cause developmental delays and body malformations (Aguilar de Soto *et al.* 2013), while oxidative stress was reported in the mussel *Mytilus galloprovincialis* after prolonged noise exposure (Dinu *et al.* 2012). To sedentary invertebrates, seabed vibrations created during anthropogenic activities such as piling and seismic surveys may also induce a response. For example, the bivalve *Mytilus edulis* has been shown to respond to substrate-borne vibrations by partially or fully closure of their valve; depending on duration this may have consequences for their fitness (Roberts *et al.* 2015). In a similar experiment, the hermit crab *Pagurus bernhardus* was also found to respond behaviourally to substrate-borne vibrations (Roberts *et al.* 2015b). From these studies however, extrapolations of effects in the wild are limited by the challenges of reproducing, controlling and measuring exposure level in small tanks, especially with respect to particle motion.

5.3.4 Controls and mitigation

Both planning and operational controls are currently in place to cover all significant noise generating activities on the UKCS, specifically including geophysical surveying and pile-driving.

The main focus is to ensure compliance with the Habitats Directive. 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* (amended in 2009 and 2010, the Offshore Marine Regulations, OMR) outside territorial waters – all state that it is an offence to deliberately injure or disturb wild animals of any species listed on Annex IVa of the Habitats Directive (which includes all cetaceans), particularly where disturbance is likely to impair breeding, rearing, hibernation and migration or to affect significantly the local distribution or abundance of the species to which they belong. In addition, any proposed activity with a potentially significant acoustic impact on a designated SAC or SPA would also be subject to the requirement for Habitat Regulation Assessment (HRA) under the above Regulations.

To help avoid or minimise the risk by activities in the marine environment to kill, injure or disturb cetaceans guidance has been prepared by JNCC, Natural England and Countryside Council for Wales (2010), for the marine area in England and Wales and the UK offshore marine area and by Marine Scotland (2014) for Scottish inshore waters. The guidance is based on a risk assessment approach, assessing the likelihood of a statutory offence, and then whether a licence to undertake the proposed activity should be sought. The likelihood of an activity resulting in injury or disturbance to a marine European Protected Species (EPS) will very much depend on the characteristics of the activity, of the environment and the species concerned, hence the need for a case-by-case approach when assessing the risk of it occurring.

The guidelines suggest that activities with the potential to deliberately injure or kill a marine EPS in areas can be long or short-lived, and include explosive use, seismic surveys, navigation by high speed vessels, and pile-driving. However, if mitigation measures are appropriate and effectively implemented, the risk could be reduced to negligible levels. In this respect, recommendations regarding mitigation measures for specific activities have been published and are available from the JNCC website on offshore industry advice (http://jncc.defra.gov.uk/page-4273); these are:

- JNCC guidelines for minimizing the risk of injury and disturbance to marine mammals from seismic surveys
- Statutory nature conservation agency protocol for minimizing the risk of injury to marine mammals from piling noise

- JNCC guidelines for minimising the risk of injury to marine mammals from using explosives.

The EPS guidelines also suggest that for most cetacean populations in UK waters, disturbance, in terms of the HR or OMR, is unlikely to result from single, short-term operations, e.g. a seismic vessel operating in an area for 4-6 weeks, or the driving of a dozen small diameter piles. Such activities would most likely result in temporary disturbance of some individuals, which on its own would not be likely to result in significant effects on the local abundance or distribution. Non-trivial disturbance, which would constitute an offence under the Regulations, would most likely result from more prevalent activities in an area, chronically exposing the same animals to disturbance or displacing animals from large areas for long periods of time. These considerations are assessed in the context of this SEA in Section 5.3.5 below.

All seismic surveys (including Vertical Seismic Profiling and high-resolution site surveys), sub-bottom profile surveys and shallow drilling activities carried out by the offshore oil and gas industry (including storage of gas and carbon dioxide) require an application for consent and cannot proceed without it. These applications are supported by an EIA, which includes a noise assessment. Applications are made through DECC's Portal Environmental Tracking System (PETS) using a standalone Master Application Template (MAT) and Geological Survey Subsidiary Application Template (SAT). DECC circulates each application to the relevant statutory consultees for advice and a decision on whether to grant consent is only made after careful consideration of their comments. Statutory consultees may request additional information or risk assessment, specific additional conditions to be attached to consent (such as specify timing or other specific mitigation measures), or advise against consent. It is a condition of consents issued under Regulation 4 of the *Petroleum Activities (Conservation of Habitats) Regulations 2001* (& 2007 Amendments) for oil and gas related seismic and sub-bottom profile surveys that the JNCC Seismic Guidelines are followed and the elements of the guidelines that are relevant to a particular survey are incorporated into the legally-binding condition of consent.

Geophysical surveys carried out for renewable energy developments in Scotland will also need consent through the EPS licensing regime but in other parts of the UK, although a stage 1 risk assessment is required, a voluntary notification of intent to carry out the survey made to the Marine Management Organisation (MMO) will be sufficient, if the proposal does not carry a risk of disturbance or injury to any EPS. In practice, relevant JNCC mitigation guidelines are followed.

The mitigation measures recommended by JNCC and the SNCBs above represent best practice in the UKCS, primarily relevant to the prevention of injury (JNCC 2010). At the detail level there are important differences between mitigation measures (type and duration) to be applied during seismic surveys as opposed to impact piling or when using explosives; however, there are important commonalities too as the approach adopted is the same in all cases, mainly:

- The importance of the planning stage is emphasised; choice of location and timing (daily/seasonal) can be key to minimise risk, especially with respect to migration, breeding, calving or pupping. Moreover, an effort should always be made to minimise the amount of noise generated from any activity to the minimum level necessary to achieve the required outcome.
- During the operational stage, the main mitigation measure recommended is to monitor for the presence of marine mammals before the start of operations and only allow operations to commence if animals are not present. The duration of the pre-search and the size of the 'mitigation zone' depend on the activity and on its location. Different

requirements are recommended with respect of the number of marine mammal observers (MMOs), their degree of expertise and additional use of passive acoustic monitoring systems (PAM) to complement visual observers.

- The second key mitigation measure is to induce an avoidance response by animals, using a sound deterrent that is less acoustically injurious than the noise produced by the activity itself. The main measure recommended to achieve this is a so called 'soft-start' i.e. when the energy used for airguns and hammering piles or indeed the charge size for detonations is incrementally increased over a limited time period, just long enough to give time to animals to move away. In some cases, especially with explosives and potentially piling, the use of acoustic deterrent devices may also be recommended.
- Reports detailing the marine mammal mitigation activities as they happen must be prepared by the MMOs and sent to JNCC. These are regularly analysed and help inform on the effectiveness of the guidelines in practice and support revisions based on evidence (Stone 2003, Stone & Tasker 2005, Stone 2015a and Stone 2015b).

The JNCC guidelines for minimising acoustic impacts from seismic surveys, first used in 1995 on a voluntary basis, were the first of their kind; as other countries have developed their own recommendations over time, the JNCC approach has been praised in many respects, but in comparison to some others it is perceived as incurring the least disruption to a survey (Weir & Dolman 2007) and has received some criticism (Weir & Dolman, 2007, Parsons *et al.* 2009, Wright & Cosentino 2015). The main points of concern raised are:

- the over-reliance on 'soft-start' procedure to ensure animals have moved away from the source, especially since MMOs and PAM are not always effective (e.g. at night, during low visibility, higher sea state or for species that don't vocalise regularly or can't be easily recognised). Critics argue the basis for the 'soft-start' procedure is theoretical and its effectiveness remains untested, while at the same time it introduces additional noise.
- the lack of shut-down of operations if a marine mammal is observed entering the 'mitigation zone' once the seismic survey is underway (as recommended in several countries).
- The focus on mitigating against risk of injury rather than disturbance.
- The 'soft' approach used in the guidelines; recommendations are made about what to take into consideration rather than mandatory, prescriptive requirements to be followed.
- The lack of incentive to ensure enforcement.

With respect to the first point, the latest analyses of marine mammal observations during seismic surveys (Stone 2015a) found detection rates of cetaceans to be significantly lower during soft-start than when the airguns were not firing. While it has to be recognised that the soft-start may not be effective in all cases (e.g. occasional instances of white-beaked dolphins bow-riding have been recorded during the soft-start, Stone & Tasker 2006), these results provide some evidence that the soft start may indeed be a useful mitigation measure for some species. The importance of accurate MMOs reporting to gather evidence should be emphasised.

A modelling study has been carried out (Hannay *et al*. 2011) to assess whether soft-start during a large airgun array operation might result in hearing damage to marine mammals. Sound exposure was compared to injury thresholds published by Southall *et al.* (2007); no instances were found in which injury threshold levels for cetaceans were reached during the initial stages of the soft-start sequence, but that for pinnipeds was approached in the worst case model. If the lower injury threshold recently proposed for harbour porpoises was to be applied (see Section 5.3.3.1), this may also be approached.

Results published in Stone (2015b) indicate that pre-shooting searches can be effective; since the introduction of the guidance, firing was delayed in 165 cases because marine mammals were found within the 'mitigation zone' during the pre-search, corresponding to 0.5% occasions where airguns were used. The increased use of PAM has been linked to a slight increase in the observed number of delays over the last 5 years of analyses (20015-2010).

To reduce noise generation from pile-driving, several technical mitigation measures can be successfully applied during piling and alternatively, low-noise foundations can be chosen instead of those based on impact-piling. In the German EEZ, a mandatory noise limit has been set (dual threshold level of 160dB single event sound pressure level, SEL / 190 dB (peak-to-peak) at 750m from the source) which, in the case of commonly used pile foundations, can only be met by applying technical mitigation measures. The industry has responded with great efforts in developing new technologies and Ludemann & Koschinki (2013) collated examples of several mitigation measures and compared noise reduction potential and development status; these included bubble curtains, isolation casings, cofferdams and hydro sound dampers. Alternative foundation types were also reviewed such as the use of vibratory pile driving, foundation drilling, gravity base foundations, bucket foundations and floating turbines (i.e. tethered turbine technology). Mitigation measures that can reduce sound up to 40dB have been described, such as the use of stationary encapsulated gas bubbles (Lee *et al.* 2012). Further technological development is on-going but until a system has been routinely applied, it is difficult to predict with certainty the time required for its installation and how it may therefore effect operations layout and work schedule. This information is necessary to compare and evaluate options at the project level with respect to cumulative ecosystem impacts.

To reduce potential impacts from seismic surveys, technological developments are focusing on options either to improve the current efficacy of airguns (e.g. optimisation of airgun design, attenuation of unwanted high frequencies) or to develop alternative sound sources such as marine vibroseis (OSPAR 2009, LGL & MAI, 2011).

To support the MSFD goal of reaching Good Environmental Status in terms of noise pollution, OSPAR has been tasked to develop, review and support the application of mitigation measures (OSPAR 2010). An OSPAR inventory of measures to mitigate the emission and environmental impact of underwater noise has been published; the focus so far has been on pile-driving but other activities including seismic surveys, explosions, high frequency impulsive sources, dredging, sonar and shipping are also being planned (OSPAR 2014).

5.3.5 Likelihood of significant effects

The following section considers the potential for significant effect, and potential for mitigation, under the following rationale:

- Definition of possible spatial effects ranges for injury and disturbance; based on synthesis of source level characterisation, propagation characteristics, effects criteria, and animal response observations discussed above
- Review of frameworks for assessment of long-term population effects

- Consideration of potential activity levels and specific sensitivities of individual Regional Seas
- Identification of specific geographical areas of concern
- Consideration of operational mitigation and potential for seasonal restrictions
- Consideration of potential cumulative effects

From the evidence described above, the following salient points have been identified.

It is appropriate to focus on marine mammals and in particular on the harbour porpoise in this SEA as they are appear to be more sensitive to sound than other receptors. Therefore if sufficient protection is offered to the harbour porpoise, it is assumed this would be sufficient for the marine environment as a whole.

Chronic exposure to increased levels of underwater noise has the potential to have long-term consequences for the health of marine species, as well as the potential to mask important biological signals but at present the evidence is insufficient to be able to set targets to ambient noise. The process established through MSFD, including noise indicators and noise registry, will help to improve our understanding.

Acute non-auditory physical damage, leading to death, is limited to the immediate vicinity (<10m) of impulsive, high amplitude sounds. Cetacean strandings may be the exception; a behavioural response (e.g. panic) to certain sounds may be the cause of abrupt change in diving behaviour, which in turn may result in decompression sickness and/or spatial disorientation leading in some instances to mass strandings. Beaked whales appear to be particularly at risk.

Southall *et al.* (2007) thresholds for injury (and the subsequent update for harbour porpoises in Lepper *et al.* (2014) based on the work of Lucke *et al.* (2009)) should be applied to estimate the onset of the risk of auditory damage. This estimate is recognised as highly conservative; efforts to incorporate new information into improved thresholds should continue at the international level with the aim to increase their accuracy and applicability. Thresholds for harbour porpoise (high-frequency cetacean) are the lowest; an assessment based on this species will therefore be precautionary for all other species.

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 in particular with seismic surveys, impact pile-driving and use of explosives. Injury thresholds are likely to be exceeded only within a limited range from source. While in many instances the range will be <500m, this may not be necessarily true for all large 2D/3D seismic surveys, especially with respect to SEL_{cum} for high-frequency cetaceans.

Current mitigation measures as described in JNCC guidelines could be sufficient in minimising the risk of injury whenever carefully applied by industry for all regular marine mammal species that are common on the continental shelf. For deep-diving species and in particular for beaked whales (long dive duration, commonly silent, high risk of mass strandings) reliance on visual observers and PAM over a pre-search period is unlikely to be sufficient (even if extended to 60mins); it follows that risk from injury is still a possibility in these species. In particular with regard to beaked whales (in regions 9,10,11) further mitigation measures should be introduced to minimise any risk of behaviourally-mediated damage.

Establishing meaningful received sound levels to estimate the onset of disturbance has proved much more difficult, mainly due to the challenges with observing and measuring behavioural responses and due to the inherent variability of the behavioural context. Field observations during industrial activities are fundamental sources of information for assessment; however, such studies face many challenges and the statistical power associated with the analyses may be limited.

With respect to the effects of pile-driving, there is sufficient evidence to conclude that harbour porpoises are displaced during piling but the magnitude of the effect may vary with sound exposure levels and duration of piling. As a conservative assessment, it is reasonable to assume that piling will displace harbour porpoises up to a distance of 20km. Once piling is over, harbour porpoises can be expected to return readily (days). Evidence for other species is limited but it appears that harbour seals may be less sensitive.

With respect to the effects of seismic surveys, there is evidence for several species of cetaceans (mainly baleen whales) to suggest avoidance over distances most commonly around 2-5km from a firing vessel; changes in acoustic communication have been recorded at much greater distances (up to several hundred kilometres) but there is a lot of uncertainty with regard to the biological significance of these observations. Relative limited evidence is available for harbour porpoises or other species common in the North Sea; as a conservative assessment, it is reasonable to assume that firing of airguns during seismic surveys will affect individuals within 10km of a vessel, resulting in changes in distribution and reduction of foraging activity; the effect is short-lived.

Information on the potential effects of other geophysical surveys is currently very limited; current evidence suggests the effects are negligible but there is a high level of uncertainty around this assessment.

There is no evidence to suggest that sound from other activities, including operating wind-farms, may lead to injury or disturbance.

So far however, the focus has been on individual effects and yet the likelihood of significant effects needs ultimately to be assessed in terms of long-term population consequences. Furthermore, assessments at the population level must be able to consider the cumulative effects of several impacts likely to impinge on a population. This is a major challenge which continues to be the focus of much research effort, as reviewed below.

Modelling frameworks to assess population level impacts of harvesting and by-catch are well established (e.g. Wade 1998) but these are concerned exclusively with lethal impacts. A conceptual framework specific to acoustic disturbance, is the PCAD model (Population Consequences of Acoustic Disturbance) (NCR 2005); it proposes to evaluate how changes in behaviour caused by sound may result in population effects through clearly described steps and includes a series of transfer functions to link behavioural responses to sound with life functions, vital rates and population change. Using results from case studies, the structure of the PCAD model has been amended and its scope extended to include all possible forms of disturbance, hence it is referred to PCoD (Populations Consequences of Disturbance) and detailed by New *et al.* (2014). Although case studies have helped to estimate some parameters for some species, empirical data to inform most of the identified variables and transfer functions are currently limited or altogether missing for most species.

Using PCAD and PCoD as starting point, novel approaches have been developed to carry out assessment of acoustic impact while dealing with the current lack of data; some of these are particularly relevant to this SEA.

A transparent way of linking predicted individual impacts to vital rates was proposed by Thompson *et al.* 2013 in an effort to assess population-level impacts of proposed wind farm construction on protected harbour seals using the Dornoch Firth and Morrich More SAC, within the Moray Firth. Spatial patterns of seal distribution and received noise levels were obtained from high-quality telemetry data and noise propagation modelling; these were integrated with available data on potential impact of noise to predict how many individuals were displaced (using criteria from Nedwell *et al.* 2007) or experienced auditory injury (using injury criteria from Southall *et al.* 2007). It was assumed that any risk of direct mortality (due to high sound levels which were estimated to occur only <50m from source) could be avoided by mitigation. Expert judgement was then used to link these impacts to changes in vital rates and the rationale applied is clearly outlined; finally the results were applied to population models that compared population changes under baseline and construction scenarios over a 25 year period. At the individual level, up to 59% of the seals population could be affected by behavioural displacement and up to 15% suffer PTS. This translated at the population level, in a short-term reduction in abundance during and immediately after the construction period followed by recovery resulting in no observable difference between baseline and impact scenarios after 25 years. Conservative estimates were chosen for all individual parameters to ensure that worst-case impacts were assessed; this has led to more significant short term impacts being predicted than what would likely be expected.

New *et al.* (2013) developed a mathematical model simulating the complex social, spatial, behavioural and motivational interactions of coastal bottlenose dolphins in the Moray Firth to assess the biological significance of increased rate of behavioural disruptions caused by vessel traffic. A scenario was explored in which vessel traffic increased from 70 to 470 vessels a year in response to the construction of a proposed offshore renewables' facility. Despite the more than six fold increase in vessel traffic, the dolphins' behavioural time budget, spatial distribution, motivations and social structure remained unchanged. It was concluded that small-scale changes in behaviour should not be automatically associated with a need to limit anthropogenic activities without further investigation as to the cumulative effects of the disturbance.

Harwood *et al.* (2014) and King *et al.* (2015) developed and applied an approach termed 'interim PCoD' which also relies on expert elicitation to estimate parameters that transfer changes in individual behaviour and physiology to vital rates. Results are then incorporated into a stochastic population model to forecast the potential effects of disturbance on population size and structure. In particular expert elicitation helps to parametrise a statistical relationship between the number of days of disturbance and vital rates. As an example, the potential effects of noise from offshore wind farm construction on the North Sea harbour porpoise population were investigated; the risk was estimated to be low or negligible (<0.5% worst-case decline <0.5% of initial population size) but authors cautioned against the interpretation of this illustrative study as a prediction of actual effects because of the simplistic and likely unrealistic way that the numbers of animals disturbed was estimated.

In the Netherlands, the Framework for Assessing Ecological and Cumulative Effects (FAECE) has been drawn up for the cumulative ecological effects of the development of offshore wind farms in the southern North Sea (Rijkswaterstaat 2015a). For marine mammals, a phased approach which incorporates the interim PCoD model has been recommended (Heinis *et al.* 2015). An initial assessment by Heinis *et al*. (2015) of the possible extent of the cumulative effects of piling noise on the harbour porpoise population used a number of scenarios for both the construction of wind farms on the Dutch Continental Shelf and in the rest of the North Sea and for seismic surveying between 2016 and 2022. Seventeen construction scenarios were compared; for the Dutch wind farms, scenarios were based on two farms being built per year while international scenarios assumed a maximum of six wind farms being constructed (two of these being in the DCS). Different scenarios were provided by inclusion of seasonal restrictions (in DCS abundance is higher in spring and lower in the autumn), by the introduction of a sound standard as currently applied in Germany (SEL1 at 750m from pile = 160 dB re $1\mu Pa^2 s$) and by varying assumptions about duration of piling and size of relevant sub-population (used mainly to test sensitivity of the model). The final outcome of the models was expressed as a change in porpoise population for the years 2022-2024. On the basis of the parameters selected, all scenarios with the exception of those where sound standards were implemented resulted in a considerable predicted reduction of the harbour porpoise population. The magnitude of the reduction ranged between ~66,000 and 100,000 individuals (5^{th} percentile using 500 simulation results) in international scenarios and between 5,000 and 28,000 when only Dutch farm constructions were considered. In addition, the simulation for an international seismic survey scenario indicated that the effects of seismic surveys may be of the same order of magnitude as the effect of the worst case scenario for piling. To put the predicted reductions into a wider ecological context, the results were further assessed by comparison with the ASCOBANS standard for annual additional mortality (Rijkswaterstaat 2015b). The relevant ASCOBANS threshold was estimated at 6375 individuals (additional mortality per year); this was exceeded in the majority of scenarios, even when only the effects of construction phase of Dutch wind farms were considered. The conclusions reached were that the construction of wind farms in the North Sea will impose a considerable pressure on the harbour porpoise population, both at the national and international levels and that significant adverse effects can only be avoided by taking mitigation measures to reduce the sounds emitted during construction.

In the UK, the Habitats and Wild Birds Directives Marine Evidence Group (MEG) commissioned an expert group to provide an objective, scientific assessment of the potential impacts of planned large-scale offshore wind energy development on marine mammals in the North Sea (Tougaard *et al.* 2016). As in previous assessments, the long-term consequences of disturbance were the primary focus of the work as the risk of injury was assumed to be already minimised through current mitigation measures. In addition, the harbour porpoise was chosen as the test species not only as the most common species in the North Sea but because it appears to be the most sensitive in terms of direct effects on both hearing and behaviour. Hence an assessment based on harbour porpoise can be assumed to be precautionary for all other shelf species. Given the gaps in knowledge on how effects at the individual level are transferred to the population and the lack of input data and validation for agent-based models currently in development, the expert group chose to use a simplified population impact model. The model used a range of simplifying and worst-case assumptions; avoidance (as complete displacement from impacted area) was the response considered for acoustic disturbance. The construction scenario consisted of two pile driving operations occurring simultaneously and continuously over the next decade. A 26km effective deterrence radius was predicted around pile driving events and its effect at the population level was estimated in terms of absolute decrease in population size over the decade to range between <2% and <7%; the magnitude of this effect is small when compared to other known negative impacts on this species (e.g. by-catch in gill net fisheries) and therefore insufficient to threaten the long-term conservation status of the porpoise in the North Sea. The Expert Group concluded that under the modelled assumptions, the planned offshore construction activity will result in a non-trivial level of acute disturbance, but *'this will not compromise the long-term health of the population'*. Nonetheless, mitigation measures should be carefully considered and preferentially adopted; recommendations focus on reducing noise emissions through modifications to offshore wind installation as well as careful planning to minimise the impact from temporal and spatial overlap between harbour porpoises and construction activity.

The evidence obtained over the last 10 years has shown that harbour porpoise are more sensitive to underwater noise than previously thought. However, as revealed by the difference in outcomes from the modelling frameworks above, the degree of uncertainty in extrapolating from individual to population effects is still uncomfortably high. Nonetheless, these exercises have raised the theoretical possibility for temporal and spatial combinations of large seismic surveys and pile-driving operations to result in significant population disturbance.

Current state of UK offshore wind developments (data derived from The Crown Estate in September 2015[57]) consists of 29 individual wind farms with a total of 1452 turbines in operation (see Figure 2.9). A further 3 are under construction (114 turbines) and 23 more farms have been consented (1539 turbines). The great majority (96%) of those in operation have foundations of steel monopile construction; assuming a hammer rate of 45 per minute and duration of 90 minutes per pile (as in previous OESEAs), the values above equate to approximately 5.9M hammer strikes to date. Among the wind projects currently in development, the proportion of alternative foundations (mainly jacket, but also gravity) has increased. There are significant differences in the regional distribution of wind farms; among those already constructed, the majority are in region 2 and 6 with 850 and 570 turbines respectively. Among those consented or in construction, most of the activity will be in Region 1 and 2 with a maximum of 442 and 891 turbines respectively. The remainder have been consented in Region 3 (116 turbines) and Region 6 (90 turbines). Possible project schedule is provided by http://www.renewableuk.com/en/publications/index.cfm/Offshore-Wind-Project-Timelines-2015 and should be considered indicative only. In terms of cumulative effects, wind farm development and turbine installations in adjacent countries need also be taken into consideration. As of 2014, Denmark had installed 513 turbines, Germany 258, Belgium 182, the Netherlands 124 and Sweden 91 (http://www.ewea.org/fileadmin/files/library/publications/statistics/EWEA-European-Offshore-Statistics-2014.pdf) and plans for further development are on-going. In terms of noise exposure, what matters is the number of pile driving operations taking place simultaneously within a region or management unit; while project schedules are estimates and changes are possible, this SEA concurs with the assumption made by the Expert Group (Tougaard *et al.* 2016) that on average two pile driving operations will take place continuously in the North Sea over the next decade or more. If sound generated during pile-driving is assumed to affect an area with a radius of 20km, it is expected that wind farm installations will disturb approximately 2500km^2 corresponding to approximately 1% of Region 1 & 2 combined.

Seismic survey coverage of the UKCS is extensive as shown in a map of recent activity (Figure 5.2). Historic seismic survey effort on the UKCS between 1997 and 2003 was reviewed for submission to the Advisory Committee to ASCOBANS (DTI 2005a), and subsequently updated for 2007-2008 (Genesis 2009). 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.

As identified in previous offshore energy SEAs, the vast majority of seismic survey effort on the UKCS has been undertaken in the developed (in terms of oil and gas) areas of the northern and central North Sea and the Faroe/Shetland Channel, with a smaller amount in the southern North Sea, the Channel, the western approaches and the Irish Sea. A GIS analysis carried out of all 3D surveys from the Oil & Gas UK database from 2000 to 2014, revealed a similar pattern with 92% of 3D surveys taking place across Regions 1, 8 and 9 (see Table 5.7). A similar geographic distribution of seismic survey effort can be anticipated in the future, although limited activity in other parts of the UKCS cannot be discounted. In addition to this UK seismic noise budget, noise propagating from surveys in contiguous national waters (particularly Irish, Faroese and Norwegian waters) will be present.

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[57] *The Crown Estate (2015) Energy and infrastructure key facts 2015-16: UK offshore wind (see section A1h.8.1 and Table A1h.3.)*

Table 5.7: Number of 3D surveys per Regional Sea between 2000 and 2014.

Regional Sea	1	2	3	4	5	6	7	8	9	10	11
n	166	14	3	0	0	1	0	44	12	0	0

Source: Oil & Gas UK database

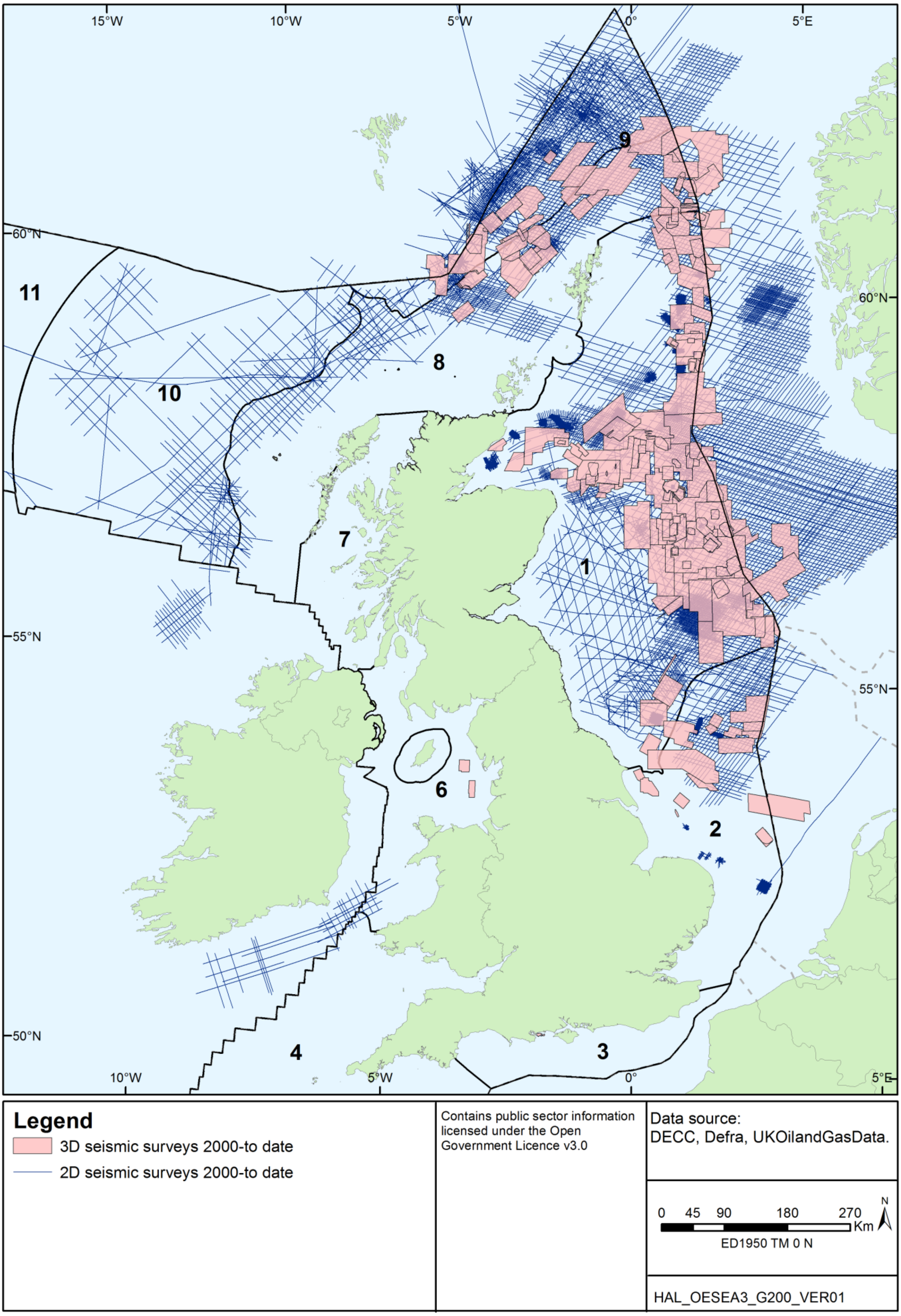
Assuming that activity over the next 5 years will not exceed the yearly average of the last 10 years, an estimate of the total area affected by seismic surveys following the plan/programme may be calculated. The number of 3D surveys carried out per year between 2004 and 2014 is ~18. Assuming each survey requires 60 days of shooting and most of the seismic activity is concentrated between April and September, 6 surveys may take place at any one time (but not geographically coincident). If it is assumed that sound from seismic surveys affects an area of 10km radius, seismic exploration could acoustically disturb approximately 1885km^2. If it is assumed that all this activity is in Region 1 and 2, the area disturbed at any one time would correspond to 0.8% of the total area or <0.5% if Regional Seas 1, 2, 8 and 9 were combined.

To further inform regional considerations of the likelihood of impacts, marine mammal sensitivities of individual Regional Seas – based on Appendix 3a.8 – are summarised below:

Regional Sea 1 - The central and northern North Sea has a moderate to high diversity and density of cetaceans, with a general trend of increasing diversity and abundance with increasing latitude. Harbour porpoise and white-beaked dolphin are the most widespread and frequently encountered species, occurring regularly throughout most of the year. Minke whales are a seasonal visitor, regularly recorded in the summer months; killer whales are sighted with increasing frequency towards the north of the area and during the summer. Atlantic white-sided dolphin, Risso's dolphin and long-finned pilot whale can be considered occasional visitors, particularly in the north of the area. Coastal waters of the Moray Firth and east coast of Scotland support an important population of largely resident bottlenose dolphins. Large numbers of grey and harbour seals breed in the area, with high densities observed in many coastal waters and some areas further offshore; large declines in harbour seals numbers have been observed in this region.

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 occur regularly throughout most of the year, and minke whale in summer. Important numbers of grey and harbour seals are present off the east coast of England, particularly around the Wash where harbour seals forage widely.

Figure 5.2: Seismic survey (2D and 3D) coverage for the UKCS



Regional Sea 3 – The eastern English Channel 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. Further offshore, occasional sightings of long-finned pilot whales or common dolphins have occurred but numbers are much less than in the Western Channel. The area is not particularly important for seals, with no major colonies present and very little activity recorded.

Regional Seas 4/5 – These regions experience a relatively high density and moderate diversity of marine mammals. Four cetacean species occur frequently: 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 – Eighteen species of cetaceans have been recorded in this region with highest species diversity offshore around the Celtic Deep and close to the Isle of Man. Coastal waters off Wales, particularly Cardigan Bay, support high densities of bottlenose dolphins. Other frequently encountered species are the harbour porpoise, the short-beaked common dolphin, Risso's dolphin and minke whale. Grey and harbour seals are also regularly present in certain areas.

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 – the waters north and west of Scotland support a rich diversity and density of marine mammals. 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; large declines in harbour seals numbers have been observed in this region.

Regional Sea 9 – the Faroe-Shetland Channel supports a rich diversity and high density of marine mammals. Most abundant species in the region is the Atlantic white-sided dolphin and other commonly sighted species include bottlenose dolphin, killer whale, long-finned pilot whale, and sperm whale. Beaked whales, common dolphins, Risso's dolphins, fin, sei and minke whales are also recorded regularly, while other species of baleen whale such as blue and humpback are occasionally observed. 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 (bottlenose dolphin, harbour porpoise, minke whale) and coastal waters south to the North of England (bottlenose dolphin, white-beaked dolphin (further from shore)); 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)
- Offshore areas of the southern North Sea (harbour porpoise)
- Western English Channel (common dolphin, minke whale)
- Coastal areas around Cornwall (bottlenose dolphin)
- Celtic Sea (common dolphin, minke whale)
- Coastal areas from Cardigan Bay to Liverpool Bay, including the Lleyn Peninsula (bottlenose dolphin, harbour porpoise, Risso’s dolphin, grey seal) and adjacent Manx waters
- Coastal areas around Pembrokeshire (harbour porpoise, Risso's dolphin, common dolphin, minke whale, grey seal)
- Carmarthen Bay (harbour porpoise, grey seal)
- Hebridean Sea – Kintyre to Skye (harbour porpoise, bottlenose dolphin, grey seal, harbour seal)
- Continental shelf edge – Barra Fan to Miller Slide (various cetaceans)
- 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 Monarchs and Flannans (grey seal)
- Deep waters to the west of the UK (various cetaceans including beaked whales, migrating humpback and blue whales)

The evidence has highlighted the potential for noise generated during seismic surveys and impact pile driving to cause disturbance on a relatively large temporal and spatial scales. The possibility that several of these activities make take place across the UKCS and indeed across neighbouring regions has also been highlighted, leading to the potential for cumulative and trans-boundary effects. The most likely response by marine mammals is to avoid the area, although other behavioural and physiological responses may also be involved. By assuming that acoustic disturbance equates to loss of foraging opportunities through avoidance, long-term population consequences can be calculated. Current understanding is that, in combination, noise generated from planned activities, are highly unlikely to result in a population level effect. Given the wide ranging distribution and individual movements of marine mammals, the relevant geographical scale for transboundary effects with respect to acoustic disturbance is that of the relevant management unit.

5.3.6 Summary of findings and recommendations

As noted throughout this section, considerable uncertainty surrounds many elements of our understanding of the effects of anthropogenic noise on the marine environment. Efforts to identify and address these gaps are ongoing through a variety of initiatives, including academic, government and industry projects.

It is accepted that marine mammals show the highest sensitivity to underwater sound, particularly the intense pulses associated with seismic surveys, impact pile-driving and the use of explosives. The severity of potential effect has therefore been related principally to marine mammal species composition and abundance in an area, although effects on fish (including spawning aggregations) and other receptors have also been considered. A major obstacle in understanding the effects on fish and invertebrates is the limited ability to measure the particle motion component of sound.

The nature of effects reviewed range widely, from masking of biological communication and small behavioural reactions, to chronic disturbance, injury and mortality. For marine mammals and fish, effects will generally increase in severity with increasing exposure to noise; a distinction can be drawn between effects associated with physical injury and effects associated with behavioural disturbance.

With respect to injury, this SEA concurs with the scientific consensus judgement that underwater sound generated during seismic and pile-driving operations has the potential to cause injury within a limited range (tens to hundreds of metres). Assessment of risk can rely on exposure thresholds but there is a need to update these to reflect the latest scientific findings (particularly regarding the harbour porpoise) and to provide further guidance on how to apply them. In addition, current mitigation measures are deemed sufficient in reducing the risk of injury to negligible levels whenever carefully applied by industry for all species common on the continental shelf. More uncertainty on their efficacy exists for deep-diving species; a particular concern identified in this SEA is for beaked whales (deep water Regional Seas 5, 9, 10, 11) which are known to be highly sensitive to some underwater sounds such as military sonar.

With respect to disturbance, there is little confidence in relying on criteria based on exposure alone as animal behaviour is largely dependent on context. Instead, field observations during industrial activities are fundamental sources of information for assessment. Impact pile-driving and seismic surveys have the largest disturbance footprint of any activity in the plan/programme. However, the main challenge when assessing the likelihood of significant disturbance effects stems from the need to assess these in terms of long-term population consequences while the available evidence relates to individual responses under relatively short-term conditions. Several modelling frameworks are being developed to assess population level impacts of acoustic disturbance. All frameworks rely on assumptions and on expert judgement to cope with the gaps in the data, but so far there are considerable differences in methodologies and outcomes, all of which need to be viewed with caution. The approach used by an expert group convened under the Habitats and Wild Birds Directives Marine Evidence Group led to the conclusion that planned offshore construction activity up to 2020 will result in a non-trivial level of acute disturbance, but *'this will not compromise the long-term health of the population'*. Since activities considered in this SEA are of a similar magnitude, the report's conclusions are considered applicable.

Previous SEAs have recommended consideration of the establishment of criteria for determining limits of acceptable cumulative impact; and for subsequent regulation of cumulative impact. The SEA recognises the advances made in this respect through the establishment of the indicator on low- and mid- frequency impulsive sounds under the Marine Strategy Framework Directive. While criteria have not yet been defined, the establishment of a database to collate occurrences of ‘noisy activities’ (the Marine Noise Registry) represents the necessary precursor.

Given the potential risk from chronic exposure to increased ambient noise level, the degree of uncertainty with population level assessment of acoustic effects and the need to achieve Good Environmental Status under the Marine Strategy Framework Directive, this SEA recognises the importance of minimising underwater noise emissions and emphasises the value of further voluntary mitigation measures at the project scale, in particular technical noise emissions reductions and careful planning to reduce temporal and spatial overlap between activities and marine mammals.

5.4 Physical damage/change to features and habitats

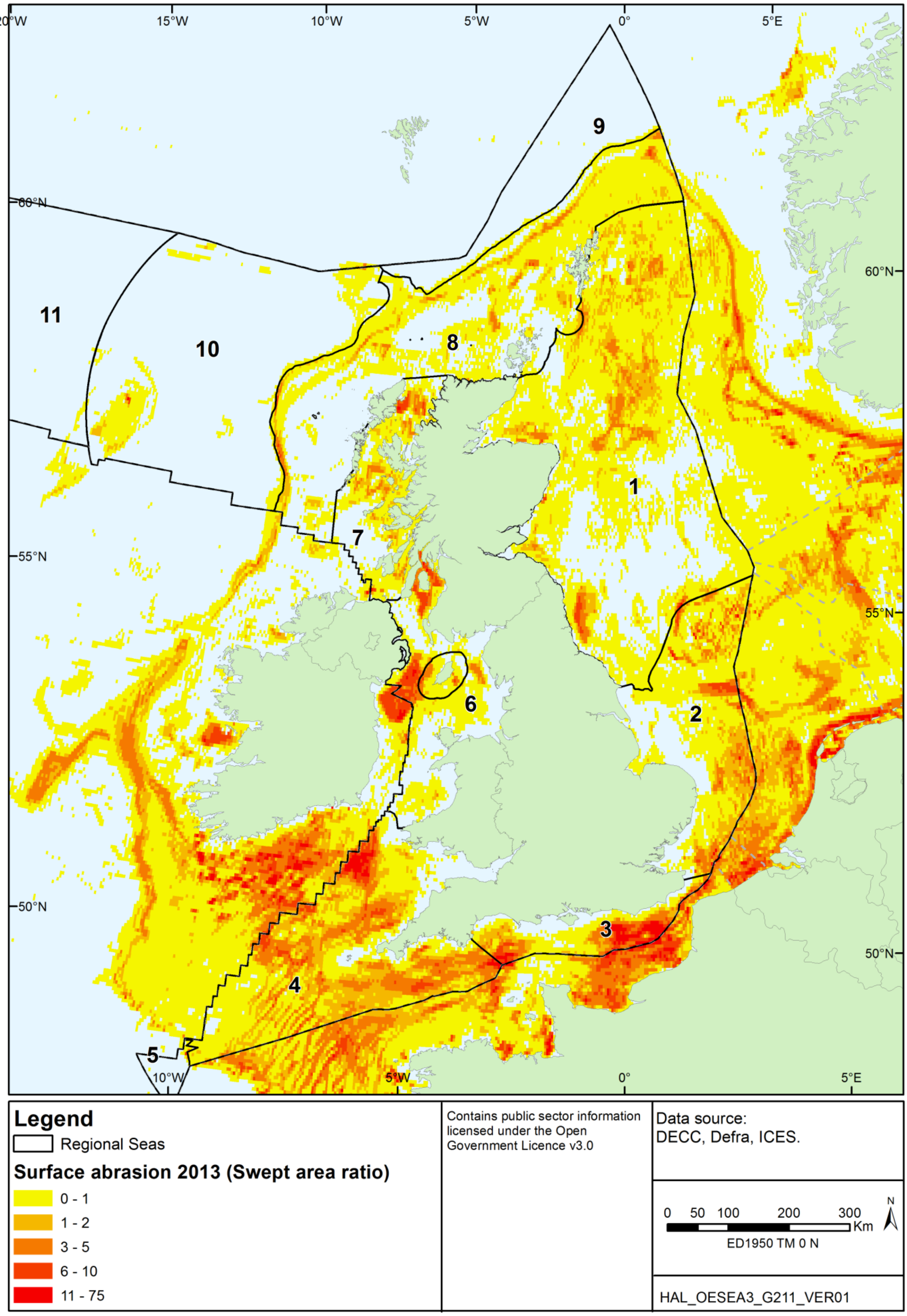
Assessment Topic	Potentially Significant Effect	Oil & Gas	Gas Storage	Carbon Dioxide Storage	Offshore Wind	Tidal Stream	Tidal Range	Wave	Assessment Section
	Physical effects of anchoring and infrastructure construction (including pipelines and cables) on seabed sediments and geomorphological features (including scour)	X	X	X	X	X	X	X	5.4.3.1
	Physical damage to biotopes from infrastructure construction, vessel/rig anchoring etc (direct effects on the physical environment)	X	X	X	X	X	X	X	5.4.3.2
	Offshore disposal of seabed dredged material	X	X	X	X	X	X	X	5.4.3.1 5.4.3.2
	Physical damage to submerged heritage/archaeological contexts from infrastructure construction, vessel/rig anchoring etc and impacts on the setting of coastal historic environmental assets and loss of access.	X	X	X	X	X	X	X	5.4.3.3
	Changes/loss of habitats from major alteration of hydrography or sedimentation (indirect effects on the physical environment)				X	?	X	?	5.4.3.4
	Post-decommissioning (legacy) effects – cuttings piles, footings, foundations, *in situ* cabling etc	X	X	X	X	X	X	X	5.4.3.5

5.4.1 Introduction

Previous SEAs have compared the physical disturbance effects of oilfield activities and OWFs to those of fishing and natural events (e.g. storm wave action), concluding generally that effects are minor on a regional scale (reflected in Round 2 SEA), although the Round 3 SEA does suggest that the risk of effect is highly variable across the nine Round 3 zones. 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). ICES have calculated the area impacted by mobile bottom-contacting gears (based on Vessel Monitoring System (VMS) and logbook data) to provide fishing abrasion maps[58]. Figure 5.3 highlights those areas where the seabed surface (upper 2cm) has been impacted by mobile bottom-contacting gears. The Greater North Sea region has the most widespread fishery using mobile bottom-contacting gears, estimated to impact 290,000km^2 (42.5%) of the region in 2013 (down from 341,000km^2 in 2009). Fishery impacts were also widespread in the Celtic Seas region with an estimated 237,000km^2 (or 26%) of the region impacted by bottom-contacting gear.

[58] http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2015/2015/DCF_indicators_567.pdf

Figure 5.3: Surface abrasion from mobile bottom-contacting gears in 2013



5.4.2 Sources of potentially significant effect

Several activities associated with the implementation of the draft plan/programme and associated technologies can lead to physical disturbance of the seabed, with consequential effects on seabed features, habitats and biotopes and potentially archaeological artefacts. The main activities which may result in disturbance are listed in the table below along with the pathways by which exposure of receptors might occur.

Table 5.8: Physical damage/change to features and habitats: sources of effect, pathways and receptors

Source activity	Relevant aspects of plan	Pathways by which exposure might occur	Potential receptors
Construction phase			
Anchoring of vessels, semi-submersible rigs, floating production, wave, tidal and offshore wind installations	All	Anchor placement, dragging and chain abrasion	Seabed sediments and features, benthic habitats
			Submerged archaeological resource
Piling of monopile or jacket foundations	Oil and gas, gas storage, CO_2 storage, offshore wind	Remobilisation of sediments during piling	Water quality (increased turbidity)
			Seabed sediments and features, benthic habitats
Pipeline, flowline and umbilical installation and trenching. Laying and trenching of cables	All	Disturbance and remobilisation of sediments during trenching and cable burial	Seabed sediments and features, benthic habitats
			Water quality (increased turbidity)
			Submerged archaeological resource and setting of coastal historic assets
Rock dumping on cable / infrastructure	All	Loss of sea bed and associated benthic habitats under footprint	Seabed sediments and features, benthic habitats
		Creation of new habitat, hard structures/ substrate	Benthic habitats
Works to level seabed and offshore disposal of seabed dredged material	All	Removal of sea bed by dredging	Seabed sediments and features, benthic habitats
			Submerged archaeological resource
		Remobilisation of sediments during disposal	Water quality (increased turbidity)
			Seabed sediments and features, benthic habitats
Placement of wellheads, subsea templates and manifolds	Oil and gas, gas storage, CO_2 storage	Loss of sea bed and associated benthic habitats under footprint	Seabed sediments and features, benthic habitats
Placement of jack-up rigs (seabed disturbance by spud cans)	Oil and gas, gas storage, CO_2 storage	Loss of sea bed and associated benthic habitats under footprint	Seabed sediments and features, benthic habitats
Placement of gravity base and suction caisson foundations	Oil and gas, offshore wind, tidal stream, wave	Loss of sea bed and associated benthic habitats under footprint	Seabed sediments and features, benthic habitats
		Creation of new habitat, hard structures/ substrate	Benthic habitats
Placement of foundations and walls associated with lagoon construction	Tidal range	Loss of sea bed and associated benthic habitats under footprint	Seabed sediments and features, benthic habitats
		Creation of new habitat, hard structures/ substrate	Benthic habitats

Source activity	Relevant aspects of plan	Pathways by which exposure might occur	Potential receptors
Operational phase			
Physical presence of structures in the water column	Offshore wind, tidal range, tidal stream, wave	Changes to hydrography or sedimentation regime	Seabed sediments and features, benthic habitats
Decommissioning phase			
Decommissioning of infrastructure	All	Pathways the same as construction phase	Receptors the same as construction phase

5.4.3 Consideration of the evidence

5.4.3.1 Physical effects of anchoring and infrastructure construction on seabed sediments and geomorphological features (including scour)

Offshore wind farms

To date, OWF developments on the UKCS have taken place in areas dominated by faunal communities rather than those of seagrass or macroalgae, due to either conditions that were too deep, too turbid or of unsuitable substrate. In general, physical damage on seabed properties, 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).

Construction phase

Round 1 and 2 OWF turbines exclusively used monopole-type foundations. However, as part of Round 3 and future development rounds, alternative foundation types for OWFs are being considered including steel jackets, gravity base foundations, suction caisson foundations and potentially floating structures for deeper waters, which have varying impacts on the physical environment. A review of the Environmental Statements for a number of recently consented R3 wind farms and a floating wind demonstrator site provides estimates of the seabed footprint associated with the different foundation types which may be used (Table 5.9).

In terms of seabed preparation, monopile and jacket structures have minimal impact on the seabed with a hole drilled into bedrock into which the monopile is placed and secured using cement. Similarly, floating structures, such as those proposed for Statoil's Hywind Scotland Pilot Park (Statoil 2015) are likely to require minimal seabed preparation although this will depend on the anchor system selected and the seabed conditions. Gravity bases and suction caisson designs however require preparation of the seabed through levelling usually done by dredging and the removal of boulders and other obstructions (see Table 5.9 for estimates of seabed preparation areas and excavation volumes associated with these foundation types). They also potentially require a thin stone bed or further dredging to create an even horizontal surface (see Figure 5.4).

Table 5.9: Seabed footprints associated with proposed foundation types for consented R3 and floating offshore wind demonstrator sites

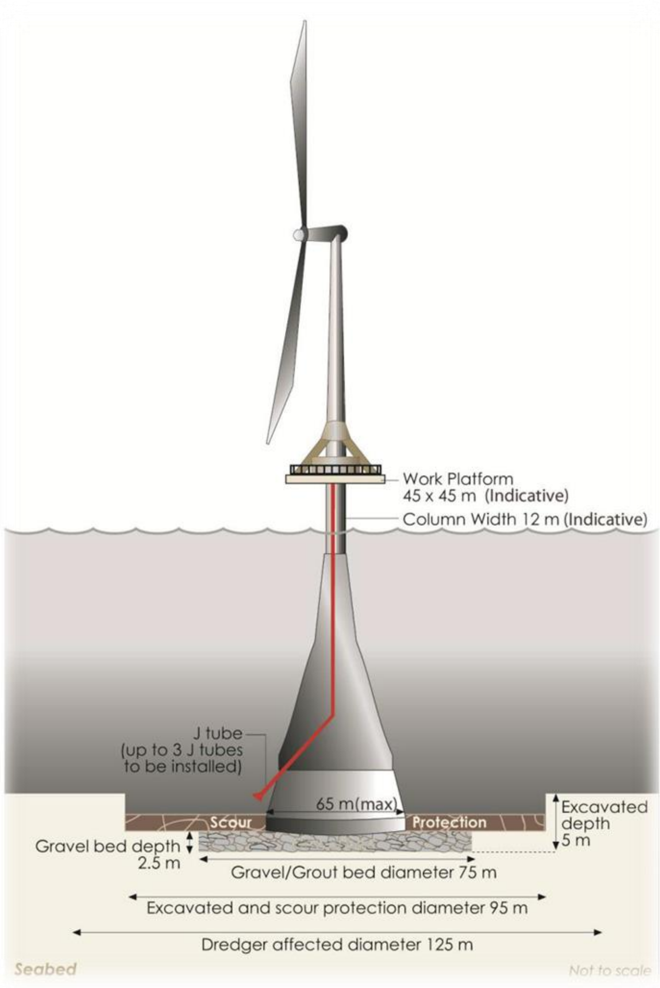
Wind farm (potential WTG capacities)	Foundation type	Seabed preparation area (m^2) / excavation volume (m^3)	Drill cuttings (m^3)	Seabed footprint (m^2)	Seabed footprint (incl. scour protection) (m^2)	Development seabed footprint[1] (km^2) and as % of development area
R3 offshore wind farm sites						
Telford, Stevenson & MacColl (Moray Firth) (3.6-8MW WTG)	Concrete gravity base	12,265m^2	-	3,316m^2	7,085m^2	2.4km^2 (0.8%)
	Steel jackets with pin piles	Limited or no requirement	-	20m^2	201m^2	-
Seagreen Alpha & Brava (Firth of Forth)	Jacket (driven piles)	Limited or no requirement	-	28m^2	-	-
	Jacket (suction piles)	Limited or no requirement	-	616m^2	907m^2	-
	Gravity base	4,295m^2 (21,475m^3 excavation volume)	-	4,295m^2	5,780	0.9km^2 (0.2%)
Creyke Beck A & B (Dogger Bank) (4-10MW WTG)	Monopile[2]	Limited or no requirement	3,691-6,220m^3	573-962m^2	Gravity base worst case	-
	Jacket	Limited or no requirement	3,691-6,220m^3	707m^2	Gravity base worst case	-
	Gravity base	3,844-4,900m^2 (2,883-3,675m^3 excavation volume)	-	1,735-2,376m^2	5,512-6,153m^2	3.3-3.7km^2 (0.3%)
Teesside A & B (Dogger Bank) (6-10MW WTG)	Monopile[2]	Limited or no requirement	4,752-6,220m^3	707-962m^2	Gravity base worst case	-
	Jacket[3]	Limited or no requirement	4,752-6,220m^3	707m^2	Gravity base worst case	-
	Gravity base	4,225-4,900m^2 (3,169m^3 excavation volume)	-	1,963-2,376m^2	5,027-5,675m^2	2-2.3km^2 (0.2%)
Hornsea Project One (3.6-8MW WTG)	Monopile	Limited or no requirement	2,837m^3	57m^2	1,419m^2	-
	Jacket (driven piles)	Limited or no requirement	2,121m^3	28m^2	707m^2	-
	Jacket (suction caisson)	Limited or no requirement	-	707m^2	6,362m^2	-
	Gravity base	3,846m^2 (17,839m^3 excavation volume)	-	1,963m^2	6,362m^2	2.1km^2 (0.5%)
East Anglia ONE (3-8MW WTG)	Jacket (pin piles)	Limited or no requirement	-	20m^2	-	-
	Jacket (suction buckets)	Limited or no requirement	-	78m^2	-	-
	Suction caisson	9,025m^2 (11,500m^3 excavation volume)	-	490m^2	16,504m^2	-
	Gravity base	14,400m^2 (22,500m^3 excavation volume)	-	1,962m^2	22,686m^2	5.4km^2 (1.8%)
Rampion (3-7MW WTG)	Monopile	Limited or no requirement	1,824m^3	33m^2	1,600m^2	-
	Jacket (pin piles)	Limited or no requirement	976m^3	21m^2	1,200m^2	-

Wind farm (potential WTG capacities)	Foundation type	Seabed preparation area (m^2) / excavation volume (m^3)	Drill cuttings (m^3)	Seabed footprint (m^2)	Seabed footprint (incl. scour protection) (m^2)	Development seabed footprint[1] (km^2) and as % of development area
	Suction caisson/bucket	962m^3 excavation volume	-	961m^2	8,700m^2	-
	Gravity base	1,820m^3 excavation volume	-	907m^2	7,900m^2	1.4km^2 (0.8%)
Floating wind demonstrator site						
Hywind Scotland Pilot Park (6MW WTG)	Suction anchors (3 per WTG)	Limited or no requirement	-	120m^2 (3 anchors) 150-850m anchor chain on seabed	2,700-3,000m^2 (3 anchors)	0.013-0.015km^2 (0.1%)

Notes: [1]Worst case development seabed footprint estimated primarily from gravity base foundation seabed footprint including scour figure multiplied by maximum number of proposed turbines from Environmental Statements. [2]Includes: monopile with steel monopile footing, monopile with concrete monopile footing, and monopile with a single suction-installed bucket footing. [3]Figures probably represent jacket with suction caisson foundations.

Sources: Moray Offshore Renewables Limited (2012), Seagreen Wind Energy Limited (2012), Forewind (2014), Smart Wind (2013), East Anglia Offshore Wind Limited (2012), E.ON Climate & Renewables UK Rampion Offshore Wind Limited (2012).

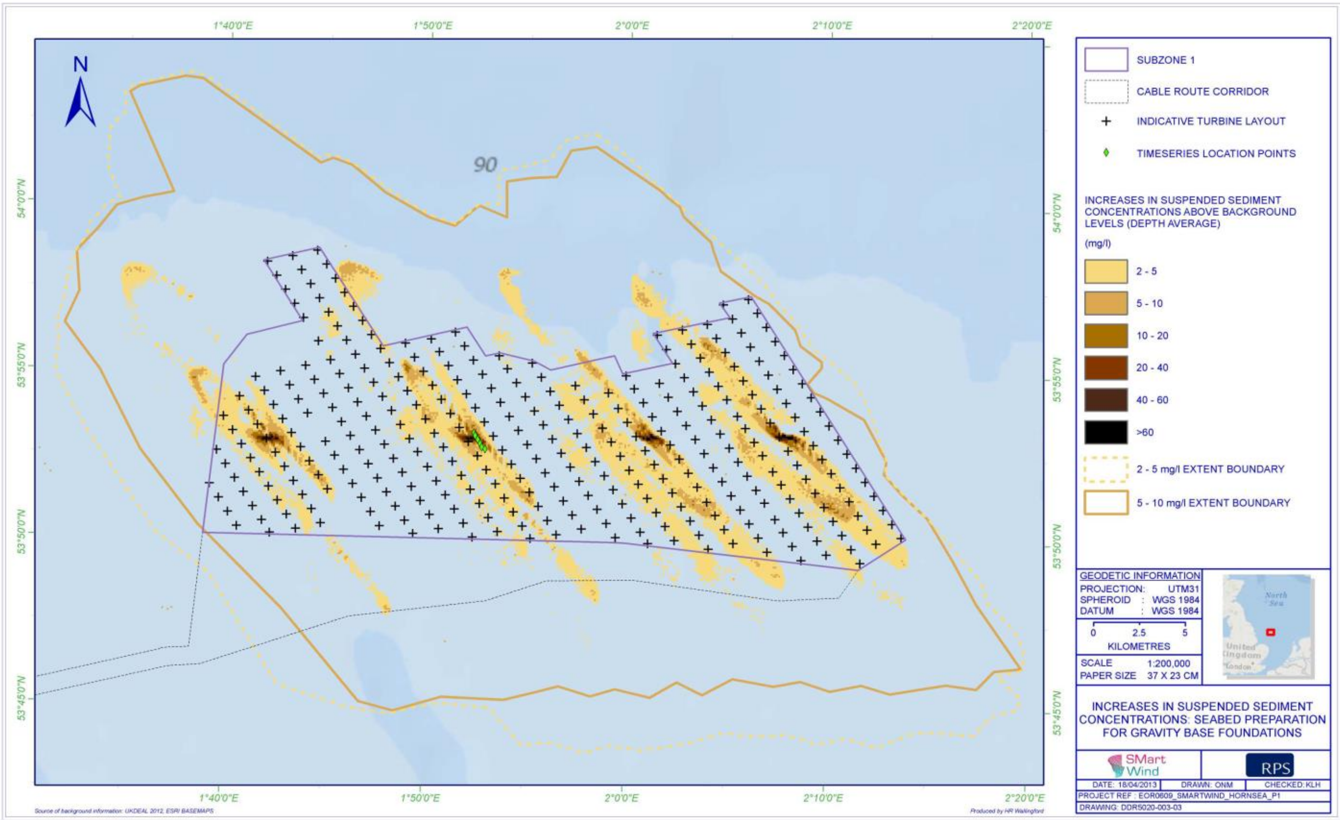
Figure 5.4: Typical gravity base structure and gravel bed foundation



Source: Moray Offshore Renewables Limited (2012)

The seabed preparation works associated with the installation of gravity base foundations has the potential to affect a much larger area than the direct seabed footprint of the foundation through increased suspended sediment concentrations (SSC) in the water column as a result of excavation and dredging activities. For example, to inform dispersion modelling for the Hornsea Project One EIA, it was assumed (worst case) that all turbines would require seabed preparation, resulting in a maximum of over 17,839m^3 (see Table 5.9 above) of material excavated per foundation (Smart Wind 2013). Based on soil type and fine contents information from a site geophysical survey, it was estimated that 892m^3 of fine material (<63µm diameter) would be dispersed into the water column (5% of 17,839m^3). Figure 5.5 shows the anticipated increase in SSC resulting from seabed preparation and disposal activities. Four turbine locations were simulated to capture differences in tidal flows (and consequent potential differences in plume dispersion patterns) across the development area. The plume extents from the four modelled simulations were transposed to all the outer perimeter turbine locations and a boundary line produced to provide an indicative worst case 'outer extent' of increases in SSC above background levels of 2 to 5mg/l and 5 to 10mg/l. From Figure 5.5, increases in SSC greater than 10mg/l above background levels were not observed outside of the development zone. Time series data for six points within the densest sediment plume, indicated that the dispersion of fine material from seabed preparation and disposal operations would be relatively rapid (lasting less than 24 hours). Background SSC levels are typically between 0 to 30mg/l in the offshore area, although under storm conditions values can increase to up to 250mg/l offshore (HR Wallingford *et al*. 2002). In the context of these background levels, an increase of 10 mg/l for a period of less than 24 hours per dredging and disposal operation was considered to be a short-term and small scale effect (Smart Wind 2013). Predicted levels of sediment deposition were very low (less than 20mm), as the material that was suspended will disperse over a very wide area and at very low levels rather than remain close to the point of disturbance (Smart Wind 2013).

Figure 5.5: Predicted increases in SSC associated with seabed preparation for gravity base foundations for Hornsea Project One



Source: Smart Wind (2013)

Monopiles may also be used as foundations for R3 turbines where depths and sediments are suitable. Steel piles are typically hammered to the desired penetration depth. However, in some cases the pile may reach a point of refusal and cannot be driven to the required penetration depth due to difficult ground conditions. In this event it is possible to drill out some or all of the volume of sediment inside the pile to reduce the driving resistance and allow the pile installation to be completed. Drilling must be carried out for concrete monopiles. Drilling of monopiles will result in the release of both fine material (silts) and granular material (sands and gravels) at the sea surface, which will deposit on the seabed (Table 5.9 provides estimates of potential drill cuttings for monopiles for R3 developments projects). Dispersion modelling of drill arisings from monopile drilling was carried out for Hornsea Project One and indicated a relatively rapid dispersion of fine material (less than 24 hours) with SSC increases of up to 10mg/l above background levels expected to be confined to an area close to the wind farm (Smart Wind 2013).

The physical placing of a structure on the seabed, the installation of scour protection (see below), cabling and anchor structures all result in direct loss of habitat and sedentary species within the footprint (and any working area) of the structure. Table 5.9 shows broad estimations of the likely size of footprint (including allowance for scour protection) of different foundation types for a number of R3 OWF developments. Any associated habitat loss is likely to be permanent for all foundation types apart from potentially suction caisson whereby the removal of the structure will allow the restoration of habitats within the footprint, although direct loss of organisms during installation will still occur. As with potential dredging effects, the recolonisation of the working area around the foundations after installation is likely to occur, again with the timescale dependent on dispersal of individuals and seabed preparation method. In terms of floating structures the physical footprint of the anchors on the seabed and therefore direct disturbance is likely to be small, depending on whether embedded anchors, piles, suction caissons or gravity bases are used, but spread out over a potentially large area (in the case of catenary structures), with large areas included in the overall device footprint that are essentially undisturbed. The calculation of the exact area of habitat affected by each individual structure reflects how much direct disturbance would potentially occur from each foundation type depending on the physical and biological characteristic of the site. For example, the consented Hywind Scotland Pilot Park will consist of the deployment of five 6MW floating turbines in an area known as the Buchan Deep, an area of deep water (95-120m) located approximately 25km off the coast at Peterhead, north east Scotland. A preliminary park layout showing the area of seabed occupied by the mooring system, anchors, inter-array cables and other associated cable protection is illustrated on Figure 5.6. Final routeing of cables and layout of anchors and turbines will depend on several factors such as seabed conditions, obstacles on the seabed and operational needs. The turbines, mooring system and inter array cables are estimated to occupy an area of up to 15km^2. However, the area of seabed on which project infrastructure will actually be installed is estimated at 0.275km^2 (Statoil 2015) or 1.8% of the area occupied.

The overall physical areas occupied by OWF developments are large e.g. 35km^2 for the Thanet Wind Farm in the southern North Sea, which began operation in September 2010[59]. However, the spacing between turbines (500m along rows and 800m between rows for Thanet) means that there are large areas of undisturbed seabed within this wider footprint, see Figure 5.7 below). Similarly, the R3 projects will consist of a large number of turbines but these will be well spaced within the large development areas with the maximum development seabed footprint estimated at between 0.09 and 1.8% of the total development area (see Table 5.9 above).

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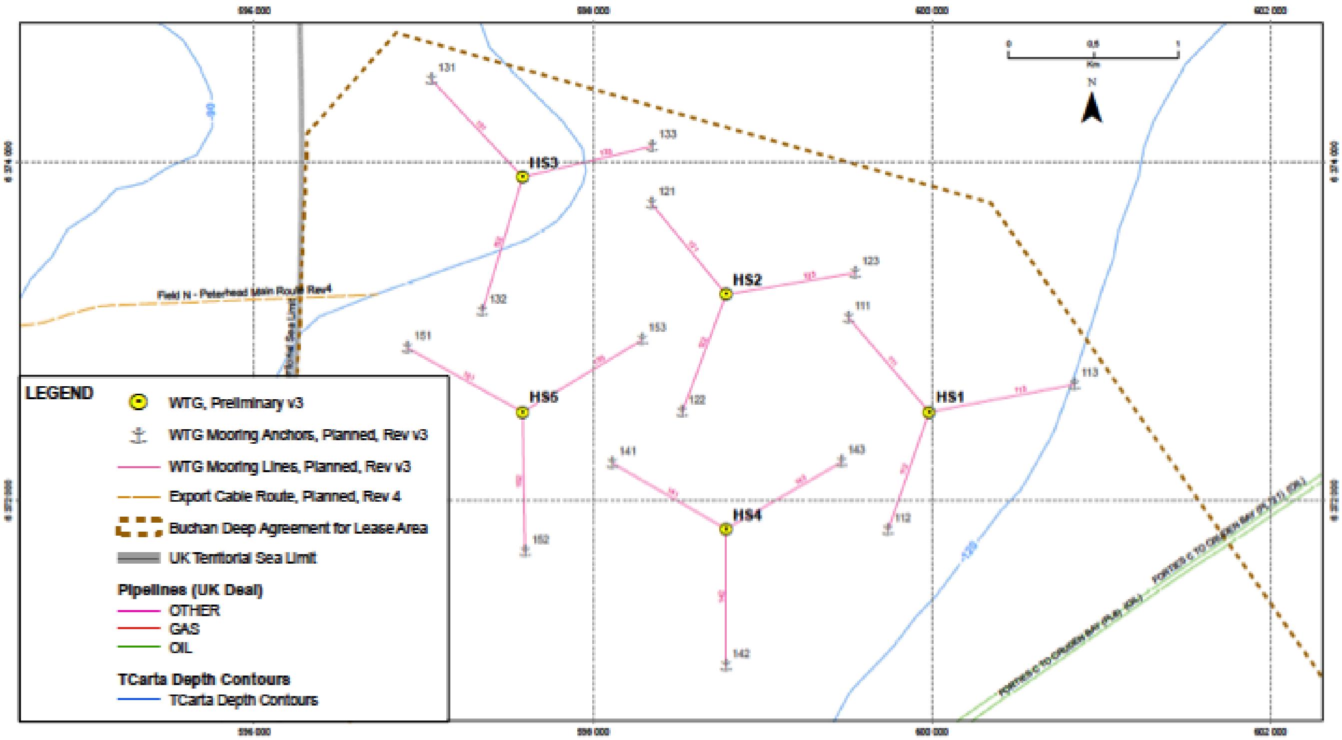
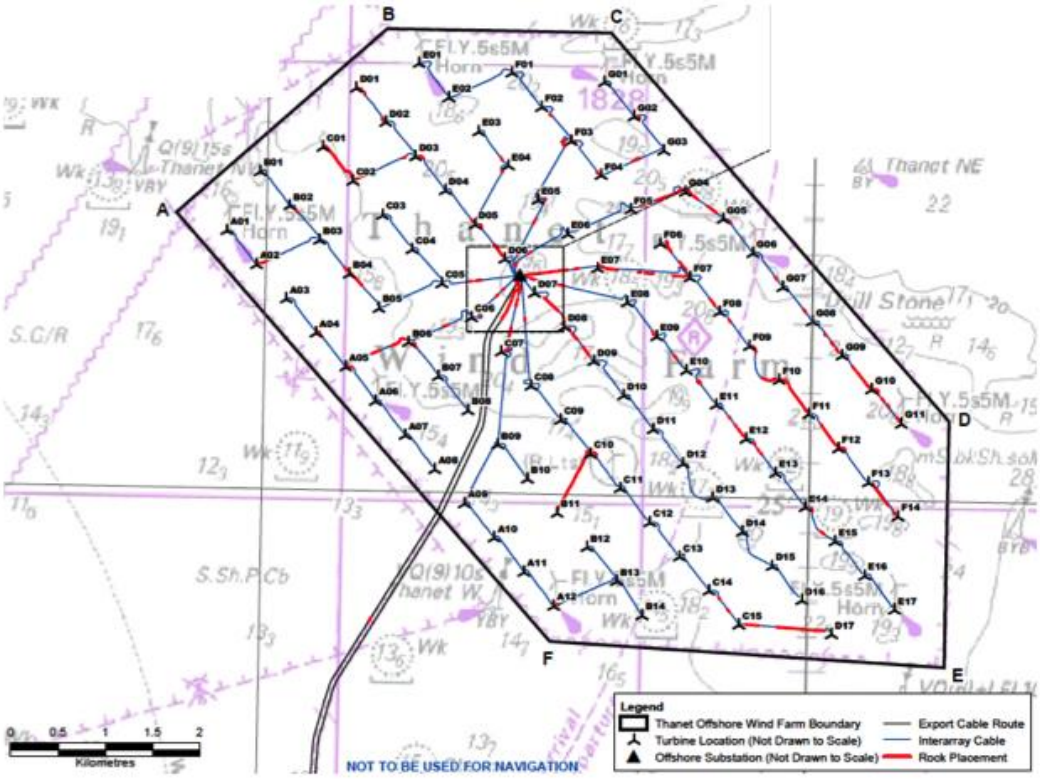
59 http://corporate.vattenfall.co.uk/projects/operational-wind-farms/thanet/

Figure 5.6: Proposed layout of the Hywind Scotland Pilot Park



Source: Modified from Statoil (2015)

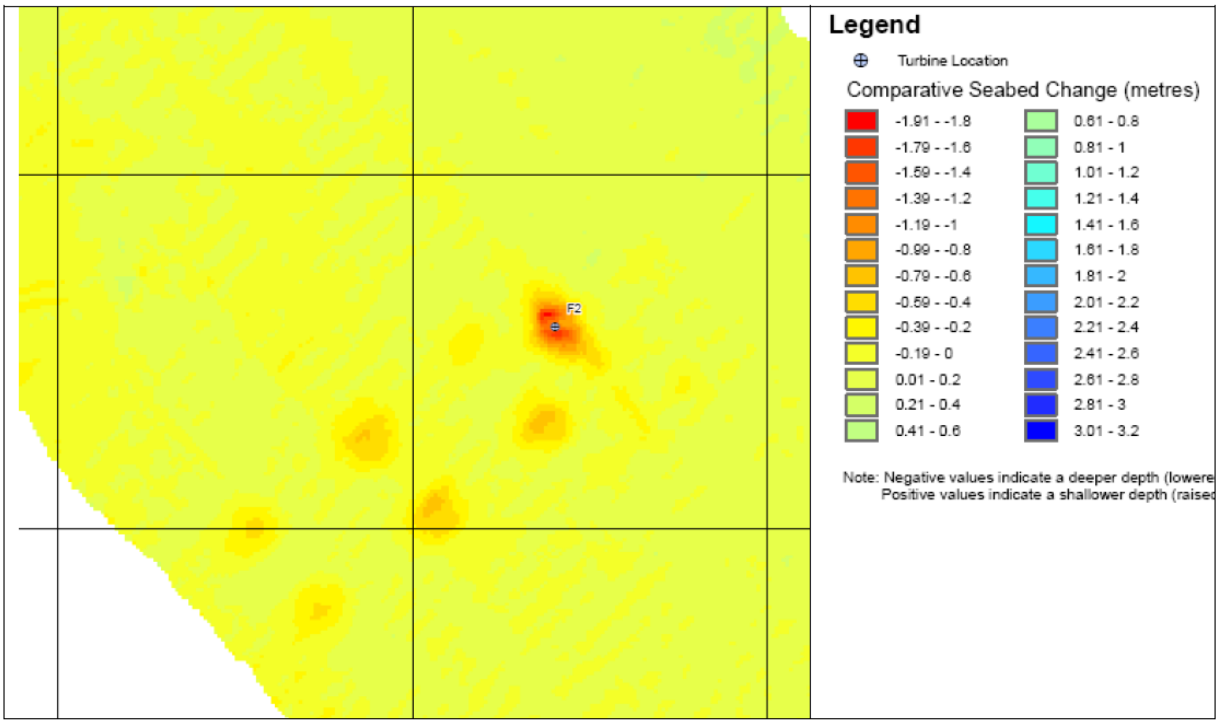
Figure 5.7: Thanet wind farm as-built



Source: Vattenfal website - http://corporate.vattenfall.co.uk/globalassets/uk/projects/thanet_publication_as-built.pdf

Offshore construction activities will utilise a range of vessels including jack-up barges, which may cause seabed disturbance through spud can placement. For example, swathe bathymetry data collected as part of FEPA monitoring of the Kentish Flats wind farm indicated a set of six regular depressions in the seabed at each of the turbine locations resulting from jack-up operations (Figure 5.8). Immediately post-construction, a January 2005 survey recorded these depressions as having depths of between 0.5 and 2.0m. By November 2007, these depths had reduced by an average of 0.6m indicating that the depressions were naturally infilling (Vattenfall 2009). The impact of these spud can depressions on the seabed is therefore local and temporary; their duration depending on the rate of sediment transport in an area. The consented and future Round 3 projects will require the installation of large numbers of turbines; the Hornsea ONE ES estimated that 341 structures (foundations and associated offshore structures would require jack-up barges for installation with each barge assumed to have a seabed footprint of 420m^2. However, the large distance between turbines (*c.a.* 600->1,000m), the very localised nature of the seabed depressions and the relatively dynamic nature of sediment transport regimes within the Round 3 zones, means that infilling of the depressions is likely to occur in the short to medium term. Turbine siting is informed by site survey which provides information on seabed topography and habitats, within the expected seabed footprint, allowing potentially sensitive features to be identified and reflected in the location selection.

Figure 5.8: Bathymetric comparison plot for Turbine F2 at Kentish Flats, March 2007



Source: Vattenfall (2009)

The on-going construction of Round 2 sites, the development of Round 3 zones, Round 1 & 2 extensions and Scottish wind farm exclusivity zones means that further extensive cable laying operations are required to transfer the generated power from the OWF to the mainland. Table 5.10 provides summary details from relevant Environmental Statements of the worst-case estimates of cabling requirements associated with consented R3 projects. Table 5.10 indicates that over 10,000km of inter-array and export cables could be installed during the construction of the first phases of development within the R3 zones. The estimates represent worst-case requirements with the precise array cable layouts and export cable routes to be determined by the final turbine layout configuration as well as ground conditions, installation limitations, environmental constraints and economic factors.

Table 5.10: Worst-case cabling requirements for consented R3 wind farms

Wind farm development	Inter-array cabling length (km)	Export cable corridor length (km)	Export cable corridor width (m)	Seabed area affected by cable installation[1] (km^2)
Telford, Stevenson & MacColl (Moray Firth)	Length not provided. 7 to 12 strings per site	105	6m (x2)	1.26 (export cable only)
Seagreen Alpha & Brava (Firth of Forth)	355 per project	530	15m (x6)	54.8
Teesside A & B (Dogger Bank)	950 per project	573 (Teesside A) 484 (Teesside B)	10m (x2)	40
Creyke Beck A & B (Dogger Bank)	950 per project	420 (Creyke Beck A) 378 (Ceyke Beck B)	Not given but assumed to be 10m (x2)	27
Hornsea Project One	450	150	10m (x4)	10.5
East Anglia ONE	550	100	Not given but assumed to be 10m (x4)	9.5
Rampion	230	23	10m (x4)	3.2
Total	**5,740**	**7,394**	**-**	**146**

Note: [1]Calculated from information provided in the Environmental Statements, assumes an inter-array cable width of 10m.

Sources: Moray Offshore Renewables Limited (2012), Seagreen Wind Energy Limited (2012), Forewind (2014), Smart Wind (2013), East Anglia Offshore Wind Limited (2012), E.ON Climate & Renewables UK Rampion Offshore Wind Limited (2012).

In 2011, The Crown Estate and National Grid undertook an offshore transmission network feasibility study to identify and assess the feasibility, benefits and challenges of adopting a more coordinated approach to the development of offshore transmission infrastructure. Using a number of broad scenarios for the deployment of offshore generation up to 2030, the report compared a number of design strategies: a purely radial design, radial plus (use of larger assets but without inter-zonal interconnection) and a fully coordinated solution (The Crown Estate & National Grid 2011). The study identified a number of benefits that were likely to result from the development of a coordinated offshore transmission network:

- Environmental and consenting benefits;
- Improved management of valuable resources including land take, corridor routes, and manufacturing capability;
- Reduced cost for UK consumer (capital cost reductions and also a reduction in operational costs such as maintenance costs and congestion management costs in relation to system operation); and
- A flexible offshore transmission network that is better able to respond to future challenges.

Similarly, the most recent National Grid Electricity Ten Year Statement 2015 compared radial and coordinated design strategies to consider options to improve the connection of offshore generation, particularly from the large offshore wind zones. In the event of the loss of any single offshore cable, the coordinated design strategy provided an alternative path for the power to the onshore collector substation. Also, larger offshore generation areas within reasonable distance of each other may offer interconnection opportunities and share onshore collector substation capacity (National Grid 2015).

OSPAR (2009a) noted that the number of offshore wind farm transmission cables would grow rapidly which could intensify the potential environmental impacts resulting from submarine cables. Potential impacts included seabed disturbance and associated impacts of damage, displacement or disturbance of flora and fauna, increased turbidity, release of contaminants and alteration of sediments. These effects were mainly restricted to the installation, repair works and/or removal phase and were generally temporary. In addition, their spatial extent was limited to the cable corridor. The principal risk was to sensitive habitats which include, for example, slower growing vulnerable or fragile species (OSPAR 2009a).

Cables are buried by either ploughing, jetting, trenching, rock wheel cutting or mechanical chain excavation or in difficult areas are laid straight onto the seabed and covered with protective mattresses (BERR 2008). Typically the corridor area affected by burial is 4-6m wide (Lambkin *et al.* 2009), with depth of burial dependant on seabed conditions and potential threats to the cables (Table 5.11). During cable burial sediments become mobilised into suspension and consequentially produce similar environmental effects as dredging activities, discussed above. Although suspended sediment plumes can cause increased turbidity and oxygen demand in the water column, in many cases cabling is likely to take place in regions with already elevated SSC due to ambient current regimes, occasional storm activity and fishing activities along the cable route (Lambkin *et al*. 2009). The most recent review of post-consent monitoring of twenty two Round 1 and 2 wind farm sites indicated that increases in SSC were localised and temporary during construction and cable laying operations, with increases in SSC often within the limits of natural variation present at the site (MMO 2014).

Table 5.11: Recommended target cable burial depths for subsea ploughs for varying seabed conditions and threats

Threat	Hard Ground (clay > 72kPa, rock)	Soft – Firm Soils (sand, gravel, clay 18-72kPa)	Very Soft – Soft Soils (mud, silt, clay 2-18kPa)
Trawl boards, beam trawls, scallop dredges	<0.4m	0.5m	>0.5m
Hydraulic dredges	<0.4m	0.6m	N/A
Slow net fishing anchors	N/A	2.0m	>2.0m
Ship's anchors up to 10,000t DWT (50% world fleet)	<1.5m	2.1m	7.3m
Ship's anchors up to 100,000t DWT (95% world fleet)	<2.2m	2.9m	9.2m

Source: BERR (2008)

With respect to the larger consented Round 3 projects, sediment dispersion modelling to inform the assessment of cable laying operations within the Dogger Bank Teesside A & B export cable corridor (which is one of the longest proposed, see Table 5.10), indicated that the maximum predicted SSC was 100-200mg/l in two small patches, near the coast and about 50km offshore. Concentrations were typically less than 100mg/l along large proportions of the corridor and maximum concentrations gradually reduced with distance from the corridor until they were predicted to be at the background of 2mg/l, up to 50km to the north and up to 45km south of the corridor. During the 30-day modelling simulation, background levels were exceeded over 90% of the time along the export cable route. Where suspended sediment concentrations were greater that 200mg/l close to the coast, the exceedance time for concentrations greater than 2mg/l was less than 10% of the simulation period. Analysis of the high suspended sediment coastal plume showed that 200mg/l was only exceeded for two hours of the 30-day simulation before returning to lower concentrations. Maximum sediment deposition along the export cable corridor was predicted to be less than 5mm, reducing to 0.5mm approximately 25-35km north of the corridor (Forewind 2014).

It is therefore suggested that although the amount of cabling required to support the expanding development of OWF sites will increase significantly, the potential effects are temporary, localised and within natural variability. For example, concentrations of suspended sediment in the southern North Sea in summer are generally low in offshore areas (0 to 4mg/l), with higher concentrations found in estuaries, especially the Thames and Humber with values over 300mg/l. Winter suspended sediment concentrations are higher, generally about double the summer concentrations but with similar patterns in the coastal areas (UKMMAS 2010).

Operational phase

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.

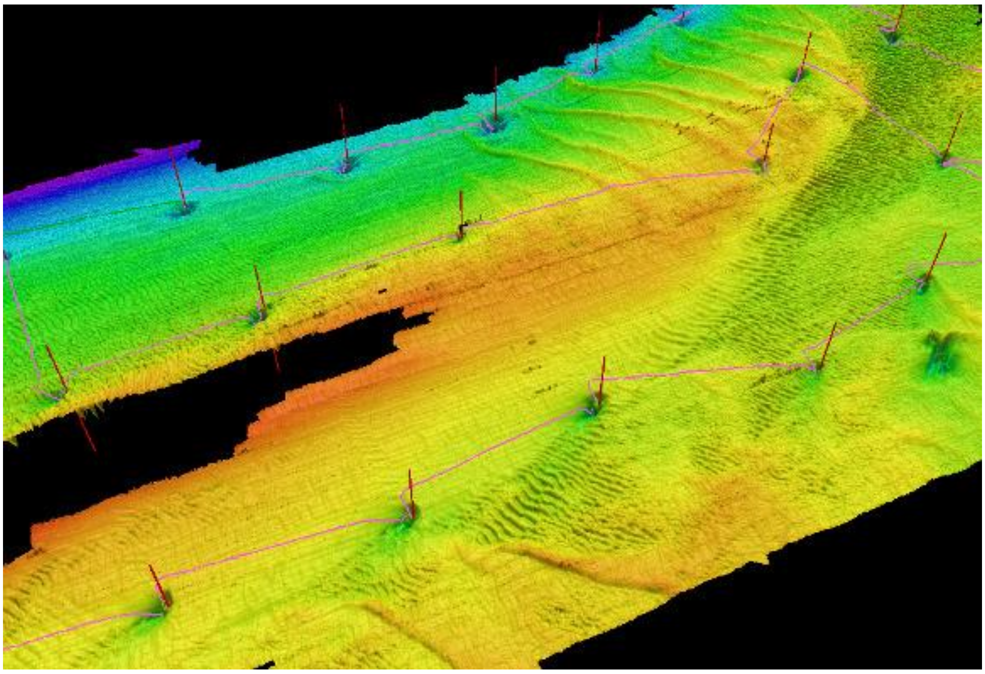
Scour is a complex process, involving various interactions between the structure and water flow patterns and with implications for stability of the structure and sediment transport in the vicinity. Scour depth around piles is often quantified in relation to the pile diameter (S/D): HR Wallingford (2008) 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 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). Data for Robin Rigg (Carroll *et al.* 2010) indicated values from 1.3D up to 1.77D. The extensive data set for this site (at 1-10m water depth) and those at Princess Amalia wind farm (offshore Netherlands in 19-24m water depth) and the range of scour values described by the COWRIE report for the sites, highlights the need for scour calculations to include geotechnical conditions and how the seabed soil structure varies spatially and with depth.

In the context of physical damage to features and habitats, 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 total scoured area at this location was of the order of 50-100m^2, and exposed sediments differed to the pre-installation substrate (but typical of till exposures in the area). One year later, scour radii were much lower, with areas typically in the range 3-12m^2 (excluding the pile itself) and two years later scour depths for most piles were reduced to 0-4m in depth, with a trend for most scour holes to be backfilled to some extent (Carroll *et al.* 2010). 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 was 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 previous FEPA licence monitoring conditions, providing a 4-year time series. Analysis by CEFAS (2006) indicates the development of scour pits associated with the monopiles (typical depths up to 5m and horizontal diameter 60m); and scour tails (trains of bedforms) extending from one monopile to the nearest downstream neighbour (Figure 5.9). 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 (note the whole area is characterised by active sandwaves, which do not appear to be influenced by the construction (CEFAS 2006)).

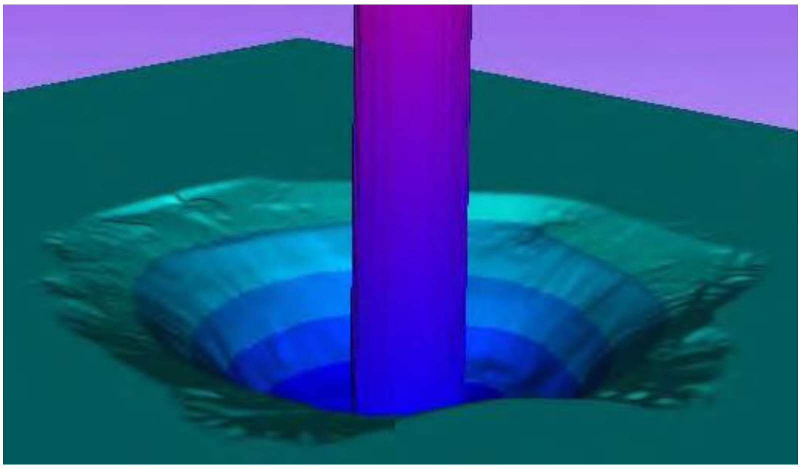
Figure 5.9: Fledermaus image showing swathe bathymetry of February 2005 from the Scroby Sands OWF.



Source: CEFAS (2006)

The seven wind turbine monopiles at Arklow Bank (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 (wave-breaking occurs during storms). In the short delay between monopile installation and scour protection, scour holes (4m deep, 25m diameter, Figure 5.10) 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 habitat modification is therefore around 450m^2 per pile (ABPmer 2008).

Figure 5.10: Contour plot of scour hole observed after monopile installation, Arklow Bank



Source: HR Wallingford (2008).

The recent review of post-consent monitoring of R1 and R2 windfarms (MMO 2014), indicated that the rationale for scour monitoring of sites was not triggered specifically by sensitive environmental receptors but was typically undertaken to inform the structural and engineering integrity of structures including foundations and export cables. The extent of scour was over-predicted in the Environmental Statements reviewed. Modelling was based on the monopile diameter, but did not take into account the underlying substrate or thickness (or absence) of overlying mobile sediments. Where sandy sediments occur in greater thicknesses, these may be scoured to an equilibrium depth and width which is roughly proportional to turbine foundation diameter (on monopile foundation structures). For sites located on highly mobile sandbanks or in areas of large mobile bedforms, scour patterns may be more variable with secondary scour forming around any foundation protection and the formation of scour wakes (e.g. as occurs at Scroby Sands). To date, all the UK windfarm monitoring is of monopile foundation structures; the only jacket foundation OWF included in the MMO review was Ormonde, which does not yet have any post-consent monitoring available. The review of post-consent scour monitoring data did not identify any significant adverse impacts on sensitive physical receptors but indicated that scour monitoring may be required where seabed erosion is identified as a potential stressor to sensitive receptors including the benthos. The review recommended that the frequency of scour monitoring should be based on the geological and metocean characteristics, with areas covered by a thin veneer of mobile sediments requiring less monitoring than locations with large mobile bedforms, palaeochannels or sandbanks (MMO 2014).

With respect to the consented Round 3 developments, scour assessments of the different potential foundation options (see Table 5.9) above indicates that in general gravity base foundations are likely to represent the worst case scenario with respect to predicted scour depths and volumes (for example, scour depths of 9-12m and volumes of 26,663m^3 were estimated for the 65m diameter gravity base foundation option for the Moray Firth development projects). However, for all the consented Round 3 projects the potential for scour will be revisited during the engineering design process when detailed geotechnical information may be available. If scour protection is required (as is likely with gravity base foundations) then scour protection measures (e.g. rock armour, concrete mattresses, frond mats etc) would be used and therefore scour is unlikely to be a significant environmental issue (although the introduction and colonisation of hard substrates (e.g. rock armour) may have a significant effect – see Section 5.6). Alternative development pathways such as the use of floating wind turbines would remove much of the construction impact associated with the generation of SSC through dredging and seabed preparation activities, together with the operational impact of scour.

Oil and gas

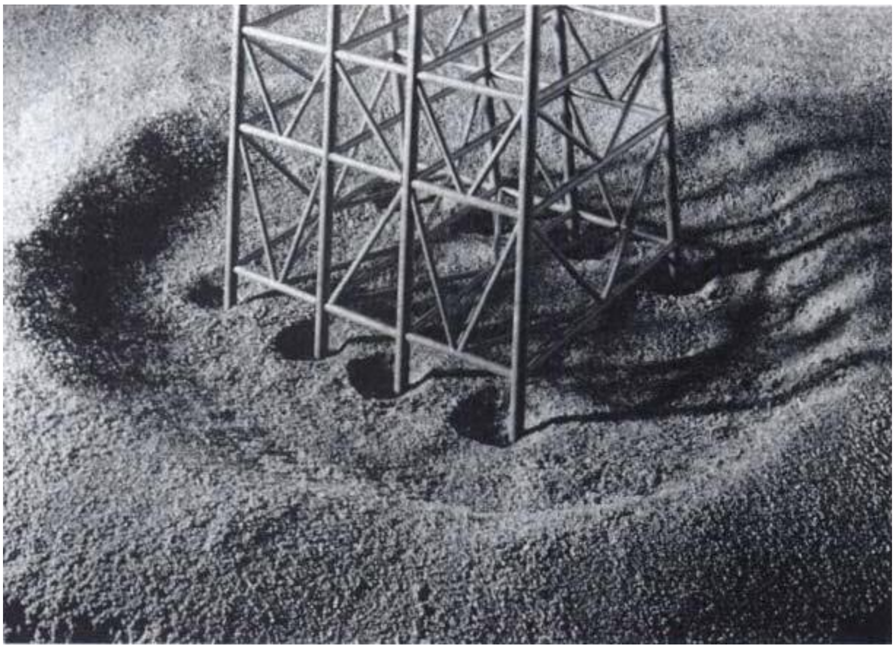
Similar to OWF, the impact of oil and gas installations on the seabed are considered minor on a regional scale in comparison to fishing activities. At present and for the foreseeable future, hydrocarbon developments are in regions dominated by faunal communities and therefore share most of the potential physical impacts with OWF, presented above. The primary issue is the placing of the infrastructure on the seabed and associated loss of habitat and installation issues described for OWF. The use of remotely operated vehicles (ROV) and precise navigational equipment to make it easier to avoid disturbance of vulnerable marine communities (OSPAR 2009b).

As described in the OWF section, the placement of jack-up legs on the seabed may cause localised and temporary physical disturbance. With respect to oil and gas activities, jack-up drilling rigs are normally used in shallower water depths (usually <100m). In deeper waters, semi-submersible rigs may be used. These typically use between 8 and 12 anchors to hold position, the radius of which depends on the water depth, seabed conditions and anticipated metocean conditions. For example, a review of a number of relevant Environmental Statements indicated that the estimated area of seabed affected by the use of semi-submersible rigs varied between 0.009km^2 in 93m water depth (Marathon Oil UK Limited 2005) to 0.11km^2 in water depths of 435m (Total 2014). The depth of sediment over-turned by anchor-scarring would be of the order of a few metres and exposed sediments are likely to be qualitatively similar to existing surficial sediments.

Another significant physical effect associated with oil and gas developments is the laying of pipelines, umbilicals and cables. In UK waters over 16,000km of oil and gas production pipelines are currently in use (https://www.gov.uk/guidance/oil-and-gas-infrastructure). The physical effects of pipelines, umbilicals and cables are the essentially the same as those for cabling presented in the OWF section above, with the footprint primarily being dependent on whether it is buried or not and the hydrology and sediment dynamics in the locality. Monitoring of the integrity of the pipelines is standard practice and therefore associated spatial environmental effects such as scour are well surveyed.

Although jacket structures piled to the seabed have been extensively used throughout the UKCS for oil and gas production, and in the southern North Sea have experienced substantial scour (and employed scour protection measures) (van Dijk 1980), this appears to have been regarded as 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 5.11). Scour protection in the form of gravel, rocks, sandbags, gabions, pre-formed concrete blocks or frond mats is routinely used for subsea structures and for pipelines to prevent free-spanning (with resulting structural and snagging risks).

Figure 5.11: Representation of global and local scour around jacket structure



Source: Angus & Moore (1982)

Gas storage

Gas storage projects in UK waters currently use existing hydrocarbon reservoirs and existing infrastructure, and impacts are the same as those detailed for oil and gas installations. However, those that are located in non hydrocarbon reservoirs (e.g. salt caverns), which require excavation, may potentially have slightly different physical impacts on the seabed and habitats.

The Environmental Statement (Gateway 2007) for a gas storage project (currently on hold) in the Eastern Irish Sea identified the following activities which could result in physical disturbance to the seabed:

- Drilling operations during cavern creation resulting in the discharge of cuttings
- Installation of the monopods (monopile foundations)
- Installation of pipelines/cables (including dredging, ploughing and jetting)
- Temporary presence of rigs and vessels during construction, installation and maintenance activities

The presence of rigs and vessels, installation of foundations, pipelines/cables and the effects of structures in the water column during operation are all discussed in the OWF and Oil & Gas sections above. In terms of the discharge of drill cuttings, Gateway (2007) estimated that approximately 6,700 tonnes of cuttings from overlying rock strata would be produced and discharged just below the sea surface to allow access for the creation of 20 separate gas storage caverns within the underlying salt strata. Modelled deposition of the material on the seabed predicted that 95% (mostly particles >1mm diameter) would be deposited within 165m of the discharge point and the remaining finer particles would settle over a wider area at low small concentrations and be undetectable. The effect of additional suspended sediment from drilling within the water column was likely to be transitory.

Carbon dioxide storage

The physical impacts of carbon dioxide storage projects are largely covered by the OWF, oil and gas and gas storage sections. For example, the offshore Environment Statement for the Yorkshire and Humber CCS offshore pipeline and storage project (National Grid 2015) indicated that sources of physical disturbance associated with the project included:

- Disturbance of nearshore and offshore seabed from pipeline installation (trenching, pre sweeping, lay-barge anchoring, rock dump including pipeline and cable crossings)
- Disturbance from installation of the microseismic network (up to 31 seismometers of 6" diameter connected by up to 40km of 25mm cable, laid at a depth of between 0.6-1m below the seabed).
- Disturbance of seabed during rig placement (spud cans and if used, stabilisation materials)
- Disturbance of seabed from installation of the NUI (normally unmanned installation)
- Disturbance of seabed from surface hole cuttings discharge

The ES concluded that the installation of the pipeline, microseismic network, NUI and drilling rig placement will generate physical disturbance to the seabed over a limited spatial extent. Given the relatively limited scale of activities and inferred general resilience and recovery potential of the seabed, habitats and species, it was concluded that there would be a negligible to moderate level of effect at the seabed with an associated low level of significance.

Tidal stream

The devices currently in use or production have one of 4 support structure types (Rourke *et al.* 2010):

- Gravity structure
- Single monopile
- Tethered floating structure
- Tripod structure – using 3 steel monopiles

The physical effects associated with the installation, decommissioning and physical presence of a structure within the water column are all discussed within the OWF and oil and gas sections above, with cabling again being a potentially important issue as the number and extent of tidal stream deployments increase.

One of the first tidal stream projects to deploy will be the Meygen tidal stream project in the Inner Sound (Pentland Firth) consented in 2013 for the first phase for the installation in stages of up to 61 turbines (the original application was for up to 86 turbines – see Table 5.12) with a permitted capacity of up to 86 megawatts. Stage one of the consented development was limited to a maximum of 6 turbines[60]. With respect to potential physical disturbance effects, the Environmental Statement (Meygen 2012) assessed the parameters described in Table 5.12.

Table 5.12: Worst case parameters for the Meygen project with respect to physical disturbance effects

Project parameters	Details
86 monopile turbine support structures (TSSs)	The maximum amount of drill cuttings that would be generated from turbine support installations is 17,200m^3.
86 gravity base TSSs	Each GBS TSS (consisting of a steel tripod with large steel weights on each of the three legs) has a maximum footprint of 40m x 30m. The total footprint for 86 turbines is 0.103km^2.
86, 120mm unbundled cables each 1,300m in length with split pipe armouring	The maximum physical area of the seabed occupied by the cables is 0.027km^2. Based on a maximum 1.3km of cable from Horizontal Directional Drill (HDD) bore exit to turbine, and a cable diameter of 120mm (x2 to account for split pipe armouring) for 86 turbines.

Source: Meygen (2012).

Like many of the areas where tidal stream devices are likely to be deployed, the Inner Sound seabed is current-scoured bedrock, so indirect effects through sediment re-suspension from piling activities or cable installation were not expected. The ES considered any impact to be of short-term duration and that any changes would be imperceptible in comparison to the baseline conditions (Meygen 2012). The Meygen project will be the first small tidal stream array to be constructed and the staged nature of its consent will allow further development to be informed by the results of site environmental monitoring.

Dynamic effects on the physical environment associated with the movement of blades within the water column are discussed in Section 5.5.2.

Tidal range

There are several different designs for extracting energy from tidal range; the main ones being tidal barrages and tidal lagoons. Both barrage and lagoon designs may have large physical footprints and may have significant environmental impacts on both the physical environment and associated habitats. However, mitigation measures (e.g. two way operation, regular sluicing and fish diversion) may reduce the impact.

Tidal barrages

The building of a tidal barrage across a bay or estuary will permanently destroy the habitat under the physical footprint of the structure and modify others both within the wider development footprint and upstream and downstream of the facility. It may also alter tidal and residual flows and impact on the hydrography and physical characteristics of the wider region.

The previously proposed 16km long Severn Barrage from Cardiff to Western-Super-Mare was calculated to have a structural footprint of between 795,000 and 1,176,000m^2 (Sir Robert McAlpine Ltd 2002) although its impact would have extended to the full 480km^2 of the basin (DECC 2010). This physical footprint and associated direct impact of removal of habitat are on a larger scale than any other renewable energy technology. Physical effects of piling, seabed preparation, dredging for construction material and the actual laying of the structure on the

[60] The approved Construction Method Statement for Stage one indicates that 4 gravity base turbine support structures made up of a tripod substructure and 6 ballast blocks will be deployed.

seabed are discussed in the OWF section but may apply on a larger scale in relation to tidal barrages.

Tidal lagoons

Tidal lagoons are similar to barrages in construction impact although they do not span the whole channel width. To date, only one lagoon project has gone through the planning process with a development consent order granted for the Tidal Lagoon Swansea Bay project in June 2015 (a correction order was issued in October 2015). A number of other lagoon projects (Newport, West Somerset, Cardiff) are at an earlier development stage and expecting to submit applications in 2017-2018. The Swansea Bay project does not yet have a marine licence from NRW or a lease from The Crown Estate. The project will involve the construction of a seawall approximately 9.5km long impounding some 11.5km^2 of the seabed, foreshore and intertidal area of Swansea Bay. The Environmental Statement (Tidal Lagoon Swansea Bay 2014) described potential effects with respect to coastal processes and sediment transport, including:

- sediment dispersion arising from dredging activities creating a plume which will impact upon the water column and estuary bed – it was estimated that 8.1 million m3 of sediment would be dredged for the project, of which 7.3Mm3 would be used for the project.
- the direct removal (loss) or physical modification to the existing seabed within the project footprint – it was estimated that 0.21km2 of intertidal and 0.68km2 of subtidal habitats would be lost under the lagoon walls and turbine housing footprint in addition to significant removal of sediment within the lagoon as part of the dredging activities
- modification to both near and far-field hydrodynamics (e.g. water levels, flow speeds and waves) as a result of construction works and capital dredge disposal; and
- direct and indirect changes to the sediment (morphological) regime due to erosion/ accretion from the presence of the new infrastructure, driven by changes to sediment transport within Swansea Bay.

The assessment was informed by modelling work which indicated that during the construction phase, there was the potential for increased SSC, and subsequent deposition, within Swansea Bay resulting from the dredging and construction activity. The predicted increases tended to be of greatest magnitude closest to the location of the construction activity, although increased SSC values were shown to be relatively short-lived before returning to within peak natural background levels.

During the construction and operations phase of the project there is expected to be changes to the hydrodynamic and wave conditions across Swansea Bay, with associated effects on sediment transport. During the operational phase, there is a potential for changes in deposition of fine material within the lagoon. Directly in the lee of the turbines and sluice gates, the higher flows experienced over the flood tide act to maintain material in suspension, thus reducing the potential for deposition in these areas. Across the upper subtidal and lower intertidal regions of the lagoon, the reduced tidal flows and calmer wave conditions (compared to the baseline, as a result of sheltering by the lagoon walls) result in a predicted increase in deposition of fine material. Outside the lagoon, the reduced flows in the western part of the Bay result in a predicted increase in the deposition of fine material across parts of the shallow subtidal region.

With regard to coarser material, inside the lagoon a similar change is predicted to that described for the finer sediment. In the lee of the turbine array, the increased flows have the potential to reduce deposition, with lower flows towards the back of the lagoon resulting in the potential for increased deposition. Outside of the lagoon, the development is predicted to interrupt the transport of sand from the area around the Neath Delta, in a westward direction towards the western part of the Bay. This is predicted to result in a build-up of sand material along the outside of the eastern lagoon (Tidal Lagoon Swansea Bay 2014).

The effects of the impoundment of water, associated reduction in current velocities and sediment characteristics is discussed in Section 5.5.2.

Wave

Most of the wave energy converting devices are either catenary or single point moored (Oxley 2006, Harris *et al.* 2004), with associated physical impacts on the seabed for different foundation types discussed in the OWF section. Different anchoring types for wave devices are summarised below (Harris *et al.* 2004):

- Drag embedment anchor - holding capacity is generated in the main instalment direction by the embedment of the anchor in the ground
- Driven pile or suction anchor - holding capacity is generated by forcing a pile mechanically or from a pressure difference into the ground, providing friction along the pile and the ground.
- High drilled and grouted anchor - holding capacity is generated by grouting a pile in a rock with a pre-drilled hole.
- Gravity anchor - holding capacity is generated by dead weight providing friction between seabed and anchor

The anchors used for wave devices are smaller than those deployed for OWF, with concrete gravity foundations at the Lyskil research site in Sweden being >2m in diameter (Leijon *et al*. 2008) compared to 20-50m for individual OWF installations. However, the associated impacts remain the same, just on a smaller scale depending on how many devices and arrays are deployed. A study into the effects of moored wave energy devices on soft-bottomed communities at the Lysekil research site (Langhammer 2010) from 2004-2008 showed that there was only minor direct ecological impacts of the device foundations beyond the natural level of variation, which was highly variable in space and time due to strong natural disturbances of the seabed by powerful waves. The primary issue is scour, discussed in the OWF section above. It is however likely that only demonstrator scale wave projects will be developed within the lifetime of this report (apart from in the Pentland Firth and Orkney region) and therefore the scale of associated effects are expected to be minimal, with an overall spatial footprint of arrays of between 1 to 10km^2.

Some wave energy devices are shoreline based (e.g. LIMPET) and therefore have associated physical impacts on coastal processes and habitats. This is predominantly due to the physical footprint of the structure, which is semipermanent/permanent and therefore unlikely to be removed after use. Wave devices work by acting as wave breakers or by removing the wave energy from the sea and have associated impacts on current and water column characteristics and sediment deposition and accretion. These physical effects of the presence of the device in the water column are discussed further in Section 5.5.2.

5.4.3.2 Physical damage to biotopes from infrastructure construction, vessel/rig anchoring etc (direct effects on the physical environment)

As described in Section 5.4.3.1, direct physical effects on habitats arise from various activities associated with the construction and placement of installations, cables and pipelines; with the operational presence of the installation and with vessel activities throughout construction, operations and decommissioning phases. These activities give rise to three mechanisms which produce habitat change: the introduction of hard substrates into a sedimentary environment, the movement of sedimentary particles over various time scales (scour, winnowing, suspended sediments and particle settlement) and direct damage to biota caused by physical abrasion (dropped objects). Direct habitat removal results from dredging/ploughing for cable laying and site preparation (for OWF gravity foundations). The effects of offshore disposal of dredging spoil are considered below. There are both short- and long-term implications for the local biological communities. The significance of any effects is likely to depend on the natural disturbance regime and the stability and resilience of the communities.

The response of benthic macrofauna to disturbance has been well characterised in peer-reviewed literature, with increases in abundance of small opportunistic fauna and decreases in larger more specialised fauna. Following a disturbance the number of species and total biomass decrease and recovery periods can vary depending on local hydrodynamic regimes, recruitment processes and the relic community at the site. Analytical and modelling work of four common benthic species in a sedimentary basin protected by a storm surge barrier in the Netherlands (Cozzoli *et al.* 2014), shows that the long-term fluctuations in macrozoobenthic biomass stocks are partly related to the effect of the coastal defence infrastructures on the basin morphology and hydrodynamics.

Potential impacts associated with construction activities

Suspended sediments

The dispersion and settling of sediment plumes from construction activities and cable or pipeline trenching activities have the potential to cause effects on pelagic and benthic biota through a number of pathways: the reduction of light for photosynthesis (Newell *et al.* 1998), temporarily altering the nature of the seabed sediments or near surface waters and the clogging of gills and feeding mechanisms. The extent of effects will vary according to the geographic location, 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). Newell *et al*. (1998) concluded that there was little evidence that deposition of sediments from outwash during the dredging process had a significant impact on the benthos outside the immediate dredged area. However, more recent evidence (Desprez *et al*. 2010) suggests that the biological impact may extend outside the immediate vicinity of the dredged area ($\leq$2km) and corresponds to the “footprint” of sediment deposition and transport along the axis of tidal streams. Desprez *et al.* (2010) found a significant reduction in species diversity and abundance associated with sediments containing high levels of fine sand (from re-sorting along tidal gradients). Suspended particulate material (SPM) does not only affect species presence or absence; SPM concentrations of $\geq$50mg/l have been shown to affect reproduction in the scleractinian coral *Acropora digitifera* (Gilmour 1999) i.e. fertilisation, larval development and larval settlement. Similar effects may be possible in the cold water corals found in deeper water of the UKCS such as *Lophelia pertusa*.

Many construction phase activities, as discussed in Section 5.4.3.1, are considered to have adverse effects due to the increase the natural background levels of suspended particulate matter (SPM) in the water column (Degraer *et al.* 2013). However, as construction activities are relatively short and localised, the overall increase in SPM concentration is limited. Regardless of extent of impact, where the near-bed SPM concentrations are naturally high, as in coastal and southern North Sea areas and the Irish Sea, the effects of such anthropogenic sediment plumes are unlikely to be significant on the existing seabed communities.

Monitoring data from Round 1 OWF sites (DECC 2008) appear to show small temporary increases of suspended sediment concentrations during construction works, followed by minimal increases indistinguishable from background conditions during operations.

Offshore disposal of seabed dredged material (long term disturbance)

The effects of disposal of dredged material on the existing seabed and benthos are well informed by the extensive literature associated with civil engineering projects and the dredging industry e.g. Maurer *et al.* (1981, 1982), Harvey *et al*. (1998), Miller *et al.* (2002) and Wilber & Clarke (2007) e.g. studies of thin-layer (<15cm) disposal of dredged material (Wilber *et al*. 2007); and Last *et al*. (2011) who provide some useful experimental data on behavioural responses of species relevant to the UK aggregate industry operating locations in Regional Seas 2 and 3.

Benthic mortality and associated benthic community change is governed by individual species' ability to survive burial and eventually re-emerge to the sediment/water interface or at least re-establish a connection with it. The extent of effects therefore will vary according to the depth of overburden, frequency of burial occurrence and the tolerance of the species involved. The average and extreme natural levels of sediment transportation/deposition in an area are reflected in the benthic composition; in areas where large re-suspension and sedimentation events are the norm, the fauna is unlikely to be vulnerable to such effects arising from anthropogenic sources such as construction activities associated with marine developments.

Many species can emerge from considerable overburdens e.g. the bivalve *Mercenaria mercenaria* can migrate through ≤16cm of sand under summer temperatures and within a short period of time (Maurer *et al*. 1981); the polychaete *Nereis succinea* can survive a 90cm sediment overburden (Maurer *et al*. 1982). Survival and overburden escape ability also vary with life stages; the remarkable ability of *M. mercenaria* described above applies only to young animals, while adults can only tolerate a 1cm overburden. It seems likely that as deep burrowing organisms, they are habitually living close to their depth tolerance. Other species are considerably less tolerant and will die within hours or days from oxygen depletion in the sediment. The instantaneous deposition of large quantities of sediment, such as during the disposal of dredged material, can result in total mortality (Miller *et al*. 2002), while burial beneath thinner layers up to 25mm thick may have no discernible effect (Trannum *et al.* 2010). If the deposited material is not identical to the sediments on which it settles, or if it has been contaminated, the rate of mortality may increase (Trannum *et al*. 2010, Holdway 2002).

Recovery of disposal areas occurs through a mixture of vertical migration of buried fauna, together with sideways migration into the area from the edges, and settlement of new larvae from the plankton. The community recolonising a disturbed area is likely to differ from that which existed prior to construction. Opportunistic species will tend to dominate initially and on occasion, introduced and invasive species may then exploit the disturbed site (Bulleri & Chapman 2009). Harvey *et al*. (1998) suggest that it may take more than two years for a community to return to a closer resemblance of its original state (although if long lived species were present this could be much longer). Shallow water (<20m) habitats in wave or current exposed regimes, with unconsolidated fine grained sediments have a high rate of natural disturbance and the benthos represents an early successional stage community. Species tend to be short lived and rapid reproducers and it is generally accepted that they recover from disturbance within months. By contrast a deep stable sand and gravel habitat is believed to take years to recover. Recent studies in the Netherlands (de Jong *et al.* 2015) describe how the presence of a distinct, highly productive and species-rich *Abra alba* assemblage occurred at both an 8m deepened shipping lane and near a disposal site for dredged fine sediment, suggesting that some of the fauna entrained in the dredge material survive disposal and migrate through the overburden.

Sabellaria spinulosa is described as being tolerant of smothering (MarLIN), this is supported by Last *et al*. (2011) who found it to be highly tolerant of short term ($\leq$32 day) burial in fine sand whatever the burial depth. They observed ‘emergence tube’ construction under sediment burial conditions. This was found to be more extensive under the shallow and medium than deep burials and was most rapid during an 8-day burial (~1mm per day) rather than 16 or 32 days burial. They suggested that emergence tube formation was a mechanism by which *S. spinulosa* can avoid gradual burial and/or a possible method of adult dispersal. Other species assessed were *Psammechinus miliaris*, able to remerge from burial depths of 7cm, with better survival in coarse sediments than fine sand and was classed as moderately tolerant; while the brittle star *Ophiura ophiura* and the anemone *Sagartiogeton laceratus* were found to be highly tolerant of burial, surviving for long periods and in all sediment fractions tested. Of the two sessile, epilithic species tested, the sea squirt *Ciona intestinalis* was, unsurprisingly, found to be highly intolerant of burial, showing no ability to re-emerge, whereas *Mytilus edulis* tolerated a lengthy burial but was also unable to re-emerge.

Anchor scarring, anchor mounds, cable scrape and trenching

Habitat recovery from temporary disturbance (caused by anchor scarring, anchor mounds, cable scrape and trenching) will depend primarily on re-mobilisation of sediments by current shear. Subsequent 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 in most of the shallower parts of the UKCS, 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). For trenching, the estimate of 4-6 years given by de Jong *et al*. (2016) in relation to their investigation of ecosystem constraints for marine sand extraction is useful. They conclude that macrozoobenthos in a borrow pit with a tide-averaged bed shear stress of around $0.41Nm^{-2}$ (the figure at which coarse sand particles are mobilised) expected to return back to pre-extraction conditions within 4–6 years. When tide-averaged bed shear stress decreases below $0.17Nm^{-2}$ (the point at which fine sand mobilises), enhanced macrozoobenthic species richness and biomass can occur. Below a tide-averaged bed shear stress of $0.08Nm^{-2}$ (the upper threshold for medium silt), increasing abundance and biomass of brittle stars, white furrow shell (*Abra alba*) and plaice (*Platessa platessa*) can be expected. Below $0.04Nm^{-2}$, an over-dominance and high biomass of brittle stars can be expected whereas demersal fish biomass and species composition may return to reference conditions.

Mud habitats, by contrast, are more sensitive to physical disturbance than the coarser sediments typical of high wave- and current-energy areas. The muddy sediments of deeper or quieter waters support benthic communities often characterised by large burrowing crustaceans and pennatulid sea-pens (*Virgularia mirabilis* and *Pennatula phosphorea*). Pennatulid mortality is probably high following physical disturbance, but crustaceans are probably able to restore burrow entrances following limited physical disturbance of the sediment surface (a few cm). Re-establishment of pennatulids is likely to take in excess of 5 years due to their slow growth rate (Gates & Jones 2012).

Placement of Infrastructure

Effects on habitats and communities (biotopes) from the construction of infrastructure (platform jackets, subsea wellheads and pipelines) for oil and gas developments are well documented in previous SEAs and there are many similarities with other types marine energy developments.

Techniques for laying of pipelines and cables are similar as are methods of scour and impact protection using mattresses and rock placement. Direct displacement or loss of seabed habitat will occur during foundations preparation, jacket footings, subsea installations, pipelines and pipeline protection. Habitat change can also result from ploughing for pipeline and cable laying. Many of these seabed activities during construction and decommissioning create a temporary increase in suspended sediments, followed by deposition of particles at varying distances from the activity site dependent on the sediment particle size and seabed current speeds. In shelf depths additional habitat loss can result from the use temporary anchors on the seabed from pipelay vessels or construction barges.

Construction of gas storage caverns and CO_2 storage facilities result is similar impact mechanisms as oil and gas construction and effects on biotopes will be comparable. The volumes of cuttings to be discharged during construction will create elevated concentrations of suspended sediments during the drilling period and the normal mitigation of effects through seasonal or spatial avoidance of vulnerable habitats such as herring spawning grounds would be standard practice.

Tidal current arrays are more likely to be installed on hard bottom seabeds, or those with coarse sediments, both being the products of high-energy environments. Benthic infaunal communities of coarse sediments are adapted to living in mobile substrates, but the sessile epibiota of hard substrata are unable to recover from burial should it occur e.g. due to a reduction in current speeds.

An overview of potential environmental interactions of tidal and wave energy generation devices given by Frid *et al.* (2012) underlined the lack of evidence on certain effects due to the limited development of the industry. Primary information comes from the Strangford Lough development and the UK's two test sites in Orkney and Cornwall. Assessments of various demonstrator projects e.g. in Ramsay Sound (Tidal Energy Ltd 2009) have concluded that the impacts on benthic habitats are absent or minimal, especially if electricity export cables are laid on the seabed rather than buried; however, burial or rock cover is normal practice to protect such cables. Placement of anchors, sinkers or turbine arrays creates short-term suspended sediment loads which quickly disperse widely or settle depending on particle size.

Wave energy converters typically have few predicted impacts, due to their relatively small direct area of interaction with the seabed. Significance of impact is strongly dependent on the species make-up of the local benthic and intertidal communities. The introduction of hard substrate and mooring lines are the primary mechanisms of impact.

Modelling and validation work by Krivtsov & Linfoot (2012) has shown that the area of benthic habitats adversely affected by the leading mooring line on a typical wave energy converter (height 19m, 16m diameter, mass 900 tonnes) monotonically increased with the increase in wave height. In regular waves of 6m height and 8s period, the area of benthic habitat adversely affected by the mooring lines may exceed $60m^2$. Moorings can adversely affect the coverage of sea grass (Hastings *et al*. 1995) and decrease the density of gymnamoebae (Anderson 1998), although it is noted that the microbial community is rarely included in UK (or other) offshore energy environmental monitoring programmes. Moore *et al*. (1998) provide evidence that human activity has adversely influenced reef growth of the calcareous tubeworm *Serpula vermicularis* through the physical disturbance caused by mooring ground tackle.

Construction and decommissioning of tidal barrages are likely to cause significant physical disturbance to the local environment. There are both short- and long-term implications for the local biological communities. The significance of any effects is likely to depend on the natural disturbance regime and the stability and resilience of the communities.

Predictions of environmental impact for the Severn barrage are summarised by Hooper & Austen (2013). As with the construction of other marine energy installations, construction of a tidal barrage will disturb seabed sediments giving rise to suspended sediment plumes, the particles of which will eventually settle onto the seabed at some distance from the construction site. Within these plumes the reduced water clarity and light penetration will impact plankton and fish in the water column; as settlement occurs, the benthic epifauna and infauna will be impacted on a spectrum ranging from no effect, through interference with feeding or digestion, to direct smothering and burial during rapid deposition of more than six or seven centimetres.

Habitat will be lost beneath the footprint of the tidal barrage, but the surface of the new structure will provide new areas for colonisation, albeit by different species. The presence of any hard substrate in areas of soft sediment (such as a muddy estuary) will act as a settlement surface, attracting species not otherwise able to extensively colonise the area and so increasing biodiversity. Evidence suggests, however, that the assemblages of species colonising artificial structures can differ from those on natural reefs (Moschella *et al*. 2005). The principal reasons for the differences are that artificial constructions have little physical similarity to natural habitats. Walls and pilings tend to be vertical, homogenous structures made of unnatural substances and lacking microhabitats and areas of refuge. They also create shelter and cause shading of the sea floor, extending the footprint of the impact (see Section 5.6).

Tidal lagoons are considered to be less environmentally damaging than barrages, since they do not obstruct the entire width of an estuary and also can be sited so as to minimise loss of intertidal areas. However, tidal lagoons would require considerably more construction materials than a barrage and damage to habitats during construction is likely to be greater and more prolonged.

Impacts during construction focus again on direct damage/obstruction to epibenthic species, and increases suspended sediment plumes followed by sediment deposition. Biological effects are likely in the subtidal benthos, the intertidal ecology and the plankton.

The area of direct loss of habitat beneath the lagoon wall will be dependent on the scale of project but is likely to be locally significant. The area lost is replaced by a greater area of new hard substrate habitat which will undergo colonisation to reach an ecological balanced community as seen at OWF turbine bases. As with the barrage though, constructed substrates of concrete are different from natural rock hard substrates and do not offer the heterogeneity and microhabitats for refuge and for predator-safe larval settlement.

Impacts from increased SPM will be as described above, but the estuarine location of tidal lagoons means that high SPM levels are a naturally frequent occurrence, hence benthic communities are adapted to survive them.

Potential impacts post-construction

Benthic communities have been monitored in the near-field around individual wind turbines, and in the far-field to identify any effects around the entire development array.

In a recent Defra investigation of how to optimise array forms for energy extraction and environmental benefit, Smith (2015) summarised how energy extraction by large arrays of wind turbines leads to a reduction in wind speed both within the array and in its lee, with consequent effects of a reduction in wave heights. Lower wave heights result in wave motion not propagating as far down into the water column, leading to less interaction between the waves and the seabed, and thus a decrease in resuspension of sediment and reduced water column turbidity. Sunlight can then penetrate further into the water column, giving rise to enhanced primary production and plankton growth (although potentially counteracted by reduced water column mixing and hence nutrient availability in stratified areas).

The primary driver of local ecosystem change is thus the reduction in wind speed in the array. For modelling purposes, Smith (2015) applied a 10% reduction based on reported observations from other sites; this lead to a reduction in wave height of 17%, a reduction in suspended sediment concentration of 25% and an increase in primary production of 8%. This work references a case study (van der Molen *et al*. 2014) which suggests also that the combined impact will be experienced to varying degrees across the array, depending on array layout and distance from turbines. Effects decrease with increasing distance between individual turbines and farms, suggesting that a smaller number of more powerful turbines may cause less impact within the water column and benthos than larger numbers of smaller ones.

Schröder *et al.* (2006) described benthic communities changes and changes to sediment composition in the vicinity of the FINO I research platform (German Bight; 28m water depth); these were attributed to hydrodynamic effects and the exclusion of trawling. Within scour pits (1-1.5m deep; up to 5m radius), sediment was more heterogenous following construction, and consisted of a layer of shell hash (sometimes more than 30cm thick) 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 changes observed over a one-year period within the 500m fishery exclusion zone, compared to fished areas, included increased densities of sedentary filter and deposit feeders and a reduction in numbers of mobile predators and scavengers. These effects are probably similarly widespread in exclusion zones around oil and gas infrastructure, but have not been well characterised in monitoring studies which have had a primary focus on the relationship between contamination and its effects with distance from the installation. However, Bergman *et al.* (2005) documented distinct differences in benthic communities between the fishery-closed area around gas production platform L07A in the southern North Sea (Frisian Front) and the regularly trawled reference areas. Dredge samples from the non-fished area near the platform had higher species richness and evenness and a higher abundance of mud shrimps (*Callianassa subterranea, Upogebia deltaura*) and bivalves (*Arctica islandica, Thracia convexa, Dosinia lupinus, Abra nitida, Cultellus pellucidus*). 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*.

The presence of scour does not appear to be always associated with benthic changes. At Barrow, despite previous scour observations, an epifaunal survey noted no effects on seabed habitats, which ranged from fine sand to cobble (consistent with a patchy sand veneer over glacial till) (RSK ENSR 2006).

At Horns Rev, no impacts attributable to the changes in the hydrodynamic regimes were detected on the seabed sediment structure, existing benthic communities, or established epibenthic communities (DONG Energy *et al.* 2006). From pre-construction to the post-construction period, a general increase in sediment coarseness and related changes to the infaunal community structure were found. However, these changes were also found at the reference sites hence could not be attributed to the presence of the wind farm.

No large-scale macrobenthic impacts were found during the first two post-construction surveys at the Thorntonbank six turbine array (Coates & Vincx 2010, Reubens *et al*. 2009); additional small scale sampling was carried out in 2010 to detect possible impacts on the soft-sediment macrobenthos in the immediate vicinity of a single turbine, two years after construction. A number of trends were observed at this scale: a lower median grain size and higher macrobenthic densities were detected in closer vicinity to the turbine; sediments from the south-west/north-east sites were characterised by high chlorophyll-a concentrations, a lower median grain size and high densities for *Lanice conchilega* and *Spiophanes bombyx*; whereas sediments from a south-east/north-west direction were mainly dominated by the tube building amphipod *Monocorophium acherusicum*. However, these three species are all known for stabilising soft substrates and Coates *et al.* (2012) concluded that this was a clear indication of a shifting macrobenthic community around the turbines on the Thorntonbank, which was yet to reach a stable balance.

Vandendriessche *et al.* (2015) also investigated effects from the Thorntonbank and Bligh Bank Belgian wind farms on epibenthos, demersal fish and benthopelagic fish. They detected several local and temporal effects including temporary construction effects - decreased densities of dab, ophiuroids and dragonets - and refugium effects e.g. the presence of relatively large plaice. No real edge effects due to changes in fisheries intensity were identified. Effects noted showed no consistency between the two wind farm areas.

Monitoring of Round 1 and 2 OWF sites has shown that in general, community disturbance outside the immediate area around piles has been minimal and cannot be distinguished from natural variability e.g. Robin Rigg in the Solway Firth (E.ON 2013). Three years of operational monitoring data showed no significant difference in benthic species composition over time.

The exclusion of fishing activity may be a significant causal factor in any benthic differences observed, but such effects may be difficult to distinguish from natural variability. For example, at North Hoyle a combination of grab sampling and beam trawling was used to assess effects on infauna and epifauna. The observed changes in numbers of species and individuals displayed no uniform pattern and were similar to changes at control stations, thus there was no substantial evidence of changes to habitats attributable to the wind farm (Npower 2007).

Recent satellite observations of two UK OWFs (London Array and Thanet) by Vanhellemont & Ruddick (2014) and aerial photographs from a Belgian OWF – Belwind 1 - (Baeye & Fettweis 2015) have shown that the individual wind turbines induce SPM plumes with concentrations that are considerably higher than in ambient waters. Landsat-8 imagery used by Vanhellemont & Ruddick (2014) revealed turbid wakes of individual turbines, 30–150m wide, several km in length and aligned with tidal currents. The source of the suspended material was not evident, but since scour protection was in place only at cable crossings and offshore sub stations (London Array) and along certain sections of the export cable (Thanet), it is possible that scoured material is coming from the monopiles or represents bedload sediment transport deflected upwards by the monopole obstruction. Turbine wakes of decreased velocity ($8cm^{-1}$) extending up to 2km from each source monopile in Liverpool Bay have also been shown by Cazeneva *et al*. (2014).

The underwater light field will be affected by increased suspended sediments and the turbid wakes could affect sediment transport and downstream sedimentation. Baeye & Fettweis (2015) showed that the SPM plumes were generated at the turbine piles, consistent with aerial and satellite imagery. They were well aligned with the tidal current direction in the wake of the monopiles, concentrations being estimated to reach up to 5 times that of the background concentration of about 3mg/l. Epifaunal communities colonising the monopile surface and the protective rock collar at the base were thought to play a key role as source of the suspended matter recorded in the plumes. The organisms filter and trap fine SPM from the water column, resulting in predominant accumulation of SPM, including detritus and (pseudo-) faeces, around the piles. When tidal currents exceed a certain velocity, fine particles in the nearbed fluff layer are re-suspended and transported downstream in the wake of the piles. SPM concentrations recorded by Baeye & Fettweis (2015) ranged from 0-20mg/l over the course of the full neap–spring tidal cycle. Maximum concentrations were reached mainly during spring tide, corresponding to the times when ebb and flood currents reach maximum speeds near the seabed (up to 0.5 and 0.4m/s respectively). During neap tide SPMC values were generally low except for three events. Intriguingly, these increases in concentration (up to 20mg/l) did not coincide with periods of maximum current speed, but occurred during slack water (when current velocities were about 0.1m/s).

Last *et al*. (2011) demonstrated behavioural responses of a range of species to a range of SPM scenarios (high SPM of 71mg/l and low SPM of 12mg/l). In high SPM conditions, two bivalve species, *Mytilus edulis* and *Aequipecten opercularis,* showed reduced shell gape which would reduce feeding time; a high level of energy consuming ‘escape’ and ‘sediment clearing’ shell movements were shown by *A. opercularis*; the crab *Cancer pagurus* appeared to have a reduced weight gain; and *Sabellaria spinulosa* showed two contrasting behaviours: significantly higher tube growth or zero tube growth.

Martin-Short *et al*. (2015) modelled a series of depth-averaged simulations in the Pentland Firth using a range of tidal turbine arrays with a maximum of 400 turbines. They found that arrays in excess of 85 turbines have the potential to significantly affect bed shear stress, with the eventual outcome being changes to the location of sediment accumulation sites. They conclude that deposits of fine gravel and coarse sand will occur within arrays of >240 turbines; and that existing deposits within shallower channel margins are likely to be removed. They argue therefore that not only can turbines have an effect on the local field flow, but regional effects on the sediment routeing in the area can occur.

In Strangford Lough, the SeaGen tidal turbine was operational since 2008 under a 5-year licence. A halo of disturbance (10-12m) has been observed around the turbine and also detected by HEAS index (O'Carrol *et al.* (2014), however, the Environmental Monitoring Programme (Seagen 2011) concluded that no major impacts had been detected. Observed changes were relatively minor and a result of a combination of normal seasonal variation and a natural process of species competition and succession and therefore deemed not to be caused by the presence of SeaGen.

The FlowBec programme, yet to report fully, is currently accessing spatial variation in epifaunal communities in response to flow modification by a tidal stream turbine. The devices themselves present new surfaces for colonisation. Broadhurst & Orme (2014) working at the EMEC wave energy test centre in Orkney, compared marine tide-swept EUNIS habitats at the device site and a control site and found with increased species biodiversity at the device site together with species compositional differences. Crustaceans prevailed at both sites, along with species of omnivore or predatory feeding habits. They concluded that the device could act as a localised artificial reef structure.

The Cobscook tidal stream development project in Maine, USA was installed in 2012 and has been subject to an environmental monitoring programme whose latest benthic and biofouling report (ORPC 2014) indicated little evidence of scouring or disturbance to the seabed or its benthic community. The device comprises a steel turbine generator unit (TGU) mounted onto a bottom frame made of steel and composite material with data cable buried by shear plough. A qualitative comparison of pre- and post-deployment images (acquired by diver held and remote drop down cameras) showed general similarity of epifauna i.e. sea urchins, tunicates, sea cucumbers and scallops which were observed as abundant to common in the shallower sections, while sea potatoes, northern red anemones, urchins and sea stars were the predominant organisms in the deeper sections. Semi-quantitative differences were observed e.g. the northern sea cucumber appeared to be more abundant in deeper water than previously observed and northern red anemones also appeared to be abundant where they were previously only common. Sea scallops appeared to be more abundant in certain stations; an increase in relative abundance of sea cucumbers and sea scallops was consistent with a reduction in fishing activity for these commercially important species in the immediate vicinity of the cable route.

The presence of a tidal barrage will cause a significant reduction on the extent of the intertidal area upstream. With the increased length of high water stand, so the length of submergence time increases for the truly intertidal species i.e. living from low water neap tides and above. Many living below low water neaps extend into the sublittoral and are unlikely to be affected. The ecological implications of the reduction of intertidal mudflat community are discussed in Section 5.6.

Loss of intertidal habitat behind the barrage can also be set in the context of intertidal habitat loss expected from other natural causes due to raising of water levels during periods of flooding upstream of the barrage. It is estimated that a range of 300-600ha of intertidal habitat may be lost over the next 20 years (of a total of 22,500ha), the range reflecting current and projected[61] rates of sea-level change and related habitat loss. Habitat loss over the next 100 years may be between 1,500 and 3,500ha (EA 2011, also see the Severn Estuary Coastal Habitat Management Plan (EA 2005) and the State of the Severn Estuary Report 2011), and a specific action in the SMP2 for the Severn has the objective of ensure the integrity, structure and function of EU sites through a habitat creation programme.

A tidal barrage will also shelter the upstream area from swell waves, but increase local wave action where incoming waves interact with outflow at sluices and locks. Local scouring may occur around high energy sluice outflows.

Barrages will also affect the currents in the wider estuary, reducing the upstream flow speed. The altered tidal dynamics upstream of a barrage could increase stratification and reduce flushing rates, increasing the eutrophication risk. Disruption of water flow can also affect larval dispersal and the connectivity of communities (Bulleri & Chapman 2009) and this may influence recruitment of organisms and the re-establishment of communities after barrage construction.

Downstream changes to habitats and benthos are also predicted for barrage schemes such as the Severn, where an overall increase in benthic species richness, abundance and biomass are all predicted. Species favouring finer sediments are likely to increase e.g. *Cerastoderma edule, Mya arenaria* and *Corophium volutator*; conversely species such as *Hydrobia ulvae, Macoma balthica* and *Nephtys hombergii* which are associated with a more dynamic regime are predicted to decrease in abundance.

Post construction, the major impact from the creation of a tidal lagoon is similar to that of a barrage i.e. reduction in wave energy to habitats behind the lagoon walls which significantly changes their characteristics (see Section 5.4.3.3).

Habitats and species vulnerable to physical disturbance

Vulnerability is associated with either our valuing of commercial species or with habitats and species that have some form of protective conservation status. Those of conservation value

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[61] UKCP09 medium emissions scenario, projecting 0.7m rise. Note that the UKCP09 scenarios are likely to be modified in the near future to reflect the latest evidence (e.g. Horsburgh & Lowe 2013, Church *et al.* 2013)

include sandbanks, deep mud communities and biogenic reefs; several examples of these habitats have been designated or proposed as MCZs and NCMPAs. Examples are located in potential oil and gas areas in Regional Seas 1, 2, 6 and 8 (see Appendix 1j).

Shallow sandbanks

Shallow sandbanks are created in high energy areas and are characterised by frequent movement of sedimentary particles, typified by the shallow linear sandbanks of Regional Sea 2 (see Section A.1a.2.5.2). The infaunal diversity is sparse but robust for the conditions. They have the ability to move through the sediment to regain contact with the sediment/water interface and are therefore unlikely to be negatively affected by temporary increases in suspended sediments or their deposition. Reefs of *Sabellaria spinulosa*, which are frequently associated with sandbanks, are equally robust to suspended sediments and burial, but vulnerable to direct physical damage.

Impacts of OWF on Annex 1 sandbanks – the North Norfolk Sandbanks SCI and Dogger Bank SCI in Regional Sea 2 – have been considered. The contrasting physical geology of the two areas has created two very different modern environments. While the North Norfolk Sandbanks are thought to be moving in a seawards direction through offshore sediment transport, the Dogger Bank is more stable with little sediment transport due to insufficiently strong tidal currents, although occasional movement of surface sediments occurs as the bottom depth is above the storm-wave base (Klein *et al.* 1999). Hypothetically, therefore, anthropogenic structures or activities which interfere with sediment mobility could – over an extended timescale – influence the physical structure and habitat of the North Norfolk Sandbanks 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 all of limited spatial extent in relation to the overall OWF footprint and it is considered extremely unlikely that OWF development would have a significant influence on the physical habitat in either area.

Deep mud communities

Muddy sediments support benthic communities characterised by the presence of large burrowing crustaceans (*Nephrops norvegicus* and *Calocaris macandreae*) and pennatulid sea-pens (*Virgularia mirabilis* and *Pennatula phosphorea*). *Nephrops* and *Calocaris* are able to restore burrow entrances following limited physical disturbance of the sediment surface (a few centimetres), and video observations of burrow and pennatulid densities on the Fladen Ground sediments show little cumulative effect of fishing disturbance. Bioturbation rates, although poorly understood in deep water, are important indicators of ecosystem function and the process is important in the recovery of soft sediments after physical disturbance. Gates & Jones (2012) looked at the recovery of benthic megafauna at a deep well site (380m) in the Norwegian Sea over a three year period and reported large burrows on the disturbed seabed, indicating activity of the decapod *Geryon* sp. in this area. These crabs were observed entering and leaving the burrows - an activity thought to be important in the re-distribution of the sediment and gradual breakdown of the cuttings material. The nearest burrow was 5m from the well indicating activity in this area in the three years since disturbance. The holothurian *Parastichopus tremulus* is important in horizontal dispersal of sediment. Pennatulids are a key species of the EUNIS 'deep mud community' and were the most common organisms on the soft sediment in Gates & Jones (2012) study. However, in comparison to pre-drill data and reference sites, their density remained low for three years post-drilling in the visibly disturbed area i.e. the extent of the cuttings pile. Pennatulids are slow growing and may therefore take some time to recover from disturbance. Although the larval recruitment rates and settlement rates for these organisms are unknown, studies on the reproduction of *Pennatula phosphorea* and *Funiculina quadrangularis* suggest that these species have lecithotrophic larvae which have the ability to remain in the water column until suitable habitat is located, thus possibly avoiding settlement on sediment disturbed by drilling mud and cuttings.

Biogenic reefs

On the UKCS biogenic reefs (as per the Habitat and Species Directive Annex I) are built by a small number of species: blue mussel *Mytilus edulis*, horse mussel *Modiolus modiolus*, ross and honeycomb 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 a Habitats Regulations Assessment before consent for the proposed activity can be given**.**

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 Baseline section). In relation to the likely locations of OWF development, *Sabellaria* reef is the Annex 1 biogenic habitat most likely to be affected by direct physical damage.

Direct impact from OWF foundations will be of relatively limited spatial extent, and in view of the wide habitat tolerance of *Sabellaria* (Jackson & Hiscock 2008), it is likely that scour protection would be as likely to support aggregations as does the surrounding seabed (particularly when overlain by a sand veneer). Response to indirect impacts of turbidity and knowledge on *Sabellaria* resilience and vulnerability has been usefully informed by recent aggregate industry sponsored research e.g. Hendrick *et al*. (2011) and Pearce *et al*. (2011). This confirms Jackson & Hiscock (2008) supposition of the species' tolerance of turbidity from sediment mobilisation or scour; the suspension of fine material during dredging operations is not now considered likely to be detrimental (Last *et al.* 2011b, Pearce *et al.* 2011).

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 habitats 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 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 *Sabellaria* reefs which are 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 deemed to be of nature conservation importance.

Despite having a high potential for recovery from indirect effects of turbidity, reefs are clearly susceptible to damage from direct impacts, e.g. towed fishing gear (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 north-east Atlantic. In the Waddensee, Riesen & Reise (1982) reported the loss of extensive subtidal *S. spinulosa* reefs 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. Similar reported losses from the Norderau area were attributed to similar causes (Reise & Schubert 1987). Shrimp trawling still occurs in these areas and the *S. spinulosa* reefs have not reappeared, their niche having been effectively replaced by mussel *Mytilus edulis* communities and assemblages of sand dwelling amphipods (Reise & Schubert 1987). In Morecambe Bay, the pink shrimp *Pandalus montagui* fishery has been implicated in the loss of subtidal *Sabellaria* reefs from the approach channels to the Bay (Mistakidis 1956, Taylor & Parker 1993). Aggregate extraction (licensed) is also as source of direct damage to *Sabellaria* reefs (Holt *et al*. 1997). Compared to fishing impacts, those from gravel extraction are likely to be more limited in extent, more controlled, and less likely to continue for very long time periods;

hence although severe, recovery from direct damage in a short time scale is more likely as adjacent undamaged areas could provide a supply of larvae for new settlement.

Apart from *Sabellaria spinulosa*, reefs of *Lophelia pertusa* are known to occur in the deeper waters of Regional Seas 8 and 10. *L. pertusa* can tolerate short-term exposure to settling particles and the effects of partial low oxygen and anoxic conditions, but complete burial of the polyps for more than 24h has been shown to result in suffocation (Allers *et al.* 2013).

Commercial species

Herring are demersal spawners and their spawning grounds are vulnerable to an increase in suspended sediments. Successful egg development is dependent on localised areas of suitable open substrate with good oxygenation in the sediment interstices. Although the prevailing hydrographic conditions make it is unlikely that sediment particles finer that naturally present in the spawning habitat would settle out, it would be possible for particles of a similar size to settle and any herring eggs present would be smothered and unable to emerge from burial. For many years there has therefore been a requirement 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 marine licensing processes to OWF developments (CEFAS 2009b).

5.4.3.3 Physical damage to submerged heritage/archaeological contexts from infrastructure construction, vessel/rig anchoring etc and impacts on the setting of coastal historic environmental assets and loss of access

Offshore wind farms, tidal stream and wave

OWF, tidal stream and wave projects have the potential to damage archaeological artefacts and sites, in particular through the trenching of cables into the seabed and through foundation installation, rig and other vessel anchoring. The recognition of the importance of prehistoric submarine archaeological remains has led to a number of 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 & English Heritage 2003) covering legislation, statutory controls, possible effects of aggregate extraction, obtaining archaeological advice, application procedures, assessment, evaluation, archaeological investigation, mitigation, and monitoring. Recognising the need for interaction between sea bed developments and the historic environment COWRIE published a guidance document entitled Historic Environment Guidance for the Offshore Renewable Energy Sector in 2007 (COWRIE 2007) which considered the survey, appraisal and monitoring of the historic environment during offshore renewable energy projects. A second COWRIE guidance document, Guidance for Assessment of the Cumulative Impacts on the Historic Environment from Offshore Renewable Energy, addressed the specific issues related to the cumulative impacts of offshore renewable energy projects on the historic environment (COWRIE 2008). A third COWRIE guidance document, Offshore Geotechnical Investigations and Historic Environment Analysis: Guidance for the Renewable Energy Sector (COWRIE 2011) provides best practice options in relation to the integration of archaeology with offshore development led geotechnical investigations, particularly with respect to the Round 3 developments. More recently, a protocol for archaeological discoveries with respect to offshore renewables projects was produced by The Crown Estate (2014), which addresses finds or anomalies of archaeological interest made on the seabed, onboard vessels, in the inter-tidal zone or on land.

The archaeology and cultural heritage assessments carried out as part of the EIA process for the consented Round 3 developments provide valuable information with respect to the known and potential archaeological resource of each of the development areas and cable corridor routes. Geotechnical surveys of each area have highlighted known and previously unidentified wrecks as well as a large number of anomalies and these have been categorised according to their archaeological potential.

Direct impacts to archaeological receptors are likely to be permanent. Once archaeological deposits and material, and the relationships between deposits and material and their wider surroundings, have been damaged or disturbed it is not possible to reinstate or reverse those changes. As such, direct impacts to the fabric or setting represent a total loss of a receptor, or part of it, and the character, composition or attributes of the receptor would be fundamentally changed or lost from the site altogether.

As indicated by the Round 3 assessments, adherence to the revised (or the 2010 original) protocol for archaeological discoveries with respect to offshore renewable projects (Crown Estate 2014) will provide for the reporting of archaeological discoveries made during the course of development. The response to reported finds will be implemented through the measures set out in the protocol, such as further survey or the establishment of Temporary Exclusion Zones (TEZs), which may be converted into new Archaeological Exclusion Zones (AEZs), if warranted.

With regard to local visual and character perceptions, the magnitude of the effect of construction activities upon local perceptions of the historic environment and local seascapes are expected to be negligible. Offshore construction activities at the landfall would be short term and comparatively small scale and the use of large construction vessels would be short term and transitory during the construction phase.

Oil and gas, gas storage and carbon dioxide storage

In terms of submerged archaeology, oil and gas, and gas storage installations have the same potential for damage as OWF, however, oil and gas and OWF 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 (2004) 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”.

Tidal range

Large scale changes to sediment regimes, erosion and deposition, mean water heights, tidal range and current velocities (discussed further in Section 5.5.2) may affect any historical or archaeological artefacts or structures either directly through physical damage from infrastructure or indirectly through sediment erosion and deposition or submergence or emergence due to changing water levels. For example, the proposed dredging activities to provide material for the seawalls of the Swansea Bay lagoon were identified as having the greatest magnitude of effect with respect to known archaeological sites and potential maritime archaeology (Tidal Lagoon Swansea Bay 2014).

5.4.3.4 Changes/loss of habitats from major alteration of hydrography or sedimentation (indirect effects on the physical environment)

Offshore wind

Foundations and structures within the water column produce resistance and therefore reduce the water transport capacity of material and subsequent sediment properties, erosion and deposition, in the area. There is also a potential for coastal morphology to be affected by OWF developments through changes in current conditions, sediment erosion and deposition although initial investigations suggest that effects are generally localised to the OWF area (RPS 2005, Morecambe Wind 2006). As there is a shift towards OWF development in deeper waters with greater wave exposure, different foundation types will be used. Ongoing monitoring of physical effects of monopile and jacket structures on sediments and geomorphological features has provided a base understanding of especially scour and wake patterns associated with these structures and related scour protection measures. In comparison, relatively little is known about the effects of other foundation types, especially large (gravity bases) and complex (multi-legged) structures.

Different foundation types are likely to have different hydrodynamic effects, with lower current speeds in the wake of the installation and slightly higher velocities around the parts of the structure facing the flow, especially for the larger gravity bases. Subsequent effects on sediment entrainment, turbidity, stratification and water quality are however very site-specific.

At the Horns Rev Wind Farm, in 6-10m water depth, modelling work (The Environment Group 2005) suggested that the total current velocity would only be reduced by a maximum of 2% after the construction of the OWF, with little impact of the foundations on water exchange. Monitoring of sandeels, which are sensitive to changes in sediment sizes, completely abandoning sites if the silt/clay content rises above 6%, showed a 300% increase in numbers over a 2 year monitoring period suggesting no increase in the content of silt/clay and very fine sand in the site. A similar modelling study done for the Anholt Wind Farm (Energinet.dk 2009) in 15-20m water depth, investigated the impact of both monopole and gravity base foundation types. The study concluded that only minor hydrographic modifications were to be expected, with a potential reduction in current speeds of less than 2% in the wind farm area and a small increase around the wind farm due to flow diversion. A reduction of wave height of 3% within the wind farm area is not expected to significantly impact the coastlines 20 and 15km away although a small increase in turbulence near the foundations is likely to slightly weaken downstream local stratification of the water column.

In terms of the effects of OWF on large geomophological features, an analysis of the Nysted wind farm (The Environment Group 2005), which has gravity base foundations 15.5m in diameter, suggested a reduction to the wave height on the nearby Rødsand barrier islands of 10% and flow rates by 5-10% with correspondingly reduced sediment transport. The monitoring study used satellite imagery to show that the barrier reefs moved 15m eastwards per year before OWF construction, with the wind farm delaying the natural morphological progression by approximately 3m a year. There is the potential that any changes in sediment distribution and therefore bathymetry may affect the height of shallow sandbanks and therefore the breaking point of waves. Modelling work for the London Array OWF (RPS 2005) has shown that different foundation types have different magnitudes of wave absorption and transmission effects. Monopile and tripod foundations were shown to have a low obstruction effect and low capacity to absorb energy from passing waves (with minimal far field effects), whereas gravity base foundations have the greatest capacity to absorb energy from passing waves, with increasing effects with decreasing depth of water as relatively more of the water column is occupied by the foundation. Prediction for effects of gravity base structures for the London Array OWF suggest values of 10cm wave height reductions just beyond the development site in north-easterly winds with effects at the Kent coast either negligible for low water and peak tides and up to 5cm at times of high water and peak ebb tides (RPS 2005). If there was an increase in waves breaking within an OWF then there would be potential for increased turbulence, sediment suspension and scour around the foundations (discussed above), although as yet no monitoring data has provided evidence to support this.

With respect to the consented Round 3 developments, modelling analysis indicates that worst case scenario layouts consisting wholly of large numbers of gravity base foundations (50-65m base diameter) is likely to reduce wave heights within or close to the development area by up to 40% depending on the wave parameters modelled (Table 5.13). Changes in wave height would recover with distance behind the wind farm. In a small number of cases (Moray Firth and Hornsea), a small reduction in wave height at the coast (up to 10%) was predicted under certain circumstances. In general and under the majority of wave parameters modelled, the magnitude of predicted change was small and unlikely to result in significant changes to sediment transport either within the site or at the coast.

Table 5.13: Modelled impacts of Round 3 developments on wave height

Round 3 development	Worst case scenario	Impact on wave height	Comment
Telford, Stevenson & MacColl (Moray Firth)	65m diameter gravity base foundations. Site 1 – 139 turbines Sites 2 & 3 – 100 turbines.	Maximum reduction in wave height, within the site boundary, varied between 0.7 and 1.2m or 12-19% of the incident wave height for all coming directions and return periods. Maximum magnitude of impact at coast predicted at 2-3% decrease in wave height.	The local effects of the GBS array on waves are of a small magnitude relative to the range of naturally occurring variability on annual and decadal timescales and do not cause the range to be exceeded. The reduction in wave height outside of the array is of a small magnitude (likely not measurable in practice in most areas).
Seagreen Alpha & Brava (Firth of Forth)	No modelling undertaken	-	-
Teesside A & B (Dogger Bank)	400 gravity base foundations with a base diameter of 50m, spaced 750m apart around site perimeters with a wider internal spacing.	Maximum change in significant wave height *ca.* 1% along the southern/south western boundary of Dogger Bank Teesside B (in a band about 12km wide) and the northern boundary of Dogger Bank Teesside A	Percentage changes are within the natural variation of wave height across Dogger Bank and surrounding sea areas.
Creyke Beck A & B (Dogger Bank)	600 gravity base foundations with a base diameter of 47m, spaced 700m across the entire developable area.	Maximum increase in significant wave height of *ca.* 6% along the northeast perimeter for waves from the northeast. Maximum decrease of *ca.* 7.5% along the southwest perimeter during northeast waves.	Percentage changes are within the natural variation of wave height across Dogger Bank and surrounding sea areas.

Round 3 development	Worst case scenario	Impact on wave height	Comment
Hornsea Project One	Up to 332 turbines with gravity base foundations with a base diameter of 50m diameter and spacing of 924m.	Predicted reduction in wave height, under the 50% no exceedance scenario of approximately 10–40% within the site. Under this scenario, predicted reduction in wave height of *ca.* 2.5-10% along the north Norfolk coastline (when waves from the north – 11% of time).	Whilst a change of this magnitude would be observed in near-bed orbital velocities, the magnitude of the velocity is such that it is below the threshold for the granular sediments found within the area and, therefore, will not significantly affect sediment transport.
East Anglia ONE	240 x gravity base foundations with a base diameter of 50m.	During large storm events, percentage reductions in wave height may be up to ~20% within the array.	At a distance of greater than ~40km from the array, maximum percentage reductions in wave height are typically less than ~2%.
Rampion	No modelling undertaken	-	-

Sources: Moray Offshore Renewables Limited (2012), Seagreen Wind Energy Limited (2012), Forewind (2014), Smart Wind (2013), East Anglia Offshore Wind Limited (2012), E.ON Climate & Renewables UK Rampion Offshore Wind Limited (2012).

Tidal range, tidal stream and wave

Relevant information is provided in Section 5.5.2.

5.4.3.5 Post-decommissioning (legacy) effects – cuttings piles, footings, foundations, in situ cabling etc

Offshore wind farms, tidal stream, wave

The expected lifetime of OWF turbines is 20 to 25 years and 40 years for cables and other associated infrastructure. Similar physical impacts to those outlined for the installation of OWF, sediment and habitat disturbance, are also likely due to decommissioning activities.

DECC (2011) guidance indicates a general presumption in favour of the whole of all disused installations being removed and subsequently taken back to land for reuse, recycling, incineration with energy recovery or disposal at a licensed site. Exceptions from this general requirement will only be considered where there are very good reasons. Any decision to allow some or all of an installation or structure to remain on or in the sea-bed will be based on a case-by-case evaluation of a range of matters, including, where appropriate:

- potential effect on the safety of surface or subsurface navigation;
- potential impact on other uses of the sea;
- potential effect on the marine environment, including living resources;
- costs of removal;
- risks of injury to personnel associated with removal.

The DECC guidance uses a number of relevant examples to illustrate objects for which it may be possible to consider solutions other than complete removal. These include:

- Structures which will be reused for renewable energy generation: where infrastructure, such as cabling, is intended to be reused for new renewable energy devices, it is likely to be preferable to leave the infrastructure in place for this new use. This may be the case, for example, at a test site for wave and tidal energy devices. In these situations, a decommissioning programme should nonetheless set out the eventual decommissioning measures envisaged when the infrastructure finally becomes 'disused'.

- Structures which serve a purpose beyond renewable energy generation: where a structure has a design life and purpose beyond that of renewable energy generation, it may be valuable to leave the structure in place even after it has finished generating energy. An example might be a breakwater with integrated wave energy device. In these situations, DECC would normally expect the decommissioning programme to set out the eventual decommissioning measures envisaged should the installation or structure finally become 'disused'.
- Foundations and structures below sea-bed level: where an installation's foundations extend some distance below the level of the seabed, removing the whole of the foundations may not be the best decommissioning option, given the potential impact of removal on the marine environment, as well as the financial costs and technical challenges involved. In these cases, the best solution might be for foundations to be cut below the natural sea-bed level at such a depth to ensure that any remains are unlikely to become uncovered. The appropriate depth would depend upon the prevailing sea-bed conditions and currents. Contingency plans should be included in the decommissioning programme, to describe the action proposed if the foundations do become exposed.
- Cables buried at a safe depth below the sea-bed: where cables remain buried at a safe depth below the sea-bed, there may be a case for leaving them there, given the potential impact of removal on the marine environment, as well as the financial costs of removal. Concerns might arise if the cables were to become exposed by natural sediment dynamics, as exposed cables might pose a risk to other maritime users, with the possibility that fishing gear or an anchor might foul a cable. The option of cables being left in place may be considered if they are buried at a safe depth below the sea-bed, such that they do not pose a risk to other maritime users. The appropriate depth will depend upon the prevailing sea-bed conditions and currents. Where it is proposed to leave cables in place, cable burial depth should be monitored over and beyond the life of the installation, to assess the risk of cables becoming exposed after decommissioning. Contingency plans should be included in the decommissioning programme, to describe the action proposed if the cables do become exposed.
- Scour protection materials: where scour protection materials have been used, there may be a case for leaving them there, to preserve any marine habitat established over the life of the installation, where they do not have a detrimental impact on the environment, conservation aims, the safety of navigation and other uses of the sea.
- Removal of OWF, tidal stream and wave devices may lead to varying degrees of disturbance to the seabed and associated communities especially where buried cables, foundations or scour protection are involved.

The foundation type with the least environmental impact in terms of decommissioning are floating foundations which are simply detached from their anchors and suction caisson where water is pumped back in to the foundation which releases from the seabed to be reused without leaving anything behind. Choosing the correct removal method and most appropriate season for biological communities present will help to reduce these impacts, alongside the re-use of as much infrastructure as possible. If decommissioning activities are likely to have a significant effect on a designated European site, a Habitats Regulations Assessment may have to be carried out as part of the *Conservation (Natural Habitats &c.) Regulations* 1994 (as amended) and the *Offshore Marine Conservation (Natural Habitats &c.) Regulations 2007*.

Due to the likelihood that many OWF installations may not be totally removed during decommissioning, post-decommissioning effects need to be taken into consideration. During decommissioning any remaining cables would need to be stay buried to a suitable depth so that they would be unlikely to become uncovered by sediment and current processes. This also applies to the cutting of piles and other below seabed style foundation types. Any foundations, scour protection or structures left on the seabed are likely to have similar impacts to those in operation, e.g. scour, and therefore some post-decommissioning monitoring would be expected in order to identify any new or increased risks to navigation or other users of the sea which may be posed by remaining materials (for example, where cables or foundations may have become exposed due to natural sediment dynamics). Due to the infancy of marine renewable energy projects no decommissioning has yet to occur, although the guidelines in place (DECC 2011) include a requirement to minimise environmental impacts. OWF projects are also obliged to detail future monitoring strategies for any objects either left in position or not wholly removed at decommissioned sites under Section 105 of the *Energy Act 2004*.

Oil and gas

The decommissioning of oil and gas installations is subject to the same conditions as those presented for OWF and similar issues with respect to potential post-decommissioning effects will need to be considered (see DECC guidance notes 2011).

The OSPAR Recommendation 2006/5 on a management regime for offshore cuttings piles introduced a two stage management regime. Stage 1 provided for initial screening of all cuttings piles, to be completed by 2008 to identify any piles that require further investigation based on the thresholds set out in the Recommendation. A stage 1 screening of UK cuttings piles by the industry in line with the Recommendation concluded that they were all below the specified thresholds. However, at the time of decommissioning the associated installations the characteristics of the relevant cuttings piles should be assessed in detail and the need for further action in line with Stage 2 of the Recommendation reviewed. Stage 2 will require comparative assessment to determine the best option for handling the cuttings piles (DECC 2011). It is considered unlikely that any oil & gas development resulting from the draft plan/programme will lead to the formation of a significant drill cuttings pile.

Decommissioning programmes will require EIA which should include the following relevant information:

- All potential impacts on the marine environment, including exposure of biota to contaminants associated with the installation, other biological impacts arising from physical effects, conflicts with the conservation of species, with the protection of their habitats, or with mariculture, and interference with other legitimate uses of the sea.
- All potential impacts on other environmental compartments, including emissions to the atmosphere, leaching to groundwater, discharges to surface fresh water and effects on the soil.

- Other consequential effects on the physical environment which may be expected to result from the option.

Draft and approved decommissioning programmes are listed on the DECC website[62] and also in Section A1h.6.1.2.

Gas and carbon dioxide storage

The decommissioning provisions of Part IV of the *Petroleum Act 1998 Act* apply to offshore facilities established for the purposes of gas storage and CCS. The framework for decommissioning outlined by DECC (2011) is also relevant to such projects. Potential post-decommissioning effects are likely to be similar to those described for oil and gas and OWF.

Tidal range

Given that there are no constructed projects, there are unlikely to be decommissioning activities in the lifetime of this plan.

5.4.4 Controls and mitigation

Site surveys are required to be undertaken before potentially damaging activities such as drilling rig placement (for safety and environmental reasons) and the results of such surveys allow for the identification of further mitigation including the relocation or resiting of the location of activities (e.g. wellhead, rig leg or anchor positions) to ensure sensitive seabed surface or subsurface features are avoided. Such survey reports are used to underpin operator environmental submissions (e.g. Environmental Statements) and survey information is made available to nature conservation bodies during the consultation phases of these assessments.

No measures are likely to be able to mitigate for the potential physical disturbance associated with tidal barrage and lagoon schemes.

5.4.5 Likelihood of significant effects

The consideration of evidence indicates that with the exception of tidal range, plan activities, particularly those associated with the construction phase are unlikely to cause significant effects at a Regional Sea level to seabed sediments, features and habitats given the localised and/or temporary nature of potential effects and the dynamic nature of many of the areas where development is likely to occur. The requirement for site surveys before activities take place will ensure that more sensitive features (both geomorphological and archaeological) and habitats can be avoided.

Potential cumulative effects from plan activities are possible where the ‘footprints’ of physical disturbance overlap incrementally with those of other plan activities or cumulatively with other non-plan activities (e.g. fishing, aggregate extraction, dredge disposal). The aspect of the plan with the greatest potential for cumulative effects is the ongoing and future development of offshore wind given the large scale development proposed over the next decade and the relative localised nature of much of this in the central and southern North Sea, an area also used extensively by other industries. The assessment has shown that the strategic-level footprint of physical disturbance associated with the construction of the consented offshore wind

[62] https://www.gov.uk/guidance/oil-and-gas-decommissioning-of-offshore-installations-and-pipelines#table-of-approved-decommissioning-programmes

development will be limited both spatially and temporally. The potential for significant incremental and cumulative physical damage/change effects is further reduced by the naturally dynamic environment of the southern North Sea which is adapted to re-suspension and sedimentation events. In a UKCS context, the contribution of all other sources of disturbance are minor in comparison to the direct physical effects of fishing – for example, ICES calculated that the fishery using mobile bottom-contacting gears impacted 290,000km^2 of the Greater North Sea in 2013.

The dispersion and settling of sediment plumes from construction activities (primarily associated with OWF) has the potential to be detectable across median lines. However, within the plume, the levels of suspended sediments, which may have a significant adverse impact on sensitive receptors, is limited both spatially and temporally. Regardless of extent of impact, where the near-bed SPM concentrations are naturally high, as in coastal and southern North Sea areas and the Irish Sea, the effects of anthropogenic sediment plumes are unlikely to be significant on the existing seabed communities.

5.4.6 Summary of findings and recommendations

Physical disturbance associated with activities resulting from proposed oil and gas licensing and OWF, wave and tidal stream 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 potential impacts of tidal range schemes however, could be very significant with the potential loss of large areas of inter-tidal habitats and salt marshes as a result of a change in water levels and sediment transport within an estuary or river channel.

In areas with vulnerable habitats and species such as cold water coral reefs mitigation may be required for physically damaging activities such as rig/vessel anchoring, discharges of drilling wastes and cable, pipeline or umbilical installation (from hydrocarbon, gas storage or renewable energy related activities). Prior to decisions on activity consenting in such areas, developers should provide a detailed assessment and seabed information so that appropriate site specific mitigation can be defined, for example no anchoring and zero discharge. Detailed site surveys should also be evaluated with regard to archaeological sensitivities.

Little information currently exists for the impacts of wave and tidal stream technologies, both on the physical environment and associated habitats and further research is needed into the effects of different foundation types and cumulative impacts of arrays of these devices.

5.5 Consequences of energy removal

Assessment Topic	Potentially Significant Effect	Oil & Gas	Gas Storage	Carbon Dioxide Storage	Offshore Wind	Tidal Stream	Tidal Range	Wave	Assessment Section
	Changes to sedimentation regime and associated physical effects					X	X	X	5.5.2.1 5.5.2.2 5.5.2.3
	Energy removal downstream of wet renewable devices					X	X	X	5.5.2.1 5.5.2.2 5.5.2.3
	Changes in seawater or estuarine salinity, turbidity and temperature from impoundment						X		5.5.2.1 5.5.2.2 5.5.2.3

5.5.1 Introduction

Energy removal by hydrokinetic turbines may cause regional changes in the tidal regime because the existing regime and environment are, in large part, established by the natural removal of energy by friction and turbulence. As a result, tides, currents and mixing throughout a waterbody can be affected by energy removal at a particular location, although the magnitude and extent of this is very site specific and also depends on where the power is extracted from within a system. It has been shown that removing the same amount of average power from two different sites within the same body of water may lead to very different effects on the far-field physical environment (e.g. Polagye *et al*. 2009). In addition, specific aspects of the device (e.g. foundation type, support structure, shape and size) can also alter the fraction of energy removed and the resulting impacts.

Sites that are high in dynamic energy are targeted as suitable for deployment of wave and tidal devices. Understanding the impact of these devices on the hydrography and morphodynamics of an area requires a baseline understanding of the movement of water and sediment through these natural systems. Despite decades of measurements of circulation, tidal dynamics and waves in oceanographic settings, very few deployments or studies have been undertaken in areas of extremely high energy. This means that baseline information on the natural dynamics of these areas are often not well understood, with studies focused on impacts from wet renewable devices reliant on modelling simulations. The infancy of these technologies also mean that few measurement campaigns have been undertaken in areas of device deployment.

As the effects of energy removal are so site specific that there is a high level of uncertainty in relation both to significance of effects, connecting changes to hydrodynamic regime to other aspects of the physical environment, and also to applying impacts from one scenario to another. The parts of the physical system most likely to be affected by energy removal are: tidal range, transport both of water and sediment, turbulent dissipation and boundary layer structure, and wave regime (dependent on wave-current interactions). These have the potential to affect water quality, sediment transport, the type and quality of marine habitats and marine ecosystem functions such as stratification and primary productivity.

As a result of the site specific nature of impacts and the lack of target generation capacity in the plan, the discussion below is generalised and focuses on the results of studies and evidence of impact without attempting to quantify potential future impacts for specific Regional Sea areas.

Despite these uncertainties there have been an increasing number of international and national project and initiatives aimed at increasing the understanding of the impacts of energy removal on natural systems, e.g. EBAO (optimising array form for energy extraction and environmental benefit), TerraWatt, EMIR International Conference (environmental interactions of marine renewable energy technologies), SMARTtide (simulated marine array resource testing), Tethys.

5.5.2 Consideration of the evidence

5.5.2.1 Tidal Stream

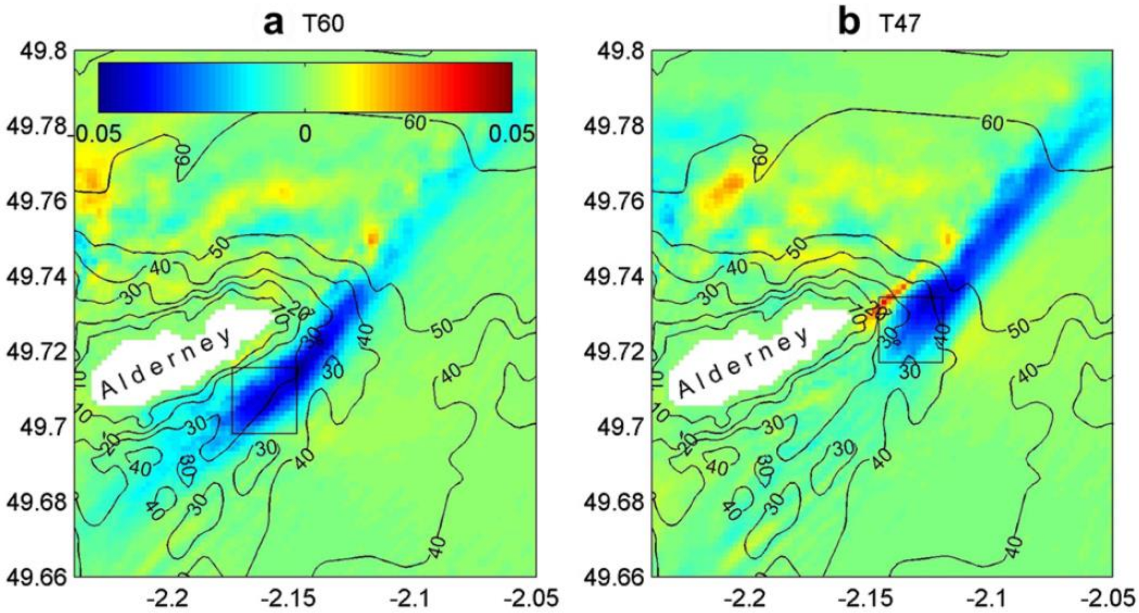
The placement of tidal stream devices in the water column has two linked but separate forcing effects: the change in natural flow of water associated with the physical presence of the device, with resulting effects such as scour around anchors and foundations (discussed in Section 5.4); and, the removal of energy from the water column, now transmitted along power cables as electricity, which primarily reduces current velocity, alters bed shear stress and sediment transport.

A number of idealised and site specific modelling studies have been undertaken to investigate the impacts of tidal devices on hydrography and sediment dynamics (e.g. Bryden & Couch 2006, Neill *et al.* 2009, Wolf *et al.* 2009, Martin-Short *et al.* 2015), with a few monitoring studies based on recent deployments in the real environment. These include the grid connected SeaGen device in Strangford Lough, deployed in 2008, and a number of demonstrator scale devices at EMEC sites in Orkney. Whilst far field impacts from single tidal stream devices or small arrays are generally shown to be insignificant (Ahmadian & Falconer 2012), 1D and 2D modelling work has started to focus on the impacts of array scales of devices, although it has been noted that 3D modelling would give more accurate results given the natural complexity of sites (Robins *et al*. 2014).

Velocity changes

Tidal energy extraction from tidal stream devices has been shown to reduce the volume of water exchanged through an area over a tidal cycle, reduce the tidal range landward of an array and reduce the power density in the tidal channel itself (Bryden & Couch 2006, Polagye *et al.* 2008, Walkington & Burrows 2009). Tidal stream devices intercept the kinetic energy in strong tidal currents resulting in a change to the velocity structure of a channel and changes to current speed over the wider area (Figure 5.12). However, it appears to be a non-linear relationship between the rate of energy extraction and the velocity reduction (Bryden & Couch 2006), due to the fact that energy extraction decreases the available energy flux and therefore diminishes the overall flow speed. Simulation of an array of 400 turbines in the Pentland Firth shows that residual tidal currents are affected within a 10km area, with the weakening not uniformly distributed over the area (Martin-Short *et al.* 2015). Modelling evidence also points to a blockage effect from flow diverting around arrays of devices, further reducing the fraction of incident energy which is extractable (Walkington & Burrows 2009), something that was not properly accounted for in early assessments of tidal stream resources. Modelling of an array in open water in the Celtic Sea suggests that this blocking effect reduces the available extractable energy by up to 14 times compared to currents undisturbed by an array (Shapiro 2011).

Figure 5.12: Modelled change in magnitude of velocity (m/s) compared to baseline due to energy extraction averaged over a spring-neap cycle for a tidal array in two locations in the Alderney Race



Notes: Black box is the location of the tidal array in two scenarios. Array contains 200 x 1.5MW devices. Source: Neill et al. (2012)

For single devices or small arrays these effects are expected to be very small (Polagye *et al.* 2011) with studies suggesting that in a tidal channel the impact of energy extraction on current speed only becomes significant at extraction values of 10-50% of available kinetic energy (see below), with current typical tidal device extraction scenarios only using ~1% of the available kinetic energy. Even for larger arrays, isolating the signal of marine energy devices from natural variability can be difficult. However, whilst this suggests minimal environmental impacts from small arrays of tidal devices, bed shear stress is also a function of current speed, with small changes in velocity leading to large changes in bed shear stress and resultant sediment transport pathways (Neill *et al.* 2012). Thus large changes in sediment erosion and deposition can occur from small changes in velocity. A study of the impact of maximum energy extraction by tidal turbines in the Minas Passage, Canada (Hasegawa *et al*. 2011), showed that significant far field effects on the residual circulation of the Bay of Fundy and Gulf of Maine similar in impact to that of a barrage can be expected. They also concluded that tidal energy extraction from the lower water column produces less far-field impacts than turbines situated throughout the water column, providing an additional variable when considering potential impacts.

Published simulation values of reductions in flow range from 56% (Vancouver Island, Canada, Sutherland *et al*. 2007), 25% (Yell Sound, Shetland, The Engineering Business Ltd. 2005), 19% for Ramsey Sound (Haverson *et al.* 2014), 15% in the Alderney Race (Thiébot *et al*. 2015), to just a few percent for 10-50MW array scenarios offshore Anglesey (Robins *et al*. 2014). The wide range of figures reflects the different physical settings of devices, with the system response to energy extraction dependent on the geometry of the area (e.g. narrow channel, estuary, wider channel), tidal regime and non-linear turbine dynamics (Polagye et al. 2008). Bryden & Couch (2006) suggested that in an idealised simulation case 10% of the raw tidal energy flux could be extracted without undue modifications to flow characteristics. Estimations of the limit of percentage energy extraction before any significant alteration to flow speeds and environmental effects occur (the *Significant Impact Factor (SIF))* for several potential tidal stream sites around the UK were detailed by a Carbon Trust study (2005) (see Table 5.14).

Table 5.14: Modelled acceptable limit of percentage energy extraction from specific UK tidal resource areas before environmental effects become significant (SIF) and associated reductions in velocity as a result of extracting this much energy.

Site	Regional Sea	Velocity change (%)	SIF(%)
Pentland Skerries	8	15	20
Stroma, Pentland Firth	8	15	20
Duncansby Head, Pentland Firth	8	15	20
Casquets, Channel Islands	-	10	8
S. Ronaldsay, Pentland Firth	8	15	20
Hoy, Pentland Firth	8	15	20
Race of Alderney, Channel Islands	-	10	12
S. Ronaldsay, Pentland Skerries	8	15	20
Rathlin Island	7	10	8
Mull of Galloway	6	10	12

Source: Carbon Trust (2005)

Values for the limit of SIF are shown to vary with physical location with inter island channels, open sea sites and headlands having a value of 10-20%, sea lochs a value of 50% and resonant estuaries values of <10% (Carbon Trust 2005). These values are based on theoretical modelling and therefore still have to be validated against physical measurements. SIF values have been built into power estimates for several tidal stream sites around the UK, with a SIF of 20% used to estimate resource extraction capacity for 4 sites in Pembrokeshire totalling a 1265GWh annually (Fairley *et al.* 2011). There have, however, been assertions that the theoretical resource and therefore environmental effects of extracting kinetic power are unrelated to cross-sectional kinetic power (Garrett & Cummins 2008) and therefore these SIF values should be treated with caution.

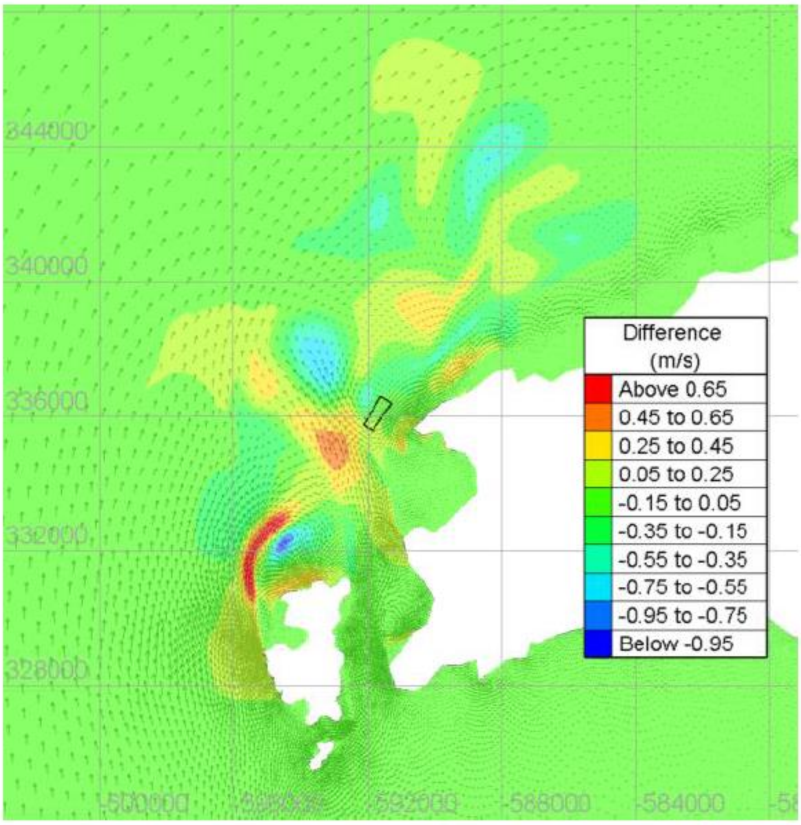
Wake effect

Despite the significant reduction in velocities associated with energy extraction, several studies have shown that this is restricted to the area within the tidal array and in the near-field (Ahmadian *et al.* 2012, Robins *et al.* 2014, Thiébot *et al*. 2015, Tidal Ventures 2015). The extent of the wake effect from a single device or array associated with physical diversion or deflection of flow around a device has been modelled to extend significantly further than the area impacted by energy removal. For single devices it has been modelled to extend ~500m downstream of the 16m rotor diameter device in Strangford Lough (larger on flood over ebb tide), 30 times the width of the turbine blades. This effect is however far smaller for the open water 11m rotor diameter Seaflow device off Lynmouth; 167m long wake effect, 15 times the blade diameter (RPS 2005, Faber Maunsell & Metoc 2007). For the 10MW Ramsey Sound array (27 turbines) this extends to 4km downstream (Haverson *et al*. 2014), up to 10km for a 300MW array in Alderney Race (Neill *et al*. 2012) and 10-20km from a large array in the open Celtic Sea (Shapiro 2011). This highlights the variability in physical effects with number of devices and geographical setting, with the most noticeable influences expected in estuarine and narrow channel conditions rather than open water or energetic channels already strongly influenced by waves and currents.

Turbulence

The reduction in current velocities in the wake of a device will increase eddy formation and associated turbulence and affect both sediment deposition and erosion, and water column turbidity. Whilst this is clearly seen in modelling studies (e.g. Churchfield *et al.* 2013, Masters *et al*. 2013) real energetic tidal channels are turbulent even without tidal devices and the nature of that flow will be far more complex than those represented in modelling studies. Understanding short term variations in velocities resulting from turbulence and wave-current interactions are essential for proper evaluation of impacts from devices (Shields *et al.* 2011), with in situ measurements at the EMEC tidal stream test site in Orkney showing complex turbulent flow, with enhanced turbulent kinetic energy near the seabed (Osalusi *et al.* 2009). Modelling work on a 10MW array of 27 turbines in the Ramsay Sound, Pembrokeshire (Haverson *et al*. 2014), shows how although the wake effect only stretched 4km downstream of the array it directly influenced an area of eddy formation on the northern tip of Ramsey Island. This produced a shift in hydrodynamics and a change in propagation of the eddies, which in turn affected propagation of eddies forming off the Bishops and Clerks to the west of Ramsay Island (Figure 5.13). As a result there were simulated large scale variations in hydrodynamics in the area extending over 10 times further than the direct wake of the array.

Figure 5.13: Changes to current speed and eddy propagation from a tidal array in Ramsey Sound



Notes: Black box denotes extent of the 10MW tidal array, consisting of 27 turbines with 18m rotor blades. Scale relates to velocity difference between model runs with and without the tidal array.
Source: Haverson et al. (2014)

Turbulence and tidal currents also play a key role in determining the location of seasonal shelf fronts, through tidal stirring and mixing of the water column (Woolf *et al.* 2014). Any changes to hydrodynamics may cause mixing in areas of strongly defined salinity or temperature gradients and promote both potential deposition of sediments in areas of reduced velocity and possible re-suspension in areas of turbulence within the wake. A reduction in thermal or salinity based stratification will have an additional effect on nutrient distribution within the water column and therefore the types of biota within the immediate area. This will potentially have a knock-on effect on the food chain, with reduced stratification and increased mixing potentially affecting primary production and larval settlement, although probably on a localised scale and in relation to larger arrays of devices. Alterations in turbulence may also affect the feeding behaviour of some seabirds, particularly terns (ICES 2010).

Sediment dynamics

It is suggested that even in areas without a local source of sediment supply, tidal devices impact sediment transport and morphodynamics. Neill *et al* (2009) demonstrated that energy extraction in a relatively long channel with tidal asymmetry produces up to 20% more bed level change associated with sediment movement than in a site with tidal symmetry. They also suggested that the presence of a tidal stream array in a different location may actually reduce the magnitude of bed level change relative to a natural system due to the general reduction in tidal velocity and hence sediment transport. Monitoring of the ambient velocity field beyond the near-field wake and flow direction for the SeaGen Turbine in Strangford Lough actually showed no evidence of significant deviation from pre-deployment values suggesting limited impact on flow dynamics, scour patterns or turbulence characteristics (Royal Haskoning 2011). This highlights the site specific nature of impacts.

Modelling of the impact of a large (300MW) array in the western side of the Alderney Race, Channel Islands (Neill *et al*. 2012), on headland sandbanks for several scenarios showed that energy extraction of this magnitude could have significant impact on the morphology of local sandbanks (a 10% difference in bed level change over a spring-neap cycle relative to the baseline). However careful siting of the array could mitigate some of this impact. Additional modelling on the eastern edge of the Race (290MW array - Thiébot *et al.* 2015) showed a change in mass balance between the sediment deposited in the eastern and western parts of the English Channel, peaking at 20% for the particles with the greatest erosion threshold.

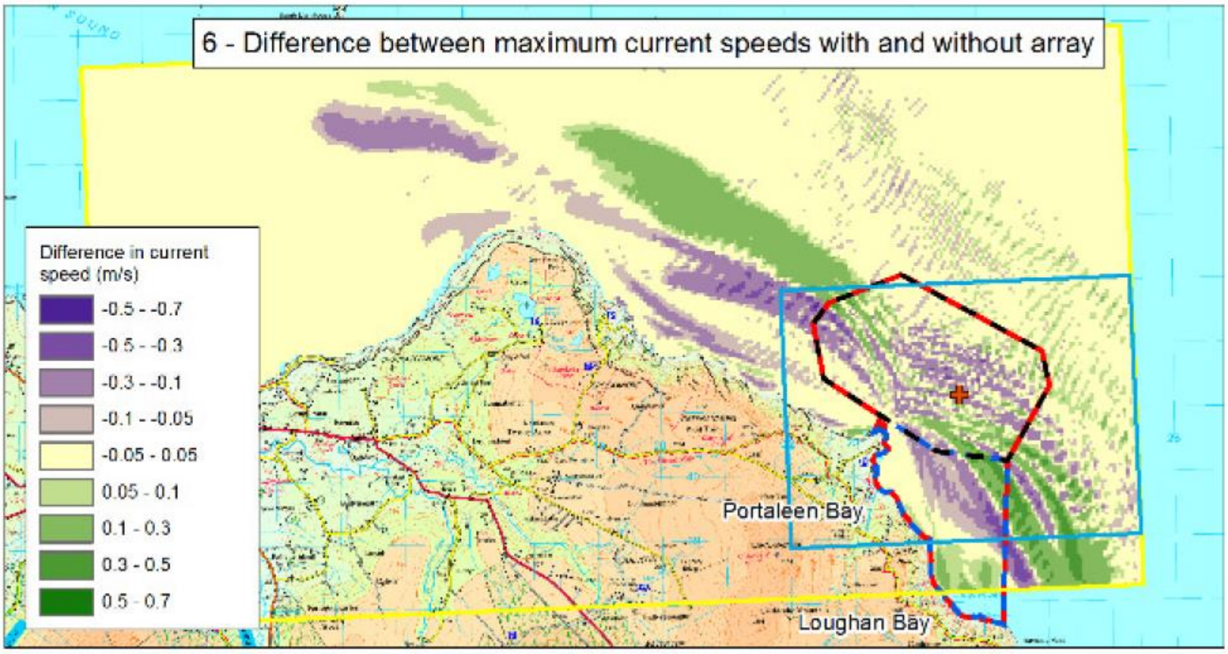
In comparison, only small differences in sediment transport were seen in modelling of an 86 tidal turbine array in the Inner Sound, Pentland Firth (MeyGen 2012) with no evidence of net bedload transport away from existing bedforms. This is supported by Robins *et al.* (2014) who found that for smaller arrays (<50MW) off the northwest coast of Anglesey the impact of energy extraction on bed shear stress and sediment transport was less than the natural variability. However, for larger arrays (>50MW) significant impacts were observed, although they did not extend to affecting sand banks 10km away. This difference in impact related to the size of an array is also seen in simulations for the Pentland Firth (arrays composed of 0-400 turbines), where arrays larger than 85 turbines affect bed shear stress distributions and the movement of sediment accumulation from the edges of the Inner Sound of Stroma towards the centre (Martin-Short *et al.* 2015). Relatively minor changes in sediment accumulation occur at arrays with <85 turbines, whilst deposits of fine gravel and sand within the array develop at arrays >240 turbines. The reduction in flow velocities within the Inner Sound appeared to have implications for sediment transport elsewhere within the Pentland Firth, although an exact pattern was hard to distinguish.

Those potential far field effects are also seen in an array of 2,000 turbines in a 7.2km^2 area of the Bristol Channel. This study showed decreases to suspended sediment concentrations both upstream and downstream of the array and an increase to the sides, up to 15km away (Ahmadian *et al*. 2012). However, a study in the open Celtic Sea north of Cornwall suggests potential impacts up to 100km from an array (Shapiro 2011) This highlights both the site specific nature of impacts due to the range of hydrodynamic, bathymetric and sedimentary properties of the sites and the size of the array.

Flow diversion

The presence of a tidal stream device within the water column will also accelerate velocities around the structure, although in open water cases the impact on far-field areas is suggested by modelling evidence to be negligible (Walkington & Burrows 2009). Modelling of the SeaGen device in Strangford Lough showed flow acceleration around the device extending 250m on either side as far as the shore (RPS 2005b). In this case the substrate, composed of rock and course sand, is unlikely to be affected but softer sediment types in other locations will experience scour and where the increased flow impacts the shore, potential erosion effects are expected (Walkington & Burrows 2009). Modelling of an array of 400 turbines in the Pentland Firth shows that on flood tides significant velocity shear zones form to the sides of the array as peak flow velocities are diverted towards the edge of the Inner Sound of Stroma, with implications for sediment dynamics (Martin-Short *et al.* 2015). This is also shown at the MeyGen turbine site (Inner Sound, Pentland Firth) which shows an 0-1m/s velocity increase under calm in the middle of the channel as a result of 86 turbines, with an increase of 0.1-0.8m/s to the north and south around the edges of the array (MeyGen 2012). Further wave refraction around devices also has the potential to affect coastal wave erosion especially in narrow and enclosed sites. Whilst increased velocities around single devices are localised, the blocking effect of arrays of devices within a channel or area does have the potential for impact, primarily associated with deflection. Modelling at the 100MW Torr Head tidal array site off Northern Ireland (Tidal Ventures 2015), shows that by removing energy from the water column the array deflects the region of high flow slightly further out into the North Channel (Figure 5.14), although the overall current flow does not change significantly.

Figure 5.14: Difference between maximum current speeds at Torr Head with and without a tidal stream array



Notes: Black and red ringed area is location of 100MW tidal array
Source: Tidal Ventures (2015)

Water levels

The extraction of energy, especially in enclosed sites, will also modify the water levels both upstream and downstream of the device, which would potentially have the effect of moving erosion up or down the coastal height profile. This is seen to be largely minimal at open water sites, e.g. 0.03% at Alderney Race for a 300MW array (Neill *et al.* 2012). Modelling work in the Solway Firth suggests that whilst the effects on maximum water levels of a tidal array are not significant, low tide levels would potentially be affected with the intertidal area covered for a greater period of time (Garcia-Oliva *et al.* 2014). This would have ecological implications for benthic habitats and species of the intertidal area.

5.5.2.2 Tidal Range

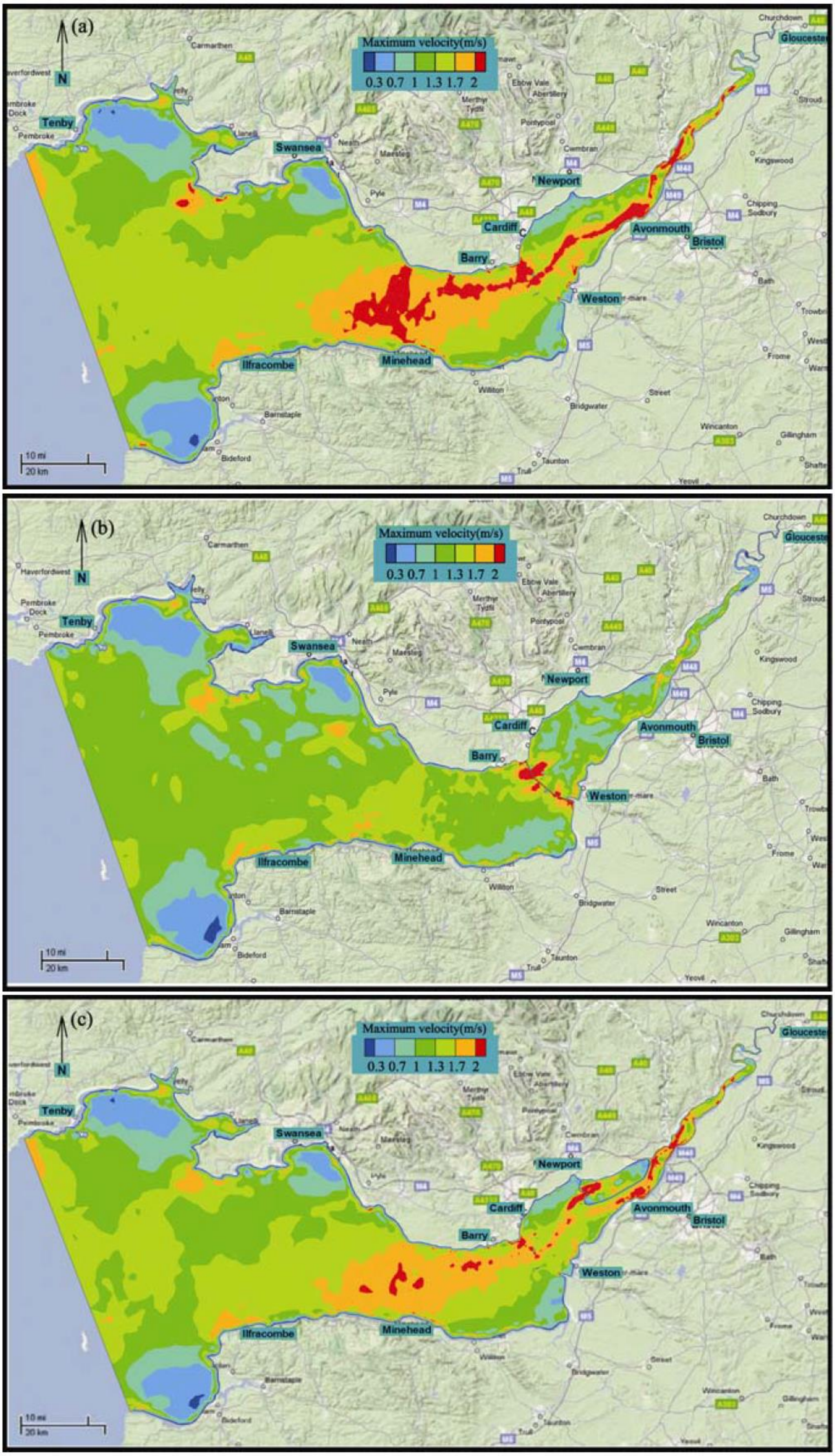
Tidal range devices, both barrages and lagoons, may have a large impact on the energy balance of the local environment and wider region. Barrages not only remove energy from the water column at a single point but also affect velocities across the whole channel and upstream and downstream of the installation. Due to the nature of a barrage it is difficult to separate out changes in hydrography due to energy extraction and those caused by physical constriction and restriction of flow by the barrage itself. As a result Section 5.4.2.2 details changes in water depth and resulting intertidal habitat loss associated with tidal range projects, and the impacts and effects of both the changes in down and across-stream current velocities and sediment transport patterns are considered below. With only a few operating tidal barrages in the world (e.g. La Rance, France), the majority of assessments of impacts are based on modelled simulations, whilst tidal lagoons are still in their infancy and have not been widely studied.

Velocity changes

The presence of a barrage or lagoon will restrict the flow of water affecting both the mean water level within a basin and causing a decrease in tidal current speed. Dual mode of operation of turbines is thought to have less severe impacts than the single flood or ebb generation modes (Ward *et al.* 2012). Several studies have modelled the impacts of different barrage options within the Severn Estuary on velocity and water characteristics (e.g. Falconer *et al.* 2009, Xia *et al.* 2010, Kadiri *et al.* 2012). Figure 5.15a,b shows the predicted changes in maximum tidal current velocities with and without a Cardiff to Weston-super-Mare Severn barrage (Falconer *et al*. 2009), and illustrates the large impact of a barrage on the flow of water through the estuary. The figure clearly shows that upstream of the barrage there is a significant reduction in current velocities, predominantly in the main channel, with similar reductions seaward of the barrage in the main channel and across large areas of the estuary as a whole. Subsequent 2D and 3D modelling (Zhou *et al*. 2014a) shows a very similar pattern with a reduction in velocity due to the barrage of up to 50% in some areas. Whilst the centre of the Bristol Channel has a reduction in maximum velocity from 2.4m/s without a barrage to 1.2m/s with a barrage, the area around the sluice gates and turbines shows much greater velocities due to barrage operation. Investigation into the impacts of different operating modes of a Cardiff to Weston-super-Mare barrage (Ahmadian *et al.* 2014a) show that the reduction in maximum velocity downstream of the barrage would be greater for a two-way generation scheme (>0.75m/s) than for an ebb only generation scheme (0.5m/s). Conversely the ebb only generation scheme produced a greater reduction in upstream velocity (0.5m/s) than the two-way generation scheme (0.25m/s). The operating of a barrage also causes a shift and a time lag in the ebb and flow velocities due to the holding phase.

Additional studies corroborate the pattern and scale of likely impacts from a Cardiff to Weston-super-Mare barrage with: a 20% reduction in upstream velocity and an 18% and 30% reduction in tidal amplitude for the M_2 and S_2 components respectively and a 17% decrease in tidal velocity downstream of the barrage (Ward *et al*. 2012); a 1.4m decrease in upstream water levels and a 0.5m/s decrease in velocity (Ahmadian *et al.* 2014b); a decrease in current speed downstream of the barrage from 2.0m/s to 1.4m/s and a decrease in water levels downstream of a barrage of 0.5m and upstream of 0.5-2m (Kadiri *et al.* 2012). A 40% reduction in tidal velocity over tidal shoals and salt marshes and a 20-40% decrease of velocity in tidal channels has also been measured at the Oosterschelde storm surge barrier, Netherlands (Louters *et al.* 1998) with similar reductions measured at La Rance in France (Kirby & Retière 2009).

Figure 5.15: Modelling comparison of maximum spring tidal currents (a) no scheme, (b) Cardiff to Weston-super-Mare barrage, (c) Flemming lagoon

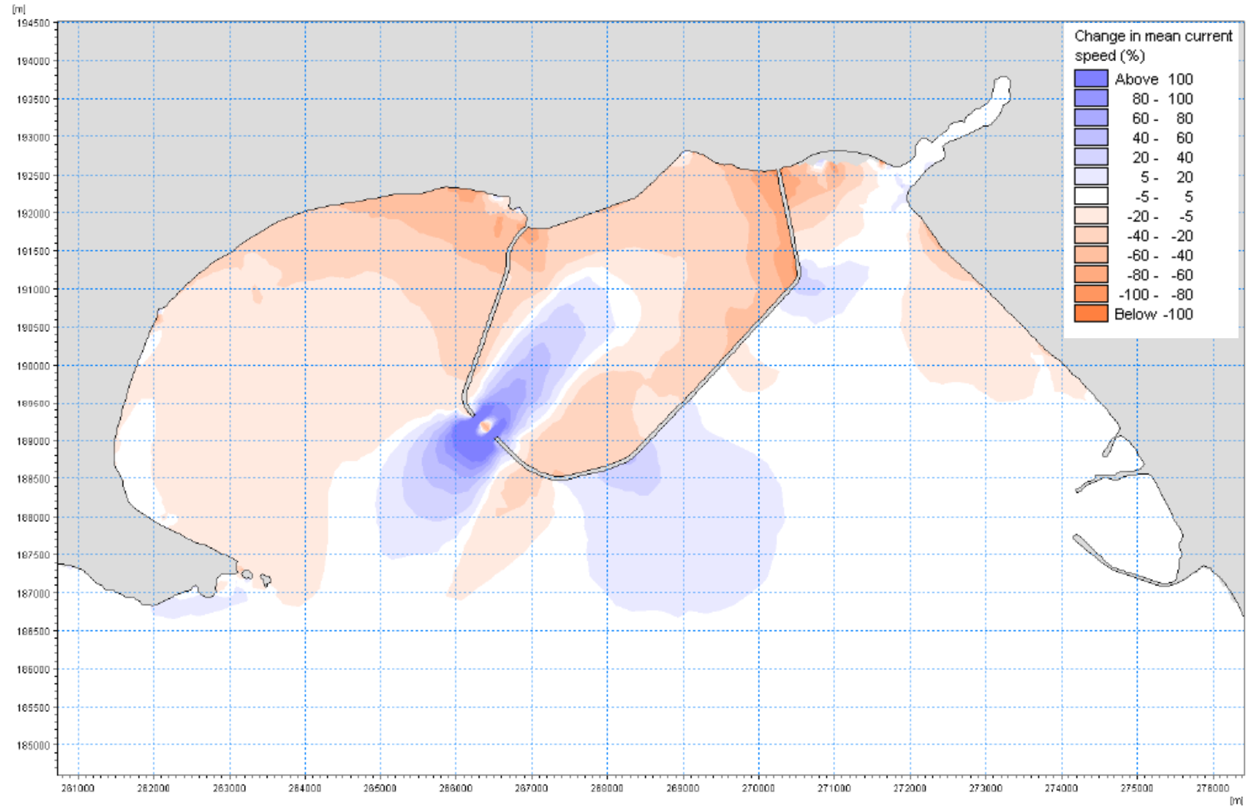


Source: Falconer et al. (2009)

In addition, the duration of slack water at La Rance has increased from 15 minutes to 2 hours since the barrage has been in operation, with the volume of water exchanged with the sea reduced by 30%. Strong local currents in potentially complex patterns form around a barrage itself, with an obvious increase in the region of the turbines and sluices (Figure 5.15b; Xia *et al* 2010, Retière 1994).

Whilst the impacts from the Cardiff to Weston-super-Mare barrage are significant, little work has been done on identifying impacts from other tidal range options within the wider Severn Estuary. Figure 5.15c shows the impact on maximum spring tidal currents of the Fleming lagoon option, between Newport and the Severn road crossing. It shows that velocity changes are not as extreme as for the full barrage option, with a decrease upstream of the lagoon and a minor decrease downstream. In the case of water levels a decrease of only 0.2-0.5m upstream of the lagoon would be expected, compared to 0.5-2m for a barrage, with no significant impact downstream (Falconer *et al*. 2009). The construction of the lagoon would therefore only slightly reduce the flood risk upstream but would have far less impact on the loss of intertidal mudflats.

Figure 5.16: Relative change in mean spring current speed as a result of a tidal lagoon in Swansea Bay



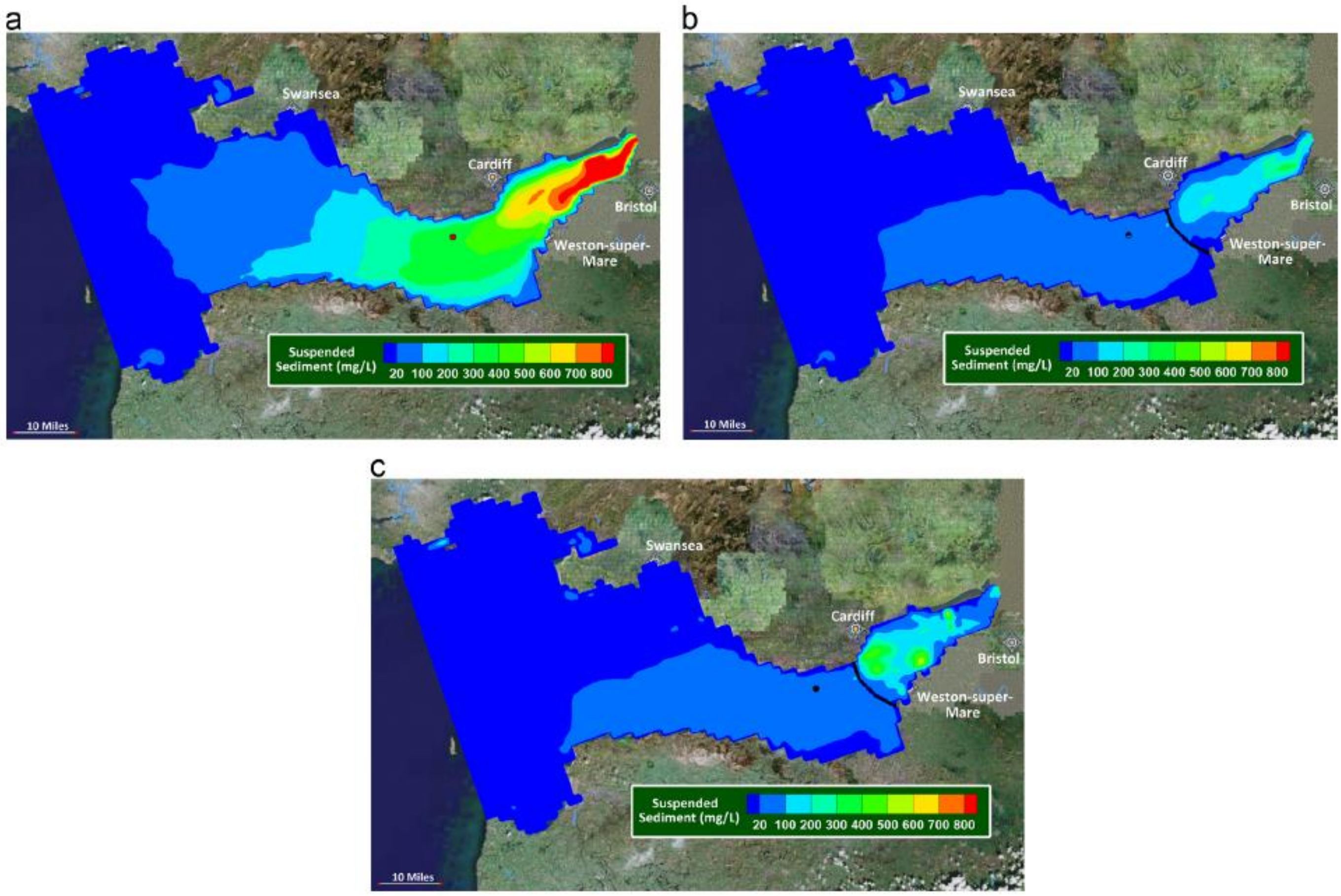
Source: Tidal Lagoon Swansea Bay (2013a)

Numerical modelling of the impact of the Swansea Bay tidal lagoon project on mean spring tidal flows (Figure 5.16) shows smaller spatial scale impacts, with changes largely restricted to Swansea Bay. The greatest changes are in the vicinity of the sluice gates/turbines (over 100% increase from baseline within 225m), decreasing with distance to around 5-20% at 2.3km from the turbines, with the variation related to 'jetting' from the turbines. This jetting is caused by a rapid increase in flow speeds approximately 3hrs after high water when the turbine gates are opened, with flow speeds of 1.7-1.9m/s compared to 0.45m/s for the baseline conditions. Just after low water, ebb flows are further accelerated when the sluice gates are opened to further drain the lagoon, with peak flow speeds of up to 3m/s for a short duration (15 minutes). Although these changes in flow speeds are relatively short in duration and spatial extent they are significant in magnitude and can be expected to have an impact on the sediment patterns of the area. Reductions in flow of typically <40% are seen within the Swansea Bay lagoon, peaking at 80% at the far eastern side, with additional decreases in flow seen to the west of the Bay probably as a result of the physical presence of the lagoon rather than energy removal.

Turbulence and sediment dynamics

Areas of large tidal range tend to be areas with high current velocities and as such generally have high suspended sediment loads, low levels of light penetration into the water column and therefore low primary productivity and dissolved oxygen concentrations. Even small changes in current speeds may have large implications, as the energy within a tidal flow is proportional to the cube of the velocity. Modelling of the Severn barrage shows a decrease in upstream suspended sediment concentrations from 1200 mg/l without a barrage to 200 mg/l after construction (Kadiri *et al*. 2012), although two-way generation slightly reduced the level of this decrease compared to ebb only generation (Figure 5.17; Ahmadian *et al*, 2014a). This significant reduction in suspended sediment concentration may increase primary productivity in the water column (through increased light penetration, and assuming equivalent nutrient fluxes), with associated effects on the ecosystem function as a whole. Simulated reductions in bottom shear stress due to reduced downstream velocities throughout the Bristol Channel, also means that the water column would become less turbid, also allowing more light penetration and increased productivity (Wolf *et al.* 2009). Greater benthic bio-diversity can also be expected as a result of decreased velocities at the sea bed (Kirby & Retière 2007).

Figure 5.17: Predicted suspended sediment levels at high water spring tide at Barry (a) without barrage, (b) with ebb only generation barrage, (c) with two-way generation barrage



Notes: Barry is represented by black dot
Source: Ahmadian et al. (2014a)

A large build up of sediment is expected upstream of any barrage, calculated to be around 8.2M tonnes compared with 1.2M tonnes downstream for a Cardiff to Weston-super-Mare barrage (DECC 2010). Calculations suggest a reduced variability in deposited sediment mass from spring to neap tide of 3M tonnes after construction of a Cardiff to Weston-super-Mare barrage compared with 5.4M tonnes under existing conditions (DECC 2010), with rapid accumulations of up to 2m in deep channel regions. The resulting calculation of reduction in the mobile sediment load by a factor of between 2 and 3 (DECC 2010) illustrates the large amount of sediment deposition and significant changes in bed profile, geomorphology and habitat types that would result from the construction of a barrage. Decreased velocities and increased sediment deposition upstream of a barrage would increase water clarity and increase phytoplankton derived primary production (Underwood 2010) It is however likely that basin wide erosion will vastly exceed accretion (as in the Eastern Schelde (Pethick *et al.* 2009)) with accretion occurring in sheltered locations, areas local to regions of erosion or tributary mouths (DECC 2010b), the barrage itself and main channels, with mudflats and sandbars experiencing high levels of flattening and erosion. The simulated large changes to tidal dynamics especially upstream of a barrage could also increase stratification and reduce flushing rates, increasing the eutrophication risk (Burrows *et al.* 2009, Wolf *et al.* 2009, Frid *et al.* 2012).

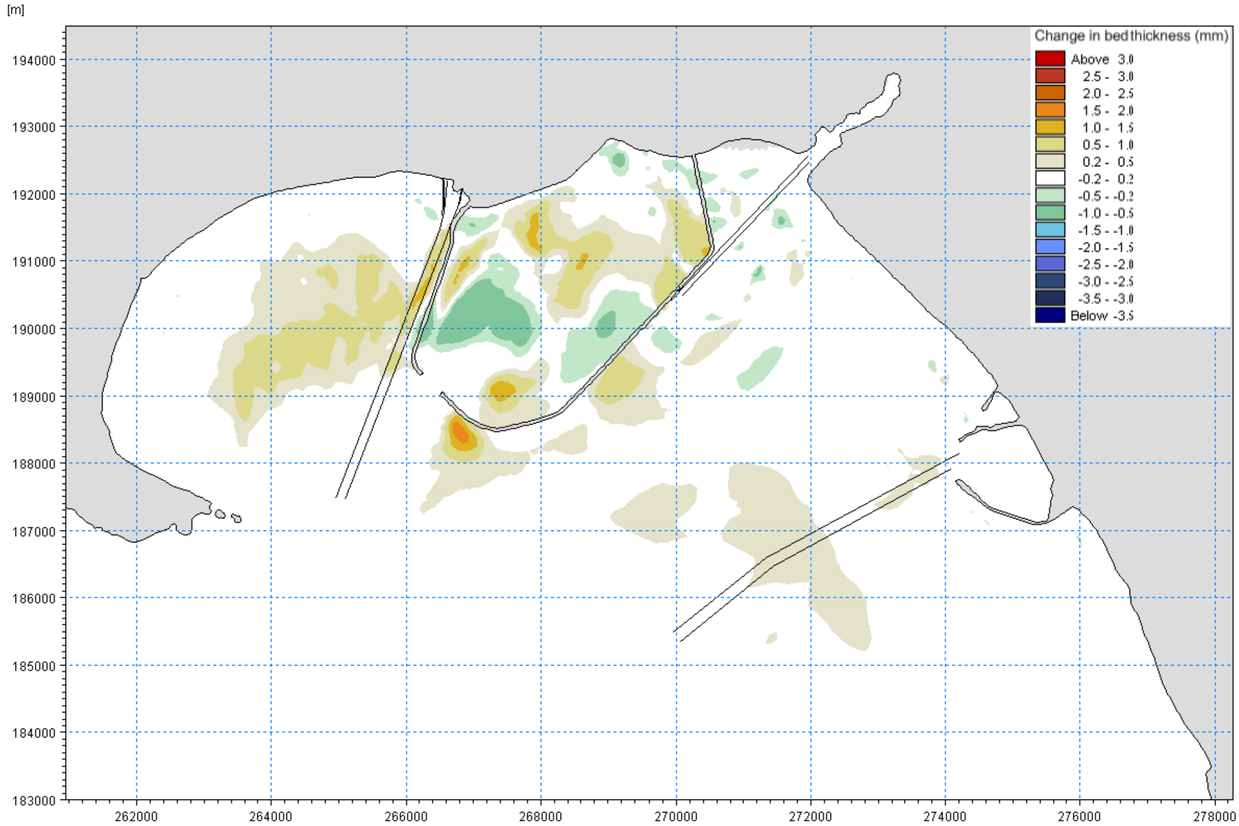
The transport of fluid mud in the Severn Estuary upstream of a barrage, which has important biological and chemical implications, would largely stop due to the reduction in current velocities. It is calculated that up to 2.5m of fluid mud could therefore be deposited in channels, which will compact to a mud bed layer about 0.3m thick (Kirby 2010). As a result of fine sediment deposition upstream of a barrage, sediment starvation may occur downstream affecting salt marsh development, allowing a further increase in erosion through greater wave propagation to the upper shore (Pethick *et al.* 2009). Presently the upper estuary has extensive sand distribution due to the high tidal flows (Underwood 2010), which would become increasingly silty with the deposition of finer sediments, changing the biotope and therefore the communities inhabiting the area. The low species richness and biomass of the present Severn Estuary, characterised by boring bivalves and species such as *Hydrobia ulvae*, *Macoma balthica* and *Nephtys hombergii* in the muds, and *Bathyporeia spp*. in the sands (Warwick & Somerfield 2010), could potentially change to one with increasing populations of deposit feeding or filter feeding invertebrates (Underwood 2010).

In addition, the constraint of flow through a barrage will lead to turbulent flows and increased mixing immediately downstream during outflow and immediately upstream during inflow. This would lead to highly turbid conditions and low primary productivity in the near-field, increasing the spatial complexity of response of the area to a barrage.

In the long term an estuary would to adapt geomorphologically to a new regime leading to modified flow conditions. Calculations of a timescale for this readjustment for the Severn Estuary place it in the order of 1,500 years (Pethick *et al.* 2009), a similar value was given for the Oosterschelde tidal barrier (Louters *et al.* 1998), which suggests 1 or 2 magnitudes larger than the two decades it took for the system to adapt to the closure of two small dams. The huge scale of these effects and their potential complexity combined with natural variations in the physical conditions of locations means that individual estuaries/river basins will respond differently to the construction of a barrage. As a result, detailed site specific data gathering and assessment should be undertaken before any decisions on suitability of the area for construction are taken.

In terms of tidal lagoons, the effects of water impoundment are largely the same but on a more localised scale than those of tidal barrages. The presence of a tidal lagoon within Swansea Bay is seen to significantly alter the residual tidal flows within the Bay (Tidal Lagoon Swansea Bay 2013a), with resulting impact on sediment dynamics. Figure 5.18 shows predicted changes to mud deposition over a spring tidal cycle within Swansea Bay compared to the baseline, with changes largely restricted to within the lagoon and wider Bay. Changes in sediment dynamics are largely driven by reductions in flow speeds resulting from the physical presence of the lagoon and from increased mobilisation of sediments in areas due to jetting. In addition the modelling identified a reduction in cross bay sand transport during storm events and a possible increase in sand deposition at the entrance to Neath due to a reduction in wave height.

Figure 5.18: Predicted changes to mud deposition during a 10 in 1 year storm event in Swansea Bay due to a tidal lagoon



Source: Tidal Lagoon Swansea Bay (2013a)

Salinity and temperature

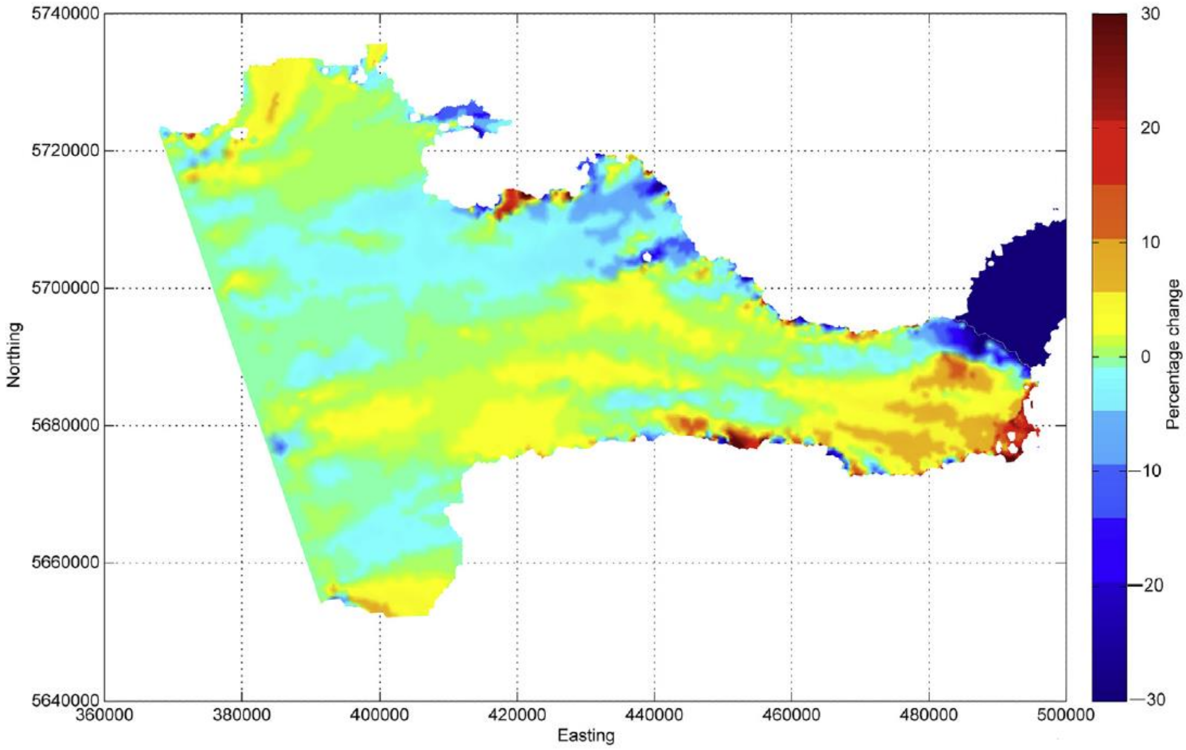
Due to the presence of a barrage there will be reduced penetration of saline water into a basin leading to freshening, i.e. more brackish water (Wolf *et al*. 2009). Initial modelling on the Cardiff to Weston-super-Mare barrage (Zhou *et al.* 2014a) shows that the salinity concentration at high water for the area seaward of the middle of the Bristol Channel is unaffected. However the salinity concentration is decreased by 1-2ppt in the regions immediately upstream and downstream of the barrage, with a dominance of freshwater inputs as the river narrows upstream of the barrage (up to 5ppt decrease between Beachley and Sharpness). The salinity concentrations are seen as relatively stable upstream and downstream of the barrage with only a small variation, suggesting that a barrage can reduce salt intrusion upstream. These changes in salinity would have implications for the extent to which marine species are able to penetrate the estuary, with implication for their local abundance. Reedbeds may also replace saltmarshes if the influence of freshwater extends further down an estuary (Hooper & Austin 2013). There may be minor changes to upstream temperatures associated with a barrage, although these are expected to be within the range of natural variability (>1ºC) and are therefore considered not significant (DECC 2010).

A reduction or change in circulation associated with tidal lagoons may be expected to affect temperature and salinity. The Swansea Bay Tidal Lagoon project (Tidal Lagoon Swansea Bay 2013b) shows that summer temperatures are largely unaffected by the lagoon, with a marginal increase in winter temperatures within the bay (0.1-0.75ºC) and the lagoon (0.5-1ºC). As with the barrage, these are within expected annual variability and are therefore not seen as significant. In terms of salinity, the lagoon would cause a change in salinity of 1-5psu within the bay with the greatest change in the shallower areas. This is due to displacement of the river plumes and increase in entrainment of offshore water into the western bay. Within the lagoon the salinity remains relatively stable at 25-30psu, compared to 15-30psu for the baseline. Again these changes fall within the range of natural variability of the bay area and are therefore also not seen as significant.

Wave Conditions

As has been shown, barrages affect tidal currents and water elevations in the wider area. In the Severn Estuary there is strong tidal modulation of the wave climate and therefore the presence of a barrage may affect the local wave climate, with impact on erosion and flooding in the wider area. A study on the impact of the Cardiff to Weston-super-Mare barrage on wave climate of the area (Fairley *et al*. 2014) showed that over one spring tidal cycle (Figure 5.19) in general the changes to the wave climate were within ±5% of the pre-barrage values. There were however localised areas of greater increase (by >10%) around the north Somerset coast between Minehead and Weston-super-Mare, Tenby, west of Bideford and the south Gower coast. The latter is due to a reduction in the tidal race around the headland which produces wave dissipation and blocking. The main area of decrease (apart from upstream of the barrage) is in the wider Swansea Bay area. It should be noted however, that whilst the sum of wave height over the tidal cycle is higher in some areas, the maximum significant wave height in these areas does not increase post barrage. Simulations for the neap tide show similar patterns, with a visibly larger increase in wave heights on the ebb rather than on the flood tide.

Figure 5.19: Percentage change to wave height over one spring tidal cycle from a Cardiff to Weston-super-Mare barrage



Source: Fairley et al. (2014)

Modelling work on the Swansea Bay tidal lagoon shows that whilst impacts on the local wave climate also results from the lagoon development, they are very localised and do not extend outside the bay area.

Far-field effects

Most of the impacts of a tidal barrage have been identified and investigated through modelling, using the same open boundary conditions for pre and post barrage simulations. In the Severn Estuary the disturbance to the tidal regime from the barrage is likely to propagate far from the barrage and affect the boundary conditions of a model if the computational domain is not large enough. Zhou *et al*. (2014b) used two models to investigate far-field effects of a Severn barrage (Cardiff to Weston-super-Mare) with the open boundaries extending to cover the continental shelf in one and Celtic and Irish Seas in the other. The presence of a barrage increases tidal velocities within the wider Bristol Channel, with increases of 0.52m/s for a site in the centre of the Channel and 0.19m/s at the boundary of the channel. However, in regions of comparatively deeper water in the Celtic Sea the impact of a barrage on tidal velocities is seen to be negligible. There is however, a discernible far-field increase in maximum water depth over most of the Irish Sea, associated with a barrage. The Cardigan Bay especially sees an increase of 4-7cm, peaking at 9cm in the north of the bay. Due to the obstruction of the barrage the volume of water flowing into the Bristol Channel is reduced forcing more water to flow into the Irish Sea, changing the resonance frequency of the Bristol Channel and Severn Estuary basin. In addition, Wolf *et al.* (2009) investigated the near and far-field impacts of barrages within 5 estuaries in the west of the Irish Sea. They showed that there was a 10% increase in tidal amplitude along the east coast of Ireland which could have implications for flooding, although the increase was less than that of a 1 in 50 year storm surge event. This highlights one major issue of evaluating far-field impacts even for large installations such as a barrage. Measurements of tidal range, for example, are confounded by long-term natural changes such as isostatic rebound and climate variability, and therefore isolating the far-field impact of a barrage from natural variability may not be statistically possible. Some other parameters, such as turbulent dissipation, would be even harder to measure in the real environment and therefore very difficult to assess at far-field scales.

These initial studies suggest that impacts on hydrodynamics may be seen at significant distances from barrages, with the need for large computational domains in modelling studies to better identify far-field effects. One of the regions evaluated for the siting of tidal stream devices and tidal lagoons is within a projected far-field area of velocity decrease due to the construction of a Cardiff to Weston-super-Mare barrage. This highlights the need to consider cumulative impacts of multiple energy devices on resource availability.

The fine sediment component of the Severn Estuary is predominantly from fluvial sources (Allen 1991) upstream of any barrage location. The alterations to sediment transport pathways associated with the building of a barrage may therefore have implications for the sediment balance of the wider area, with a reduction in inputs of finer, fluvial sediments which contribute to mud flats to the downstream region. The extent of the implications of this are currently unknown, but have the potential to extend to the far-field. In addition, the reduction in flushing rate of water upstream of a barrage and increased resident time would likely mean a reduction in nutrient dispersion throughout the estuary. This may also have implications for far-field nutrient concentrations if the estuary is a source for the wider area.

Climate change impacts

There is evidence that a rise in sea level, associated with climate change, may have significant impacts on the tides on the European shelf, changing the tidal amplitude by potentially tens of centimetres (Pickering *et al.* 2012). This would have implications for tidal range projects, especially barrages which have a long life span, although the same study suggested that response to climate change was very variable both spatially and in magnitude. Ward *et al.* (2012) modelled the impact of sea level rise and a tidal barrage in the Severn Estuary, and sea level rise and tidal devices in the Solway Firth and Morecambe Bay. They discovered that whilst the presence of a barrage in the Severn Estuary would reduce current velocities compared to present day, sea level rise of 2m combined with a barrage would actually increase velocities due to more water entering the Estuary. Sea levels also affected the spatial extent of impacts of energy extraction when there were multiple tidal plants in the Irish Sea.

Additional modelling work on the Severn Estuary (Ahmadian *et al.* 2014b) applying a lower sea level rise estimate of 0.48m showed that the presence of a barrage would reduce the water level rise upstream of the barrage by 0.18m so it would only experience a 0.3m rise compared to the 0.48m rise for the downstream part of the Estuary. This would reduce the flood risk associated with increased sea levels upstream of a barrage. The study also suggested that whilst building a barrage could reduce the intertidal mudflats in the estuary by $127km^2$, a sea level rise of 0.48m by 2100 would reduce the mudflats by a further $41km^2$ if a barrage was present. This would have significant ecological and environmental implications, discussed further in Section 5.4.

5.5.2.3 Wave

Wave devices remove energy from the wave train, potentially affecting water mixing properties in the near field, sediment transport in the near and far field, wave-current interaction and current power generation capacity of neighbouring areas. The interaction between waves diffracted by devices and the waves radiated by the motions of a device can also strongly impact both the power production and impact of an array (Borgarino *et al* 2012). As with tidal stream and range technologies, the majority of studies on environmental impacts are based on modelling evidence (e.g. Folley *et al*. 2012) with few deployments of individual devices in the real environment. Modelling has tended to focus primarily on the impact of devices to wave fields, local wave climate and accurately representing wave devices in numerical models. Less work has been undertaken on the changes to sediment transport and morphological changes, although the use of wave devices for coastal defence has been focused on by some studies.

Wave height and wake effect

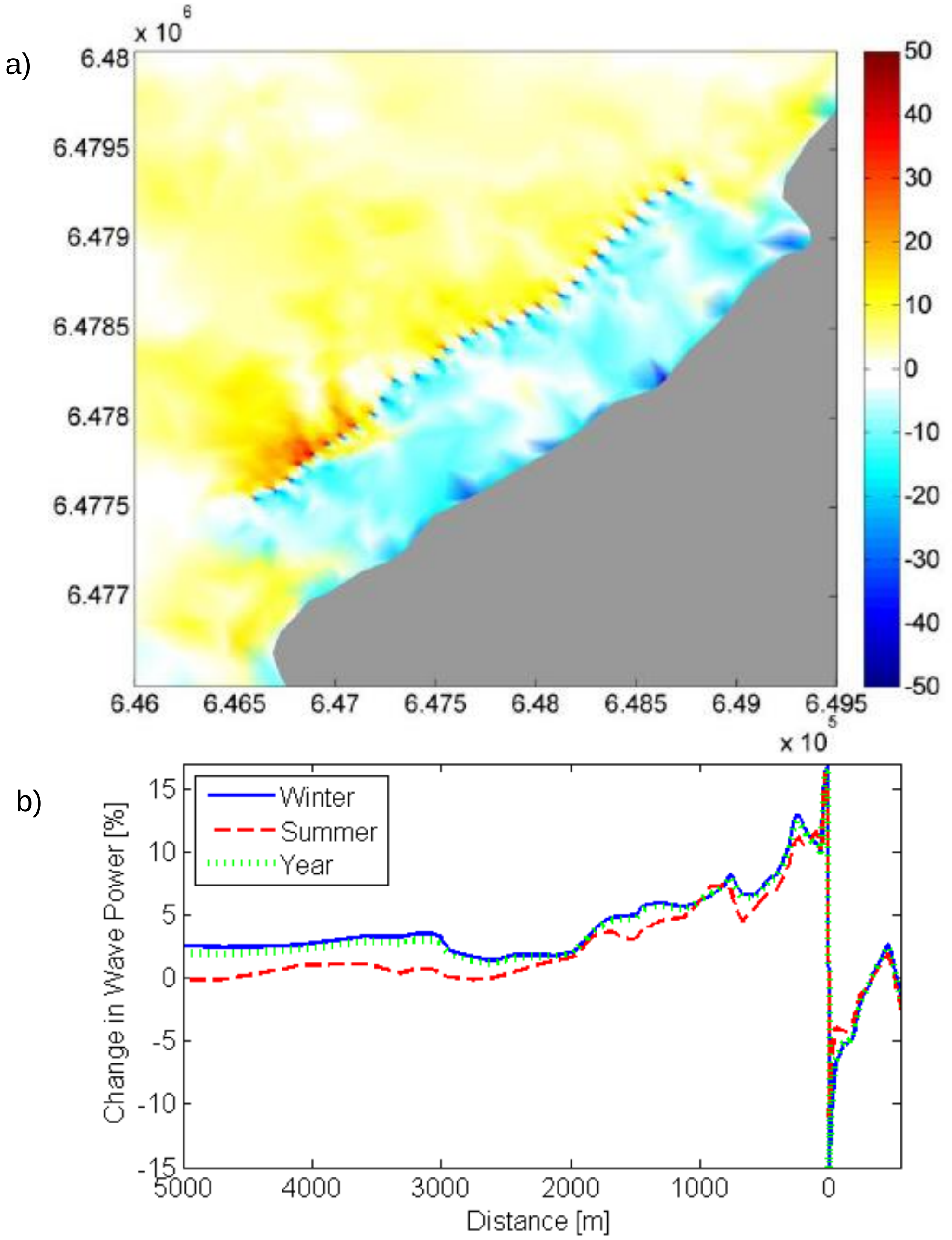
Reductions in simulated wave height immediately downstream of wave devices are modelled to be significant (e.g. around 45% for a device 10m wide and 160m long (Venugopal & Smith 2007)). However this is not a reflection of the large absorption of energy by the device, it is predominantly due to the high level of diffraction of wave energy around the structure (calculated as 70% of the wave power for long-crested waves for the Wave Dragon device type (Beels *et al.* 2010)). This diffraction is seen as a small increase in wave height at the edge of the wake (Troch *et al.* 2010).

Variations in the maximum reduction in wave heights within the wake (with values ranging from 13–69% reduction (Venugopal & Smith 2007)) are also modelled to occur for different porosities of devices (how much energy they absorb) and different array sizes and shapes: 18% for an array of 25 devices (Troch *et al*. 2014) in the DHI Shallow Water Wave Basin as part of the WECwakes project; 30% for 11 devices arranged in 2 rows offshore Perranporth Beach, Cornwall at the WaveHub site (Abanandes *et al* 2014).

Modelling of a row of 30 devices parallel to the shore off the Isle of Lewis (Figure 5.20) shows a 15% wave power reduction behind the devices, although the largest impact can be seen behind the southern end of the array due to incident wave direction (Greenwood *et al.* 2013). Figure

5.20b also shows that wave power reaches pre-device levels approximately 320m downstream of the array. Maximum wave power reduction values of 36-38% have been modelled for the immediate lee of the first row of 10 devices offshore NE Spain (Iglesias & Carballo 2014). By the second row of 10 devices (270m behind first array) the wave field had partially recovered through energy diffraction, with the second reduction in incident wave power lower at 17-18% at 500m. A slightly different pattern was shown by Abernandes *et al.* (2015) whereby the reduction in wave height actually peaked with the second row of devices in an array (50% reduction) with a secondary peak occurring 1.5km from the second row due to the merging of shadows caused by the first and second rows of devices. This highlights the importance of array spacing and shape on wake effects.

Figure 5.20: Simulated a) percentage change (yearly average) in wave power behind multiple wave devices offshore west coast of Lewis, Scotland, b) change in wave power along a perpendicular transect through the central device



Source: Greenwood et al (2013)

The size of the wake effect of a device will also be dependent on device shape and wave type, with wider but far shorter wakes observed for short-crested compared to long-crested waves. The wake effect of the device is reduced with distance due to wave diffraction and energy redistribution so that for short-crested waves modelling has shown that after 3km downstream from the device the wave height is the same as that in front of the device (Beels *et al.* 2010). However for long-crested waves at 3km downstream only 70% of the initial wave height is recorded. Measurements in the Shallow Water Wave Basin (Stratigaki *et al*. 2014) shows that for an array of 25 turbines arranged in 5 rows of 5 devices a wave height decrease is seen after the first row of 5 devices in a sea state dominated by short-crested waves. However a decrease in wave height is only seen after the 3rd row of devices for a sea state dominated by long-crested waves. Troch *et al.* (2010) confirmed that regeneration behind a wave device depends on the wave length, peak period and directional spreading of the incident wave climate, with the higher the peak period and directional spreading the faster the waves regenerate downstream of the device. Greenwood *et al.* (2013) suggest that there is a greater change in wave power outwith and within the wake of an array in winter due to more energetic wave conditions. Palha *et al*. (2010) also suggest that the percentage of wave energy extracted by a wave device exhibits seasonal variability, with the proportion of energy removed greatest in summer.

The wake effect is also dependent on the distance of the array from shore. A study of an array at different distances from shore at the WaveHub site (Abanandes *et al*. 2015) showed that an array close into shore (2km) caused a greater reduction in wave height than the same array at 6km offshore, however the resource in the shallower area was seen to be lower and therefore caution should be taken when comparing impacts and resource generation capacity from different arrays.

A local increase in wave height is also seen in front of devices (Beels *et al.* 2010), due to reflection, with calculations suggesting increases of up to 31% (Venugopal & Smith 2007, Troch *et al*. 2014). The modelling study of Greenwood *et al*. (2013) however suggests that there is a significant upstream increase in peak wave power (15% close to devices) due to an array (Figure 5.20) which may propagate over 3km from the array affecting the surrounding wave climate.

The effect on wave height has a potentially greater impact for those devices which are shore-based or situated close to land. Modelling work on the Siadar breakwater project, Isle of Lewis (Amoudry *et al.* 2009), showed that most of the wave energy will be diffracted around the structure with very little energy remaining in the lee, with a large potential for changes in shoreline and surf-zone processes and sediment accumulation. This has the potential to be a positive effect in areas with significant coastal defence issues and could possibly be used as part of a system to manage coastal erosion and coastline retreat. However any changes to surface productivity linked to reduced turbulence or mixing of the water column will potentially modify the food supply to benthic populations (Pelc & Fujita 2002). This is likely however to be very localised and the area affected is likely to vary with changing wave direction.

All of these factors confirm the need for careful planning of spatial array designs to maximise power and minimise wake effects, including device type, array shape and size, and location in relation to the local wave climate.

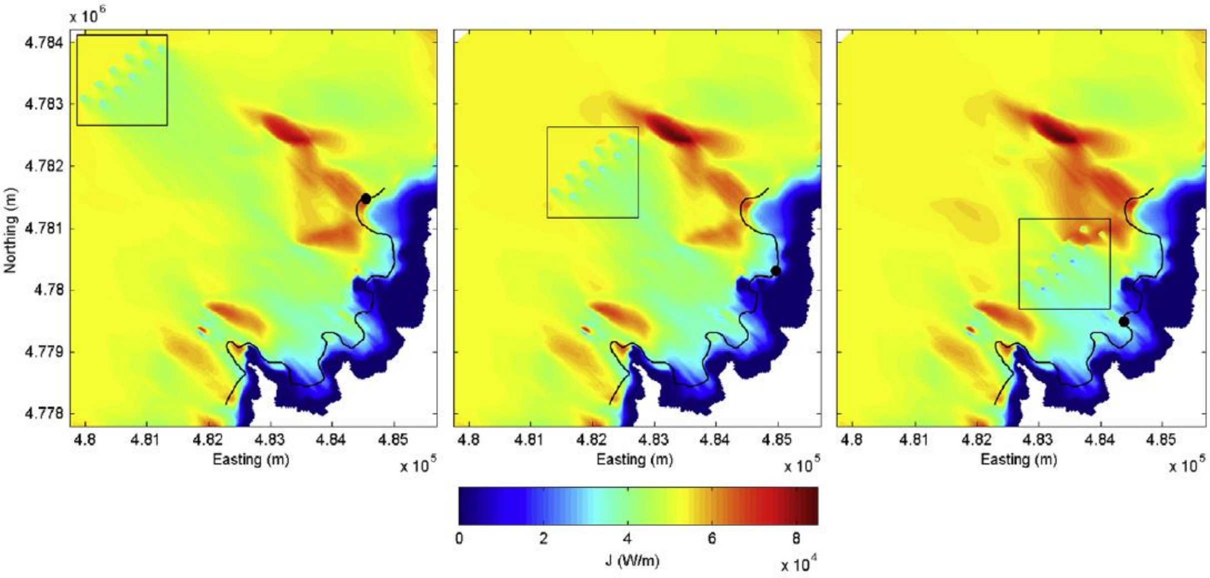
Far field impacts

In terms of a reduction in wave height, both the Pelamis and Wave Hub modelling work suggests that a ~30km (20-26km for Pelamis depending on the configuration of array) section of coastline is likely to be affected by a wave array 3km in length (taking a 60° variation in wind direction into consideration), with between 1-2cm (Millar *et al.* 2007) and <5cm decreases in wave height at the coast predicted (Palha *et al* 2010). A slightly greater change in wave height of 5-10cm in the nearshore line in the wake of an array at the WaveHub site has subsequently been simulated, with the potential impact of the array stretching 26km northwards (González-Santamaría *et al.* 2012). This suggests potential far reaching impacts from an array, even if wave height changes at the coast are relatively minor. Despite the high level of refraction of wave energy around devices modelling has also suggested that in the far field the wave direction is not modified significantly, with differences of less than 0.5° (Palha *et al.* 2010). This small defraction does however also have the potential to increase the impact from a farm by altering sediment dynamics especially along coastlines.

Even small changes in wave height at shorelines may have a significant effect on intertidal habitats. Intertidal habitats have well defined zones of organisms which are all ecologically adapted to different levels of exposure. A significant change in mean wave weight will therefore alter the ecology of these areas. Similarly, any change in hydrodynamics may increase the drag acting on an organism or affect marine organisms that are specially adapted to cope with extreme hydrodynamic forces like breaking waves or strong currents (Shields *et al.* 2011), although this is likely to be a localised effect. Sediment re-suspension, outside the boundaries of normal natural variations, may also cause health effects in fish, with prey detection abilities of species that rely on visual cues also potentially hindered by increased turbulence (DFO 2009).

A modelling study investigated the effect of distance of a wave array from the coast on impact of nearshore wave conditions on the NW coast of Spain (Iglesias & Carballo 2014). Figure 5.21 shows that the point of maximum nearshore impact (black circle) can be within the direct array shadow when the distance from the array to shore is small but when that distance increases the point of maximum impact can move outwith the array shadow area a significant distance along the coastline. This is due to the waves experiencing greater refraction in their propagation from array to coast when the array is further offshore. This is also seen in modelling of an array at the WaveHub site at varying distances off Perranporth Beach, Cornwall (Abanandes *et al*. 2015). Here the length of coastline affected by a reduction in wave height was 7km for the array furthest from the coast (6km) compared to just 4km for an array situated 2km offshore. However this smaller area of impact had a greater reduction in wave height (>10%) compared to <5% for the 6km scenario, so a more concentrated wave energy impact over a smaller area.

Figure 5.21: Winter wave power pattern for an array of wave devices at differing distances from the coast of NW Spain



Notes: Distance of array from coast is from left to right: 6km, 4km, 2km. The maximum nearshore impact point is shows as a black circle on the 10m contour line.
Source: Iglesias &Carballo (2014)

Sediment dynamics & coastal protection

Most devices are tuned to extract power from swell or low frequency wind-waves which generally represent a much greater source of power than higher frequency waves (PMSS 2007, Shields *et al*. 2011). A reduction in wave height will reduce the associated stress on the seabed and sediment resuspension and also reduce wave breaking and turbulence. Often wave energy is expended at the shore or nearshore and therefore the extraction of energy may be expected to have an effect on shoreline environments rather than in the immediate vicinity of the devices themselves (Boehlert *et al.* 2008). In addition, some wave devices have an operating limit and will not operate during storm conditions. Large waves during storm events are therefore not modulated or reduced by arrays, with resulting onshore erosion and offshore transport of sediment. However smaller waves, which are generally responsible for offshore erosion and onshore transport of sediment, would be affected by tidal devices. This means that potentially a reduction in energy of smaller waves combined with no reduction to larger waves could result in long term migration of sediment offshore (Shields *et al* 2011). It should however be noted that this process already occurs naturally in some areas, modulated by inter-annual variation in wave energy and direction and climate change (Woolf *et al*. 2006, Wolf & Woolf 2006). This impact of an array on sediment dynamics is therefore dependent on device type, setting, local wave climate and morphodynamics.

Initially, modelling at the WaveHub site suggested near-shoreline bathymetry changes of -0.2 to +0.2 metres from an array, which would likely be indiscernible against background sediment transport and beach level changes (Halcrow 2006). However subsequent modelling at the site (González-Santamaría *et al*. 2012) has shown that the wave contribution to bottom stress is significantly larger than the tidal contribution and therefore is driving sediment transport especially during storms. Reductions in wave energy in the lee of an array are shown to affect bottom stress in the shallow water and nearshore region with a maximum change in sediment concentration with and without the wave array of -0.1 to 0.1 kg/m^3 at low tide. Sediment concentrations are higher within the lee of the array, as longshore transport has been diverted around the array, with impacts greatest to the north of St Ives Bay. There is also evidence of a northwards shift of erosion and deposition patterns due to wave defraction caused by the array.

Further modelling at the site found a 1.5m reduction in erosion of bed levels after a storm at the beach face with an array, compared to baseline (Abanandes *et al*. 2015). This study also suggested that an array closer to shore (2km) caused a greater reduction in erosion (5% more) than the same array further offshore (at either 4 or 6km). However the sediment erosion and deposition patterns were complex, suggesting that careful siting would be needed if a wave array was to be used for coastal protection, as has been suggested by multiple studies (e.g. Ruol *et al.* 2011, Nørgaard *et al.* 2011, Zanuttigh & Angelelli 2013). This is corroborated by additional modelling at the same site, which found that the effect of a wave farm varied in different parts of the beach with a reduction of the eroded area of up to 35% in the north of study area and 20% in centre of the beach (Abanandes *et al*. 2014). There was also a significant reduction in erosion in a nearshore bar which formed part of the natural defence of the beach face, increasing the defence of sand levels on the beach.

In addition to the distance offshore, the type of device and the natural setting also need to be taken into consideration for coastal protection purposes. A study investigating 4 different wave devices at 2 sites, a semi-enclosed water body (Bay of Santander, Spain) and an open beach (Las Glorias, Mexico), shows that the impacts can vary greatly from site to site (Mendoza *et al.* 2014). At the Santander site the selection of the most effective device for shoreline impact protection was complex, although it did conform to the previously described notion that to cover a larger length of coastline the devices should be placed in deeper waters (although the level of protection will be reduced compared to a nearshore siting). Whereas the Las Glorias site suggests that for an open beach having an array occupying a larger marine area does not necessarily mean a higher wake effect or wave energy reduction, or greater beach protection. It was then concluded that devices with smaller longshore gaps should be used to protect longer stretched of coastline, whilst arrays with more lines of devices should be used where high wave reduction is needed in a short length. This added complexity is also highlighted by Iglesias & Carballo (2014) who concluded that by increasing the distance of the array from the coast does not necessarily result in a reduction in maximum absolute impact, it may just result in a change in the location of impact. So moving an array further offshore is not necessarily the answer to reducing impacts, with a recommendation for including array to coast distances as part of impact assessments for specific sites.

A significant issue associated with the modelling of sediment transport and wave and tidal devices is the highly spatially variable nature of the natural sediment in the study areas. For example a model for a tidal array in the Pentland Firth covers a wide range of seabed types including: swept bedrock areas, sand veneers on bedrock, large cobbles with interstitial sand and gravel, large sandbanks and sand wave fields (Fairley & Karunarathna 2014). Varying quality and availability of data makes it difficult to build such variability into models with most studies showing areas of uniform and abundant sediment (e.g. Abanandes *et al*. 2014, Mendoza *et al.* 2014).

5.5.3 Controls and mitigation

Evidence, primarily from modelling work, on the placement of different devices/schemes in different settings highlights the complexity of impacts arising from wave and tidal schemes. Scales and spatial extent of impact are heavily dependent on physical, hydrodynamic, bathymetric and sedimentary properties and regimes of an area. Additionally, variability in device type, array size and pattern also contributes to the unique response of an area to a specific scheme. It is therefore suggested that detailed site specific investigations be undertaken including impacts from different device types, array size and shapes, distance from shore and position within a channel or area

5.5.4 Likelihood of significant effects

It is thought that some environmental impacts, such as changes to intertidal areas, are not likely to scale smoothly with extraction. There are likely to be ‘tipping points’ where a small increase in extraction results in disproportionately large changes to the physical environment. An example would be incremental reductions in tidal range that may initially have little effect but could beyond a certain point lead to a landlocked tidal pool (Polagye *et al.* 2011). This example highlights that impacts cannot easily be scaled up from pilot scale to array scale, without introducing very large uncertainties.

Whilst there has been a significant increase in the number of studies conducted on arrays of wave and tidal devices and tidal range projects, the scale and dynamics of impacts from energy removal are still primarily based on evidence from modelling. It is likely that barrages and large arrays of tidal and wave devices may produce significant, far-field effects (extending over hundreds of km), with permanent impacts on the energy balance, physical hydrography and associated ecology of the estuary/river basin. This is reasonably well understood for barrages but further work is needed to investigate array sizes, shapes and siting and understand at which point and under which physical and hydrodynamic conditions impacts both become significant, and extend from near- to far field. Some evidence suggests that careful siting of wave and tidal devices can mitigate impacts to some degree and can even be used for positive coastal defence purposes, although again this is very site and device specific.

Since wave and tidal energy have yet to proliferate at a commercial scale in the UK, there is neither evidence for cumulative effects nor the opportunity to validate those modelling predictions which do suggest cumulative effect from the upscaling of arrays. Wave and tidal devices tend to occupy different geographic zones i.e. the typically estuarine requirement for tidal range and land-constrained narrows for tidal stream versus an along-shore siting of wave devices in open water; these scenarios have very different dependent habitats downstream of the devices. An upscaling of wave energy converters is likely to affect an increased length of open coastline, whereas upscaling of tidal devices are more likely to affect the degree of intensity of habitat change in the immediate upstream area. Some models predict far-field effects of up to hundreds of kilometres; therefore it seems inevitable that multiple energy extraction devices within the same hydrographic basin, will have impacts. These impacts are predicted to range through reduction in current speed and particle size of sedimentary habitats, with subsequent changes to infaunal elements. At a strategic level however, the anticipated scale and geographical location of wave and tidal development is unlikely to create significant cumulative effects within the currency of this plan.

5.5.5 Summary of findings and recommendations

Whilst there has been a significant increase in the number of studies on the hydrodynamic effects of energy removal, results are site specific and connecting those changes to other aspects of the physical environment (e.g. sediment dynamics) is still in its relative infancy. The same applies to studies on the number and type and devices. There is a general consensus that there are limited impacts from single or pilot scale deployments of tidal stream and wave devices, but scaling those impacts up to array scales potentially has some significant issues. An inability to validate any predicted changes at estuary or larger scales, issues with tuning for calibration and boundary conditions for models and issues with monitoring far-field impacts (separating them from natural variability) also adds to uncertainty surrounding array scale modelling.

Impacts from single tidal stream devices and small arrays tend to be localised, with rapid dissipation with distance. However, studies on larger arrays have identified the potential for significant impact of energy removal on hydrodynamics and sediment patterns over potentially large areas. What all the studies highlight is the site specific nature of impacts, often not repeated from site to site, and the hydrographic complexity of high tidal power areas which are often not well represented in models. Whilst significant work has been undertaken to start to address some of these issues, additional modelling work needs to be undertaken, especially on sediment dynamics and their representation in models.

Tidal barrages have far reaching, large scale impacts that potentially change the energy balance, physical hydrography and associated ecology of the estuary/river basin permanently. For this reason and because individual estuary/embayments are so different it is recommended that detailed site specific data gathering and assessment is required before decisions can be taken on the acceptability or otherwise of a development. The infancy of tidal lagoon technology means that further work is needed to understand the nature and extent of impacts, especially in relation to far-field and cumulative effects.

Whilst wake effects from wave devices are smaller than those produced by tidal stream devices, their general proximity to coastline means that there is the potential for impact to the wave climate and morphodynamics of an area. There is evidence that the type of device, size and shape of array, distance from land, morphology of the site and local wave climate all influence impacts. As with the spacing of turbines in offshore wind farms, careful consideration therefore needs to be given to the spatial arrangement of devices within arrays in order that shadow effects do not impact on downstream devices, and large cumulative impacts and far-field effects from multiple devices does not occur. The potential dual use of wave arrays for coastal protection should be investigated further, although it is noted that early studies suggest that effects from arrays of wave devices are potentially so site specific that individual assessments need to be undertaken to evaluate site suitability.

The largest barrier to effective and accurate modelling is collecting data from the natural environment to validate models. This needs to be improved so as to better understand the natural dynamics of the baseline environment, as does the need to develop models which couple effects from the near-field and far-field and consider cumulative impacts from multiple arrays. This is especially pertinent for areas with multiple deployments of potentially different technologies (e.g. wider Severn Estuary) where impacts from one installation may affect the available energy at a different far-field deployment site. Initial site studies should focus on the order or magnitude of hydrodynamic changes at different levels of extraction, with the effect on different receptors following on. The number of different marine energy device designs also make it difficult to judge the applicability of generalised results from studies to specific devices deployed in specific waterbodies. As a result interactions between device design and the marine environment are needed to simulate many types of devices to assess varying levels of impacts for specific sites.

5.6 Physical presence - ecological implications

Assessment Topic	Potentially Significant Effect	Oil & Gas	Gas Storage	Carbon Dioxide Storage	Offshore Wind	Tidal Stream	Tidal Range	Wave	Assessment Section
	The introduction and spread of non-native species	X	X	X	X	X	X	X	5.6.2.1 5.6.3.1
	Behavioural disturbance to fish, birds and marine mammals etc from physical presence of infrastructure and support activities	X	X	X	X	X	X	X	5.6.2.2 5.6.3.6
	Collision risks to birds				X	X	X	X	5.6.3.4
	Collision risks to bats				X				5.6.3.4
	Collision risks to water column megafauna (e.g. fish, marine mammals).					X	X	X	5.6.3.5
	Barriers to movement of birds				X	X	X		5.6.3.2
	Barriers to movement of fish and marine mammals					X	X	X	5.6.3.3
	EMF effects on electrosensitive species				X	X	X	X	5.6.3.7

5.6.1 Introduction

This Section discusses the potentially significant ecological effects that may arise from the physical presence of structures associated with the draft plan/programme. These include the risk of introduction and spread of non-native species as well as several potential interactions between mobile species and infrastructure and support activities, including collision, avoidance, barrier effects, 'reef effects' and electromagnetic field (EMF) effects.

5.6.2 Sources of potentially significant effect

5.6.2.1 Introduction and spread of non-native species

Shipping is the major pathway for introducing invasive aquatic species to new environments. The areas with a high volume of shipping traffic are hotspots for non-native species in UK waters (Pearce *et al.* 2012). The primary mechanism is through ballast water discharge and exchange; international mitigation is through IMO guidelines (IMO 2004)[63] which include the requirement for all ships to have a ballast water management plan and to conduct any ballast water exchange at least 200 nautical miles from the coast and in at least 200m water depth.

The establishment of non-native species requires successful settlement, growth and reproduction and it is aided by marine structures. In fact all energy installations in the marine environment provide additional hard substrate available for colonisation by algae and benthic invertebrates from planktonic larval settlement.

The deliberate and accidental placement of hard substrates in the marine environment 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

[63] IMO (2004) Guidelines for the control and management of ships' ballast water to minimise the transfer of harmful aquatic organisms and pathogens.

surfaces as indicated in **Error! Reference source not found.** could provide "stepping stones" llowing species with short lived larvae to spread to areas where previously they were effectively excluded. Such "islands" are naturally widespread and numerous in continental shelf areas, for example on glacial dropstones and moraines, but less so in the shallower waters of the southern North Sea, English Channel and eastern Irish Sea.

5.6.2.2 Interactions between infrastructure and mobile species

Aerial structures are a potential source of collision for birds and bats and of greatest concern are the rotating blades of wind turbines. Collision risk depends on a range of species specific, site specific and wind turbine/farm specific factors (many of which are interrelated) as summarised in Table 5.15. (Marques *et al.* 2014).

Table 5.15: Factors influencing collision risk with offshore wind farms

Species specific	Site specific	Wind turbine/farm specific
Morphology (e.g. body mass, wing loading, wing span – factors affecting flight strategy and manoeuvrability and hence collision vulnerability).	**Flight paths** (although the abundance of a species *per se* may not contribute to higher collision rate, areas with higher concentrations of birds seem to present a higher risk of collision).	**Turbine features/design** (e.g. turbine size, rotor diameter, rotor speed, sound and lighting, faster moving objects are harder to avoid than slow moving ones (caution is needed when analysing rotor speed alone, as it is usually correlated with other features that may influence collision risk such as turbine size, tower height and rotor diameter).
Sensorial perception (e.g. species with relatively small frontal binocular fields, limited visual fields of perception, motion smear, birds looking down rather than ahead during flight).	**Weather** (strongly influences flight behaviour and can influence ability to perceive and avoid risk. E.g. strong winds affecting ability to control flight manoeuvrability, poor visibility, low altitude clouds can lower flight altitudes and daily temperatures and thermal convection can affect migrating birds flight altitudes).	**Blade visibility** (e.g. if blades are spinning at high speeds, a motion smear effect can occur – something moving too fast for the brain to process the image and as a consequence the moving objet appears blurred or even transparent).
Avoidance ability (e.g. some birds can take last minute action to avoid turbine blades – closely linked to morphology and perception).	**Food and other resource availability** (e.g. the "reef effect" of structures, attracting fish aggregations and in turn attracting birds, increasing potential for collision, provide resting/roosting platforms.	**Wind farm configuration** (layout may have an impact, e.g. turbines arranged perpendicular to a main flight path).
Age (e.g. age and experience may influence flight capacity and recognition of danger).		**Lights** (lit structures can attract birds, increasing the potential for collision, especially in conditions of poor visibility, and nights of heavy migration movements).
Behaviour (e.g. flight type appears to be influential such as hovering, foraging (breeding) birds commuting repeatedly through a wind farm area, (this can also show sex-bias in fatality rate, with higher proportion of adult male deaths), song-flights, frequency of trips, night flying, including migrating birds, social behaviour, e.g. flocking birds.		

Source: adapted from Marques et al. (2014).

Wind farms are also associated with the potential for displacement and barrier effects in birds and bats. In principle all aerial structure can induce an avoidance response by individuals, but currently only wind farms are at a scale large enough to potentially cause a displacement that may result in biologically significant impacts (e.g. loss of high quality habitat, large increase in travel time between roosting and feeding areas). The activity of support vessels may also contribute to the overall effect. The main factors at play are linked to the size and configuration of wind farms as well as their position with respect to flight paths.

Details of offshore wind farms in English/Welsh waters[64] relevant to estimation of collision and avoidance risks are summarised in Table 5.16.

Table 5.16: Turbine details for UK current offshore wind developments[1]

Wind farm (status[2])	No. of turbines	Sea surface area (km^2)	Hub height (m)	Max. height to tip of rotor blade (m)	Lowest height of rotor blade (m)	Rotor blade diameter (m)	Rotor speed (RPM)	Distance between turbines (m)
Regional Sea 1								
Blyth (IO)	2	-	62	95	29	66	-	-
Blyth Demo (C)	15	4	90-110	195	-	-	-	-
Teesside (IO)	27	10	80	126	33	93	-	300-600
Regional Sea 2								
Creyke Beck A (C)	200	515	-	<315	>26	<215	-	700-1290
Creyke Beck B (C)	200	599	-	<315	>26	<215	-	700-1290
Teesside A (C)	200	560	-	<315	>26	<215	-	700-1290
Teesside B (C)	200	593	-	<315	>26	<215	-	700-1290
Heron Wind (C)	75-120	407[4]	<82	<200	>22	<178	-	>924
Njord (C)	75-120	407[4]	<82	<200	>22	<178	-	>924
Optimus (AC)	130	-	<151	<276	>26	<250	-	>810
Breesea (AC)	130	-	<151	<276	>26	<250	-	>810
Westermost Rough (IO)	35	35	-	177	23	154	-	-
Humber Gateway (IO)	73	25	80	136	24	112	-	-
Triton Knoll (C)	75-150	134	<140	<220	>22	<180	-	-
Lynn (IO)	27	10	80	134	27	107	5-13	-
Inner Dowsing (IO)	27	10	80	134	27	107	5-13	-
Lincs (IO)	75	35	100	160	40	120	-	-
Race Bank (C)	91	75	-	180	36	154	-	-
Dudgeon (UC)	67	55	110	187	33	154	-	-
Sheringham Shoals (IO)	88	35	82	135	28	107	-	-
Scroby Sands (IO)	30	4	68	108	28	80	-	-
East Anglia ONE (C)	89-102	297	<120	<200	>22	<170	-	>675
Galloper Extension (C)	56-68	175	<120	<195	>22	<164	-	>642
Greater Gabbard (IO)	140	146	105	170	40	130	-	>650
Gunfleet Sands I (IO)	30	10	76	129	22	107	-	435-890

[64] the Scottish Renewable Energy Zone and Northern Irish waters within the 12 nautical mile territory sea limit are not included, neither are those developments currently in the pre-application stage

Wind farm (status[2])	No. of turbines	Sea surface area (km^2)	Hub height (m)	Max. height to tip of rotor blade (m)	Lowest height of rotor blade (m)	Rotor blade diameter (m)	Rotor speed (RPM)	Distance between turbines (m)
Gunfleet Sands II (IO)	18	7.5	76	129	22	107	-	435-890
Gunfleet Sands Demonstrator (IO)	2	1	-	144	24	120	5-11	-
London Array 1 (IO)	175	100	87	147	>22	120	-	650-1000
Kentish Flats 1 (IO)	30	10	70	115	>22	90	-	700
Kentish Flats 2 (UC)	15	8	84	140	>22	126	-	-
Thanet (IO)	100	35	70	115	>22	90	-	500-800
Regional Sea 3								
Rampion (C)	116	167	<124	<210	>22	<172	-	>600
Regional Sea 6								
Rhyl Flats (IO)	25	10	80	134	-	107	-	-
Gwynt y Môr (IO)	160	79	98	150	-	107	-	450-1000
North Hoyle (IO)	30	10	67	-	-	80	-	350-800
Burbo Bank (IO)	25	10	84	137	-	107	-	530-720
Burbo Bank Extension (UC)	32	40	79-123	141–223	>22	112-200	-	700-1960
West of Duddon Sands (IO)	108	67	-	-	-	120	-	-
Barrow (IO)	30	10	75	120	-	90	-	-
Ormonde (IO)	30	9	90	153	27	126	-	-
Walney 1 (IO)	51	28	84	137	30	107	-	749-958
Walney 2 (IO)	51	45	90	150	30	120	-	749-958
Walney Extension (C)	90	145	<122	<222	>22	120-200	-	>737
Robin Rigg East (IO)	30	*18*[5]	80	125	-	90	-	-
Robin Rigg West (IO)	30	*18*[5]	80	125	-	90	-	-

Notes: [1]Wind farms in Scottish waters have not been included. [2]IO = In Operation, C= Consented, AC= Awaiting Consent, UC= Under Construction. Wind farms currently in the Pre-Planning Application stage have not been included as these have no defined project proposals. [3]Minimum clearance from sea surface to lower blade tip. [4]Total area of Project One. [5]Area estimate is the total area for Robin Rigg East and West combined.
Source: Planning Inspectorate website, Scottish Government website, Vattenfall Website, EDF website, Sheringham Shoal project website, SSE website, 4C website, RWE website, E.ON website, DONG Energy website, all accessed February 2016.

Other aerial elements which may attract birds and bats are the lights and flares on offshore oil and gas platforms and rigs. Including floating oil installations, there are 302 oil and gas installations in the UKCS, of which, 273 are operational[65]. All require navigation lights, including those installations that are generally unmanned (most of these are located in the gas fields of the southern North Sea) and many will have operational flaring. Wind farms also carry navigational lights which may be an attractant to birds and bats.

The presence of structures may present a physical or sensory barrier to the movement of marine species, particularly migratory species of fish, birds and marine mammals. It can relate to regional/global migrations as well as local movements (within and between breeding and feeding areas) in open waters and in coastal environments, including up-river movements.

[65] DECC website, accessed February 2016

Tidal range schemes (e.g. tidal barrages) represent physical obstructions but all wave but any wave or tidal stream device may constitute an obstacle to normal movements or provoke a behavioural disturbance; these effects can be similar to the potential displacement effect created by large wind farms for birds. Displacement may result from acoustic disturbance during installation or operation (see Section 5.3.2.2) but may also be the result of a response to the general physical presence of devices and/or vessels and increased human activity (Sparling *et al.* 2015); displacement may result in a barrier effect for example when animals are impeded from using an area previously used for transit. To assess these effects, the key factors for consideration are the location and the size of the development relative to the width of the movement 'corridor' utilised by species.

Rotating turbines and other moving submerged infrastructure associated with wave and tidal power are perceived to carry a risk of collision particularly for marine mammals, fish and marine birds (Wilson *et al.* 2007). Collision risk depends on the type of device and its physical and mechanical features. Tidal stream energy devices have the potential for collision (Linley *et al.* 2009) but the actual risk will vary depending on several technical factors including the type and size of turbines, their rotating speed and the depth at which they are operating. SeaGen installed in Strangford Lough, is a horizontal axis tidal stream turbine with twin rotors of 16m diameter; tips speed reaches 12m/s and depending on the state of the tide, the turbines would be between 3m and 7m below sea surface; a gap of 5m exists between rotor and seabed. Turbine schematics for the MeyGen project in the Pentland Firth show a single rotor horizontal axis turbine of 16-20m placed to allow an 8m clearance of the sea surface and 5-8m of the seabed (http://www.meygen.com/technology/). OpenHydro consists of open-centre turbines with blade tips within an outer housing (http://www.openhydro.com/technology.html). Deep Green uses a novel design, similar to a wind kite, where the turbine is part of the wing (wing span between 8 and 14m), attached by a tether (up to 120m long) to a fixed point on the seabed (http://www.nesto.com/deep-green/).

Tidal barrages and lagoons operate on the same basic principle, and include rows of turbines in a high tidal range area which generate electricity from water flows. The turbines used in barrages and lagoons rotate in sluices or constricted ducts and present a collision risk to a range of marine fauna.

Collision with wave devices may also be possible but much less probable; instead wave devices are more readily associated with a risk of entanglement in mooring lines (Sparling *et al.* 2013).

Cables associated with wind, tidal stream and wave devices present the risk of electromagnetic fields to electrosensitive animals. Electromagnetic fields (EMFs) are generated when electricity is transported through a cable. An industry standard AC offshore cable produces 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. A number of marine taxa are potentially capable of responding to anthropogenic sources of electric and magnetic fields.

5.6.3 Consideration of the evidence

5.6.3.1 Non-native species introductions

Evidence for the introduction of non-natives species comes primarily from the wind sector as these developments now have a reasonable body of monitoring data available. Despite the UK's 40 year history of oil and gas development, there has been little focus on its role in benthic species introductions. Establishing patterns and consequences of biofouling have been useful, including reef effects and the spread of species. Artificial reefs, such as wind turbine foundations, have been found to act as stepping-stones for the dispersal of hard bottom organisms facilitating the spread of both exotic and indigenous species (Connell 2001, Bulleri & Airoldi 2005, Glasby *et al.* 2007, Bulleri & Chapman 2010, Zintzen & Massin 2010, Kerckhof *et al.* 2012). Non-indigenous species have the potential to exploit new niches in the indigenous communities which can result in overpowering native populations of species of similar niches e.g. the intertidal seaweed *Sargassum muticum* (Farnham *et al.* 1981) which spread along the south coast of England at rate of about 30km/year, or catastrophic ecosystem change through trophic proliferation e.g. the planktonic, carnivorous sea gooseberry *Mnemiopsis leidyi* in the Caspian Sea (Ivanov *et al.* 2000, Shiganova *et al.* 2004). The overarching environmental effect of offshore wind parks appears to be reef creation (Lindeboom *et al.* 2011, DONG Energy *et al.* 2006). At the Danish sites (Horns Rev and Nysted), the introduction of turbine foundations and scour protection has resulted in greater habitat diversity and changed the benthic communities at the turbine sites from typical infauna communities to hard bottom communities (DONG Energy *et al.* 2006). Monitoring surveys at a number of locations show that the various fouling communities of amphipods, hydroids and bivalves are often not previously established in the area. In particular, in areas where natural hard substrata are rare, high numbers of artificial constructions favour the establishment of taxa such as cnidarians and mussels whose life histories include temporary or permanent attachment to solid substrates (Richardson *et al.* 2009). Many similarities have been found in the establishment, succession and distribution of epifouling communities on structures and scour protection; at Horns Rev and Nysted the differences in species composition were mainly attributable to differences in salinity between the two sites (DONG Energy *et al.* 2006). A recent survey by Van der Stap *et al*. (2016) identified a total of 30 taxa as fouling organisms on the legs of five gas platforms sampled at a range of distances offshore in the SNS (Netherlands sector). Through modelling, they demonstrated a significant non-linear relation between species richness and with water depth: from a low richness in shallow waters, species richness increased with depth until 15–20 m, after which it decreased again. They also found that water depth, community age and the interaction between distance from shore and community age showed a significant effect on the species assemblages. It is also important to note that faunal communities on artificial hard substrata may differ from those on natural hard substrata (People 2006, Wilhelmsson & Malm 2008, Andersson *et al.* 2010) and on soft bottoms (Barros *et al.*, 2001, Fabi *et al.* 2002, Langlois *et al.* 2006, Langhamer 2010). The colonisation of hard surfaces by epifaunal species at the FINO 1 research platform in the German Bight (28m water depth), have also been described by Schröder *et al.* (2006).

A strategic review of OWF monitoring data associated with FEPA licence conditions (CEFAS 2010) indicated that the long term effects of epifaunal colonisation should be monitoring and/or researched to address issues of concern, such as their potential as ‘stepping-stones’ for invasive species. The review concluded that epifaunal colonisation of monopiles could result in a localised increase in species diversity, but whether this was a ‘beneficial’ impact as was often predicted in Environmental Statements, was debatable and highly subjective as the colonising species were different from the original community. The review recommended that benthic monitoring associated with OWF development should link with national monitoring programmes (such as National Marine Monitoring Programme - NMMP), to support the interpretation of any community change by informing on whether similar change has been noted regionally or historically. The Regional Environmental Assessments conducted by the aggregate industry are also useful data sources in this respect and have been used to inform this assessment.

During and post-construction, the initial speed of species colonisation (biofouling) depends on timing of the introduction of new surfaces in relation to the major and secondary plankton blooms. 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. Large numbers of shrimp (*Crangon* spp.) and whiting were observed, particularly where mussel populations were well developed; this highlights the development of complex ecologies through trophic interactions and provision of micro-habitats. The development and long term dynamics of fouling communities is well studied in various environments e.g. Butler & Connolly (1996; 1999) and monopiles are likely to display similar species succession see example in Figure 5.22.

Fig. 5.22: Monopile fouling at the Belwind I OWF 7 months after piling.

Notes: Bio-fouling is mainly by the hydroid Tubularia larynx*. In the water column, marine snow or fine grained flocs are visible. Scale bar 15 cm. Photograph taken by A. Norro RBINS-OD Nature.*
Source: Baeye & Fettweis (2015).

Monitoring of new concrete wind turbine foundations 30km off the Belgian coast (Kerckhof *et al.* 2010) showed that the overall structure of the marine biofouling assemblage at the Thornton Bank site was similar to that on the foundations of other offshore wind farms in Germany, Denmark and the Netherlands, as well as on other hard structures in the North Sea. The amphipod *Jassa herdmani* was found to be a key species at windmill foundation reaching densities of up to 200,000 per metre squared; it is a short-lived, highly fecund, tube builder and constitutes an important food source for fish species associated with the hard substrata (Reubens *et al.* 2010). Specimens of *Balanus perforatus* (a warm water species spreading into the North Sea) were found to have colonised, but suffered mortality caused by predation and smothering. Large individuals were also found surviving under the mussel cover. As with any species with plankton larvae, spatfall success varies annually which will affect the epifauna community structure of wind farm turbines. At Thornton Bank for example, a good spatfall of *B. perforatus* was observed in 2008 (autumn) with that of 2009 being less successful.

A consequence of this increase in hard substrate epifauna is the production and accumulation of faecal pellets, pseudo-faecal pellets and detritus around the OWF turbine piles (McKindsey *et al.* 2011; Coates *et al.* 2014). Pseudo-faeces are rejected mucus-bound pellets of fine-grained material produced discarded by filter feeders (Maar *et al.* 2009, Ysebaert *et al.* 2009, McKindsey *et al.* 2011). Increasing numbers of filter feeding mussels (Winter 1973, Clausen & Riisgård 1996) may influence particle and nutrient fluxes between the water column and the sediment, thereby potentially affecting the plankton biomass (Wilhelmsson & Malm, 2008).

Mussels, in turn, provide secondary hard substrate attractive for other epifaunal organisms (Norling & Kautsky, 2007). The continuous detrital fall of mussel shell litter modifies the grain size of the sediment where shells aggregate at the seafloor, providing new habitats sessile organisms which require solid attachment sites, and for typical hard bottom crabs (Wolfson *et al.* 1979, Freire & González-Gurriarán 1995, Riis & Dolmer 2003). Other organisms such as the amphipod *Jassa herdmani* and various species of the hydroid *Tubularia* filter the water column and build tube-like structures that trap SPM (de Mesel *et al.* 2015). In offshore areas SPM typically consists of fine mineral and organic particles that aggregate into larger flocs (e.g. Fettweis *et al.* 2006) with settling velocities of generally less than 1 mm/s (Manning *et al.* 2010). In contrast, the larger pseudo-faecal pellets have settling velocities of a few cm/s (Giles *et al.* 2009, McKindsey *et al.* 2009). This results in high deposition rates at the base of the turbine piles, causing a fining of the sediment and enrichment in organic matter at the seabed (Coates *et al.* 2014). Orvain *et al.* (2003) termed this organically enriched bed layer as biogenic fluff. The fluff favours the establishment of a benthic community dominated by opportunistic deposit feeders. In the North Sea, Krone *et al.* (2013b) observed that wind turbine foundations concentrated 35 times more macrozoobenthos biomass per unit area of seafloor than was the case for the reference soft bottom sediments. Aggregations of marine biota at wind turbines and other structures will therefore change the invertebrate communities, biomass and the local physico-chemical conditions (Wolfson *et al.*, 1979, Freire & González-Gurriarán 1995, Page *et al.* 1999, Wilhelmsson *et al.* 2006, Falcão *et al.* 2007, Krone *et al.* 2013b).

As well as supporting the spread of hard bottom fauna between wreck sites across soft bottom area within the German Bight, it is predicted that the amount of new hard substrate provided by wind turbine foundations will also allow the stocks of substrata-limited mobile demersal hard bottom species to increase by 25-165% in that area (Krone *et al.* 2013a). They estimate that the 5000 wind turbines for the German segment of the North Sea will provide >4 times the hard substrate currently available through ship wrecks.

Gas and oil platforms and pipelines in the North Sea have supplied additional hard substrate 'islands' for colonisation through fouling for the last 40 years and the long–term dynamics of these epifaunal communities is relatively well documented (Whomersley & Picken, 2003). *Lophelia pertusa* has been found on a number of oil and gas platforms in the northern North Sea (Roberts 2002, Gass & Roberts 2006). A first record of the anemone *Caryophyllia smithii* in the southern North Sea was made by Coolen *et al.* (2015) on a shipwreck. Such observations demonstrate the ability of a species with pelagic larvae to use any suitable substrate to extend its range. The recent discussion around using obsolete offshore structures for the conservation of *Lophelia pertusa* in the North Sea (Bergmark & Jørgensen 2014) highlights the positive potential of marine structures and the functional pathways created.

The addition of artificial reefs in shallow waters is a well-established practice in the Gulf of Mexico, but in the North Sea the creation of artificial reefs from decommissioned platforms remains against UK policy (DECC 2011d). More recent discussion of artificial reefs in the deep sea (Macreadie *et al.* 2011) is relevant to the UK Regional Seas 4, 5, 10 and 11, where they could increase ecological connectivity, with potential biogeographical consequences. These may include increased genetic homogeneity and reduced opportunity for allopatric speciation (when biological populations of the same species become isolated as a result of geographical changes), because rig structures may remove isolating barriers to long-range dispersal. Depending on the species, this could be a positive or negative impact. Thorpe (2012) tested the conjecture that the platforms in the North Sea are biologically connected by the principal semi-diurnal tidal currents which result in a relatively rapid transfer of organisms between neighbouring platforms. Some 60% of platforms in the southern UK Sector are directly connected by tidal flows, but in the northern Sector this is relatively rare, with only about 23% of platforms being so connected. Mean flows connect platforms in 'strings' sharing a common streamline spread by turbulent dispersion. Strings are broken when contributions to the concentration of organisms from platforms fall below detection limits. Many platforms are likely to be connected in strings in the southern UK Sector, but relatively few in the northern Sector.

Non-native invasive species (NNIS) have been recorded on wind turbine foundations (Leonard & Birklund 2006, de Mesel 2015) during the course of routine monitoring programmes. The first record of caprellid amphipod *Caprella mutica* in Denmark was from offshore wind-turbine monopiles, along with large numbers of another non-native species, the marine splash midge *Telmatogeton japonicus* (Leonard & Birklund 2006). This followed a report of mass occurrences of *C. mutica* of > 3000 individuals per m^2 in island harbours in the German Bight (Buchsbaum & Gutow 2005). Although then restricted to artificial hard substrata it was expected to become a new species in natural hard bottom assemblages in the region. The *Caprella mutica* is indigenous to coastal waters of north-east Asia and was first recorded in European waters in 1995. During investigations of the macrobenthic fouling community on the concrete foundations of the first Belgian offshore wind turbines de Mesel *et al.* (2015) described the prominent vertical zonation from splash zone down to the deep sublittoral. From a species count of 80, ten non-indigenous species were recorded, the highest proportion occurring in the intertidal (eight out of 17 species).

At developments where the study of monopile colonisation continues through an environmental monitoring programme, the emerging long term data sets of species succession, annual variability and community change will be increasingly valuable, especially if NNIS are present.

5.6.3.2 Barrier to movement, displacement and other behavioural effects – marine birds

5.6.3.2.1 Offshore wind farms

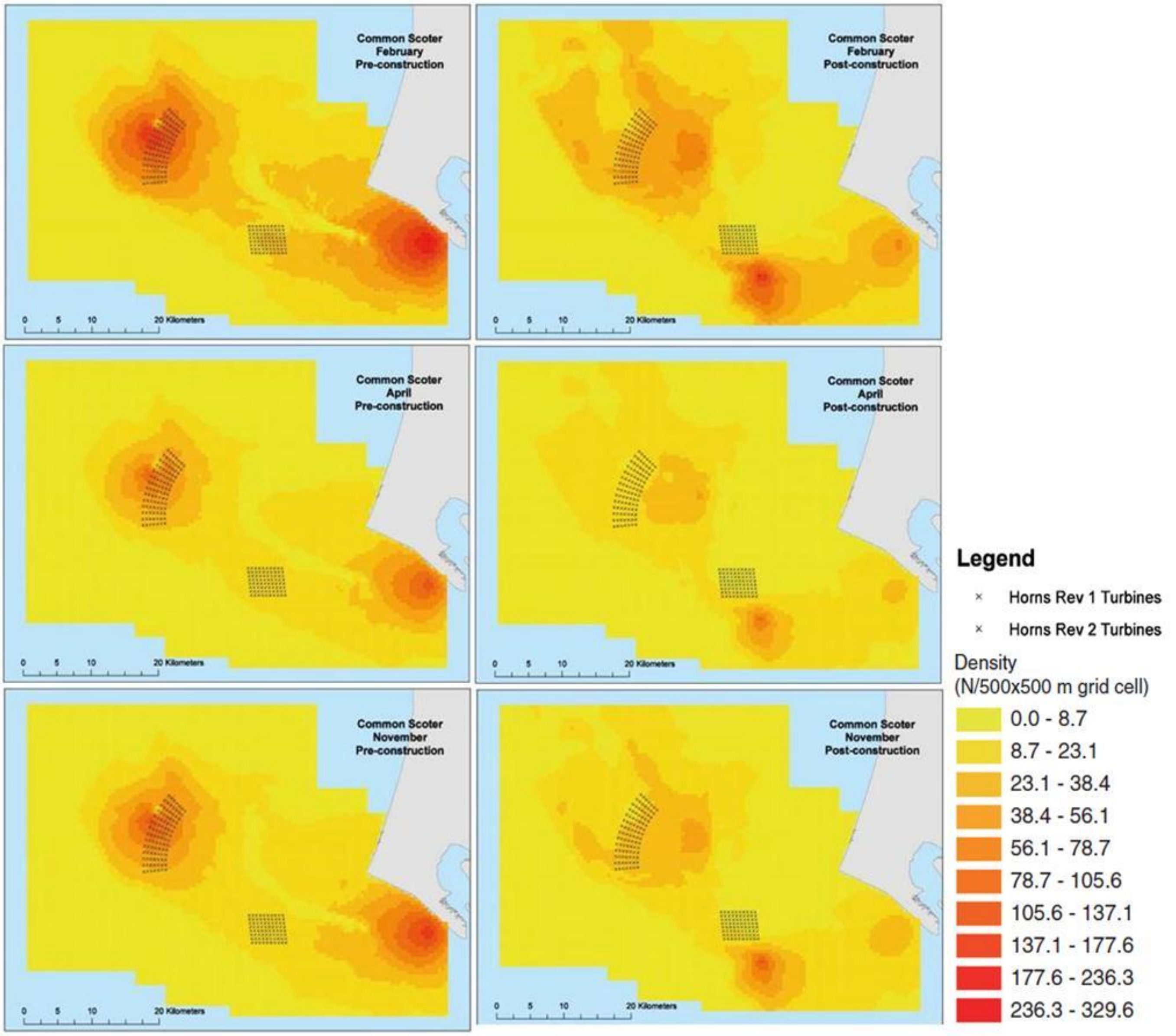
In relation to birds, the potential barrier effects of offshore wind farms and displacement of birds from offshore wind farm areas have been extensively recognised with a growing number of publications on this topic (e.g. Percival 2001, 2014, Drewitt & Langston 2006, Fox *et al.* 2006, Stienen *et al.* 2008, Norman *et al.* 2007, Krijgsveld *et al.* 2011, Krijgsveld 2014, Searle *et al.* 2014, Busch *et al.* 2015, Busch & Garthe 2016); however there is still little convincing data showing significant effects. 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, and birds undertaking local movements (e.g. between nesting/roosting sites and feeding areas.

Both barrier effects and displacement effects are closely related to avoidance behaviour; the stronger the avoidance of the wind farms the larger the potential barrier and displacement effects of these wind farms.

Studies on the barrier effect using aerial surveys carried out before, during and following construction of the first wind farm at Horns Rev have been described in previous SEAs (OESEA, OESEA2). The analyses showed divers, gannets, common scoters, guillemots and razorbills to be present in lower numbers than expected in the wider wind farm area following construction. Conversely, gulls and terns showed a preference for the wind farm area following construction (Petersen *et al.* 2004). Subsequent surveys indicated common scoters were distributed in comparable densities inside and outside the development and suggested the possibility that changes in food availability rather than displacement by disturbance led to the observed changes in distribution. Alternatively the changes may reflect habituation to wind farm presence and associated activities (Petersen *et al.* 2006).

Survey efforts have continued across the Horns Rev study area in support of Horn Rev 2 OWF. The latest surveys (post-construction) were undertaken during the winters and springs of 2011 and 2012, using methodology consistent to pre-construction surveys, enabling before and after comparison (Petersen *et al.* 2014). Some 187,000 individual common scoter were recorded in a single survey in March 2011, this being the most abundant bird in the study area. Whilst overall abundance of this species was similar comparing the pre- and post- construction periods, distributional changes were evident; the most notable of these was a marked decrease in abundance post-construction in an area measuring ~100km^2 around the Horns Rev 2 wind farm and the coastal area west of Skallingen, in contrast to increasing densities seen in areas south of the horns Rev 1 wind farm, east of the Horns Rev 2 wind farm and in the western and north-western parts of the survey area (Figure 5.23). It was concluded that decreases in common scoter density in the immediate Horns Rev 2 area, are likely to be associated with the presence of the wind farm (Petersen *et al.* 2014).

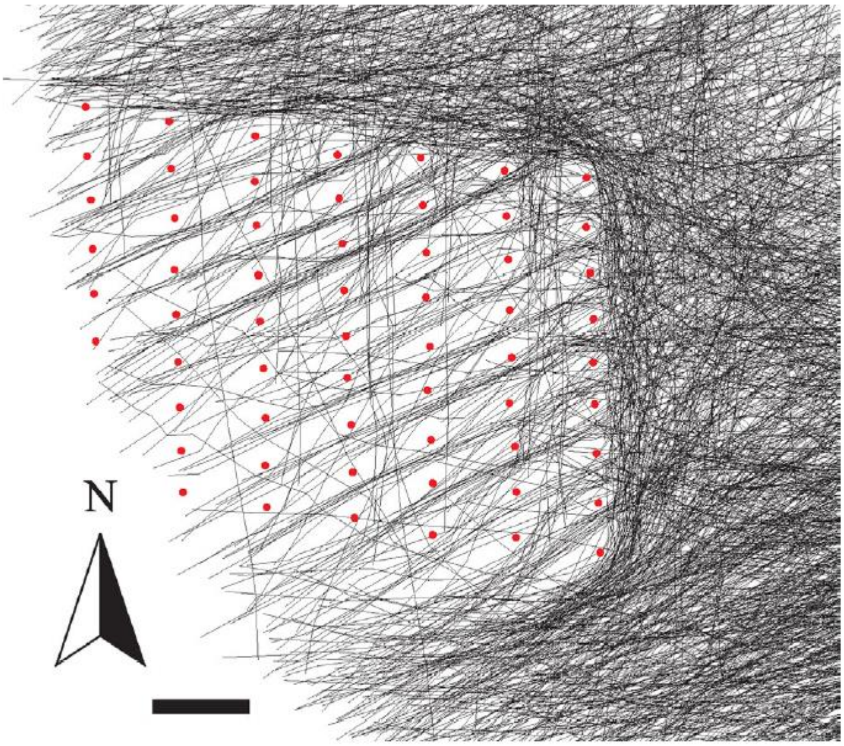
Figure 5.23: Estimated densities of common scoter in the Horns Rev survey area, comparing periods pre- (left maps) and post- (right maps) construction of the Horns Rev 2 OWF, in the western part of the area



Source: Petersen et al. (2014).

Barrier effects have also been identified in migrating common eiders. Their flight trajectories passing through the Nysted wind farm area pre- and post-construction showed a curvature around the wind farm. The post-construction median curvature was significantly greater than pre-construction, suggesting that the birds adjusted their flight paths in the presence of the wind farm (Masden *et al.* 2009). The response of eiders to the wind farm and the differences in space use are illustrated in Figure 5.24.

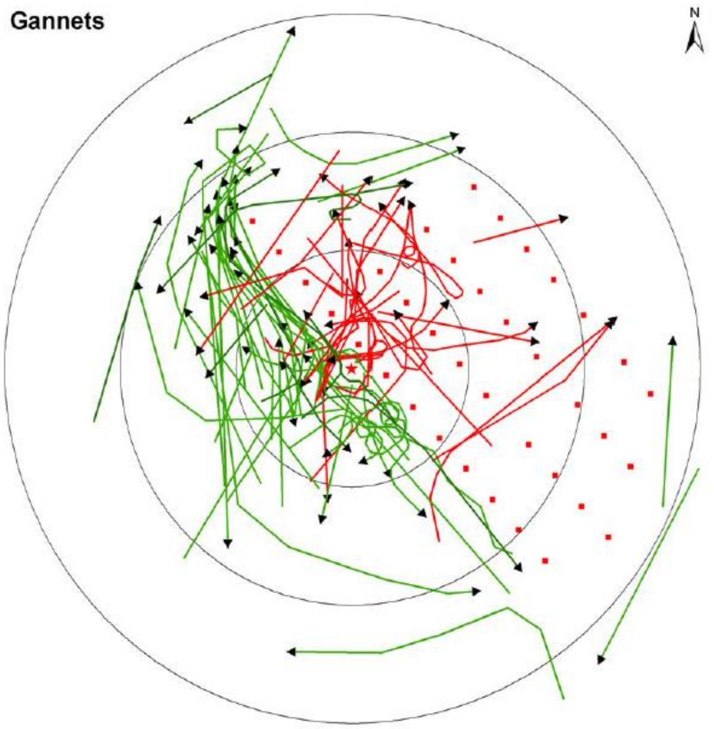
Figure 5.24: Westerly orientated flight trajectories during the initial operation of the wind turbines at Nysted OWF. Black lines indicate migrating waterbird flocks, red dots the wind turbines. Scale bar, 1000m



Source: Desholm & Kahlert (2005)

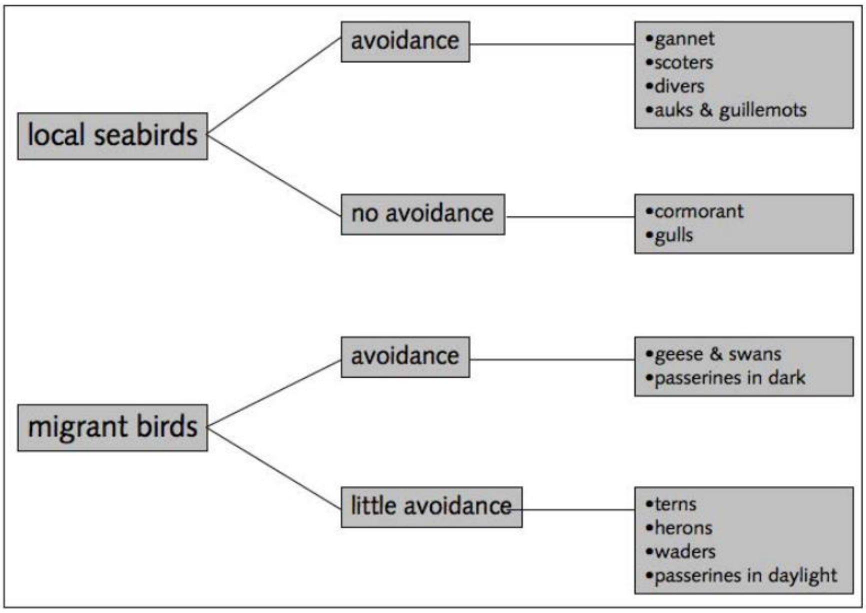
Krijgsveld *et al.* (2011), reported the results of studies on both local and migratory movements carried out between 2007 and 2010 (following a baseline carried out between 2003 and 2005) of the effects of the Egmond aan Zee offshore wind farm. The presence of the wind farm was found to affect bird flight direction: with birds adjusting their flight paths to avoid individual turbines (micro-avoidance) and also to avoid the entire wind farm (macro-avoidance) (see section below describing micro, meso and macro avoidance). Birds showed varying degrees of avoidance; gannets, scoters, alcids and divers showed the greatest avoidance, however some species, e.g. gulls and cormorants showed none (see Figure 5.25 for an example of a gannet flight path). A similar pattern was also seen in migrants (i.e. some avoided, some did not/showed little avoidance), with avoidance greater in some groups, if flying at night e.g. passerines. The results are summarised in Figure 5.26.

Figure 5.25: Flight paths of gannets in the area of the Egmond aan Zee windfarm, showing avoidance at close distance.



Notes: Visual observation data. Red lines = birds that passed within the wind farm, green lines = birds that did not enter the wind farm, red dots = wind turbines, red star in centre = metmast. Rings spaced at 1nm = 1852m Source: Krijgsveld et al. (2011).

Figure 5.26: Overview of levels of avoidance as observed for individual species



Source: Krijgsveld et al. (2011).

Barrier effects of birds altering their migration flyways or local flight paths to avoid a wind farm are also a form of displacement (Drewitt & Langston 2006) and this effect is related to the possibility of increased energy expenditure when birds have to fly further. In a 2013 review, Furness *et al.* defined displacement as a reduced number of birds occurring within or immediately adjacent to offshore wind farms and disturbance as birds spending extra time and/or energy to avoid structures or human activity associated with the wind farms. Using a sensitivity index incorporating disturbance, habitat specialisation and conservation importance elements, Furness *et al.* (2013) identified populations of divers and common scoter as most vulnerable to population level impacts of displacement. In terms of energy expenditure, the potential energetic costs to seabirds (migrants and residents) of commuting around offshore wind farms, were found to be trivial (e.g. depletion of <2% of available fat reserves even if birds had to travel an extra 30km), with greater potential costs to birds having to make regular deviations around a facility located between nesting/roosting sites and feeding areas (e.g. Speakman *et al.* 2009, Masden *et al.* 2010).

Seabird abundance and distribution was studied through monthly ship-based seabird surveys following a before–after control–impact monitoring design at the Bligh Bank offshore wind farm. Three years of post-impact monitoring showed that gannet, guillemot and razorbill avoided the wind farm area, and decreased in abundance by 85, 71 and 64% respectively Vanermen *et al.* (2014). In contrast, lesser black-backed gull and herring gull appeared to be attracted to the wind farm, as their numbers increased, while other gull species were also found to frequent the turbine-built area, most notably common gull, kittiwake and great black-backed gull. The ecological incentives behind such attraction effects are still poorly understood (e.g. possibly the availability of roosting platforms or enhanced feeding opportunities etc.) but Vanermen *et al.* (2014) concluded that the attraction of seabirds to the offshore wind farm does imply an increased collision risk potential.

Krijgsveld (2014) reviewed results of avoidance behaviour at different wind farms and described patterns in individual species and groups of species to determine if wind farm size and turbine spacing are factors affecting the behavioural responses of birds. Across studies, strong consistencies were found in bird densities and behaviour within species groups or species. Pelagic seabirds (gannets, divers and alcids) showed strong avoidance behaviour in the vicinity of offshore wind farms; the few exceptions appeared to coincide with high food availability, with birds entered the area to exploit those food resources. Gulls showed more variation; larger gull species showed indifference, or attraction, while no consistent pattern could be found for smaller species. Differences in study methods and low bird abundances may have contributed to the large variability observed in the smaller species. Detailed descriptions of avoidance behaviour in different species groups are provided by Krijsgveld (2014) who found that the lack of consistent methodology made comparisons between wind farms difficult, particularly of the effects of wind farm configuration. No difference in avoidance behaviour was evident between wind farms of different turbine spacings. Krijgsveld *et al.* (2011) suggested that the spacing of turbines within a wind farm is likely to have a considerable effect on avoidance behaviour of birds, and that careful design of wind farms could lead birds along flight paths through or away from a wind farm.

Percival (2014) provides an analysis of post-construction survey data recorded at the Kentish Flats offshore wind farm during 2011-12 and 2012-13[66]. In each of the seven years of post-construction monitoring, displacement of divers from the wind farm site was evident. The 2011-12 and 2012-13 results confirmed a much reduced diver density within the wind farm area, with a suggested displacement of between 89% (comparing recent densities within and outside the wind farm) and 94% (comparing with previous pre-construction densities). The author noted that the magnitude of the effect is dependent on which comparisons are made[67] and whether

[66] Surveys on red-throated diver at the Kentish Flats wind farm during pre-construction, construction and post-construction phased have been undertaken prior to 2011-12 and these have been reported previously
[67] The original statistical analysis carried out for monitoring conducted under the FEPA licence utilised a BACI (before-after-control-impact) approach however it was acknowledged in the monitoring report this was of relatively

account is taken on the variability in diver populations in the wider survey area. Data from 2008-09 had suggested the magnitude of diver displacement may be decreasing over time, perhaps from birds habituating to the presence of the structures; data from 2011-12 and 2012-13 did not support this however, with no records of divers within the wind farm in 2012-13. Similar results were found from post-construction monitoring of the Thanet offshore wind farm (Percival 2013); a clear reduction in diver numbers was evident following construction although there was no evidence of reduction from pre-construction levels in diver numbers outside the wind farm. In contrast, post construction monitoring at Egmond aan Zee offshore wind farm, found no significant effects on divers but this site is outside the divers main preferred areas.

5.6.3.2.2 Tidal ranges

The effects of tidal range developments on waterbirds are not limited to the infrastructure itself but also from habitat changes, changes to quality of the intertidal habitat, and loss of or reduced access to intertidal areas for feeding. For example, the potential loss of (and associated changes to) intertidal habitat resulting from the largest of the Severn Estuary tidal power options, the Brean Down to Lavernock Point Barrage (B3), was assessed to be the main effect source of effect on waterbirds. The main, initial effect would probably follow construction, when an estimated 51% of the intertidal might be lost (based on area exposed at lowest astronomical tide and not including intertidal areas of sub-estuaries); an additional 7.4% decrease in the extent of the intertidal was predicted over the operational phase. The predicted level of $2.0Mm^3$ of maintenance dredging per year would also affect intertidal habitat quality. This effect of the B3 option was identified as a likely significant negative effect for 30 waterbird species, including the overall waterbird assemblage, as the scale of (both immediate and long-term) habitat loss and the changes to the intertidal exposure period were predicted to outweigh any positive changes in the quality of intertidal habitat (DECC 2010g). Visual and noise disturbance during construction and to a lesser extent during operation of any similar project could cause behavioural disturbance and displacement from an area, potentially resulting in an effect on fitness and mortality of individuals.

Energy generation using barrage systems that generate power on both ebb and flood tides could considerably reduce the changes in exposure of the intertidal area and so reduce the potential impacts on the bird community (ICES 2010).

Various studies have described methods for assessing the sensitivity of birds to barrier effect/displacement and tried to develop methods for scoring risk and categories for species groups (e.g. Frid *et al.* 2012, Furness *et al.*, 2012). It should be noted that while the concept of displacement and disturbance from tidal (and wave) generation schemes is understood, relating the concept of disturbance to the quantification of an impact at the level of local, regional and national populations is problematic (Kirby *et al.* 2013).

5.6.3.3 Barrier to movement, displacement and other behavioural effects – fish and marine mammals

Concerns have been raised in relation to possible barrier effects of offshore wind farm developments to fish and marine mammals; however, these are mainly related to noise effects and EMF effects and discussed in Sections 5.3.3 and 5.6.3.7, respectively.

The potential for wind farm structures to act as artificial reefs or fish aggregating devices in the case of floating turbines (Inger *et al.* 2009) is ranked as a behavioural effect (and often referred

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low power which meant no statistically significant effect was identified although a qualitative assessment suggested an avoidance of the site by divers.

to as a positive impact). Preliminary evidence shows that a greater abundance of fish has been recorded within the immediate vicinity of wind turbines and that several harbour seals have been observed to concentrate their foraging efforts there (Wilhelmsson *et al.* 2006, Reubens *et al.* 2013, Russell *et al.* 2014).

Large, man-made offshore structures provide shelter for fish, and the biofouling communities which develop form the basis of a new local ecosystem (see also Section **Error! Reference ource not found.**). Such "reef effects" have been noted for oil platforms (Løkkeborg *et al.* 2002, Soldal *et al.* 2002) and offshore wind farms (Reubens *et al.* 2014, Stenberg *et al.* 2015). Cod at OWFs in the southern North Sea were found to display site fidelity over summer and autumn, with little movement away from favoured locations during this time (Reubens *et al.* 2013). Summer and autumn are periods of feeding for cod, prior to migration to winter spawning grounds, and the indication is that the OWFs act as convenient feeding grounds. Fujii (2016), studying the stomach contents of predatory gadoids around the Miller platform in the central North Sea, found that communities of cod, saithe, haddock and tusk there were feeding on prey items from a range of benthic and pelagic habitats, indicative of the habitat diversity provided by these man-made artificial reefs. The diet of saithe sampled around the region was found to be influenced by the concentrations of offshore structures in the area where they were caught. Long-term effects on the wider community are unclear. Reubens *et al.* (2014) observed that the aggregation of cod (and pouting) around the turbines is biased towards younger animals; however although aggregation may lead to recruitment at a local scale, it does not necessarily mean increased species abundance at a regional scale.

Across the UKCS, marine mammal migrations, as an organised seasonal behavioural pattern comparable to that of many marine bird species, are seen only in sperm whales and possibly baleen whales along the continental shelf margin (see Appendix Section A1a.8); harbour porpoises and several other species have been sighted in increased numbers in inshore areas during the summer months but no specific migration 'corridor' has been identified. The potential for any renewable energy development to become a significant barrier to regional movement of marine mammals within UK waters is therefore negligible.

The likelihood of tidal stream energy developments acting as a barrier to local movements of individuals needs further consideration, since suitable development locations such as tidal straits and channels are spatially constrained. Current understanding of the effects is hampered by limited empirical evidence. The potential for displacement effects and barrier effects of the SeaGen tidal stream turbine in Strangford Lough have been investigated through a comprehensive Environmental Monitoring Plan (Royal HaskoningDHV 2011). Passive acoustic monitoring of harbour porpoises and harbour seal tracking by telemetry led to the conclusion that SeaGen does not cause a barrier effect although small changes in distribution and movement patterns were observed. Overall the observations are suggestive of small-scale local redistribution (250m) in relation to the SeaGen presence and operation, with the likelihood of little ecological significance (Savidge *et al.* 2014).

Among fish, several species show differences in their distribution with season and in some cases large-scale migratory patterns (see Appendix Section A1a.5) but the focus of concern with regard to any potential barrier to movement are the diadromous species, e.g. Atlantic salmon, brown trout, European eel, lampreys and shad (Malcolm *et al.* 2010, Frid *et al.* 2011). Less than 2% of river lamprey tagged below the tidal barrage at the River Derwent were later recorded at their spawning habitat 50km upstream (Lucas *et al.* 2009). A number of these diadromous species are among the most threatened fish species in UK waters. Changes in the nature or physical characteristics of habitats may affect their suitability as nursery or spawning grounds for fish (Frid *et al.* 2011).

Topic papers on migratory and estuarine fish produced as part of the DECC Severn Tidal Power feasibility study (DECC 2008c, 2010g) indicated that the placement of a tidal range scheme within the Severn Estuary could result in effects to fish passage and movement both for the seasonal migration of diadromous species and the daily movement of estuarine species. In a high tidal range and strong excursion environment such as the Severn Estuary, upstream migrants are likely to use tidal stream transport as a mechanism of moving up the estuary. Many species depend on currents to transport larvae (Frid *et al.* 2011). A tidal range scheme across the estuary could alter this tidal regime with resultant changes to the mechanism and rate of upstream movement of migratory fish. Furthermore, migratory fish are likely to change their behaviour as they move into the estuary from coastal waters, through the main estuary and into the inner estuaries and freshwater environments. Changes to the tidal and freshwater patterns due to the construction of a barrage structure may further the negative impacts on migratory behaviour and consequential impacts upon individuals and populations. Such changes to migratory movement may result in delayed and increased passage time, which in turn may cause further effects including increased predation and extended exposure to any changes in water quality (DECC 2008c, 2010g). It is likely that the development of tidal lagoons will also have effects on fish behaviour within estuaries, although the exact nature and scale of any impacts is currently unknown.

5.6.3.4 Collisions risk - birds

5.6.3.4.1 Offshore wind farms

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. OESEA2 discussion of the evidence for collision utilised two main reviews, both of which are still relevant, Desholm *et al.* (2006) and Drewitt & Langston (2006). More recently, several studies and reviews have described and where possible updated and amended species specific or species group methods for determining vulnerability scores for collision risk (e.g. Langston 2010, Furness *et al.* 2013, Bradbury *et al.* 2014) and the discussion of the evidence base is provided by these and other relevant publications.

Direct mortality and lethal injury of birds and bats as a result of collision with wind turbines (and associated infrastructure) is widely acknowledged but the empirical evidence base for quantifying the numbers of birds likely to collide with offshore turbines is limited. Therefore, accurately estimating collision risk is still problematic, as is determining the impact that the loss of individual birds has at a species and population level.

Collision risk depends on a range of factors related to bird species, numbers, behaviours, weather conditions, topography and the nature of the offshore structure itself, including the use of lighting (Drewitt & Langston 2006). The impact of collision may have a disproportionate effect on some species; even low mortality rates, were they to be experienced by long-lived species with slow maturation rates and low productivity could have a significant impact at the population level (e.g. Drewitt & Langston 2006).

Collision Risk Modelling (CRM) has been extensively used for both onshore and offshore sites, including a range of UK offshore developments. Most CRMs include a calculation of the probability of a collision occurring (assuming no evasive action or behaviour) and a measure of the number of birds within a risk window, with the probability of collision generally based on the probability of a turbine blade occupying the same space as the bird, during the time that bird takes to pass through the rotor. This assumes a collision with the moving parts of the turbine, and does not take into account collision with the stationary parts, i.e. tower.

Information required for input to a CRM includes (but is not limited to):

- Bird morphometrics
- Bird flight speed and height
- Turbine rotor speed and diameter
- Turbine size

An estimate of bird avoidance (or preferably a range) is often included to more realistically predict collision events and risk.

CRM predictions presented in Environmental Statements from several UK offshore wind farms are collated in Table 5.17. It should be noted that across these examples CRMs were not always used consistently and with appropriate input data. For example the critical review of collision risk modelling for the Kentish Flats offshore wind farm (Chamberlain *et al.* 2006) notes that in Gill *et al.* (2002) the use of a single estimate of avoidance rate which was derived from passerines and applied to terns, divers, gannets and black-headed gulls.

The main conclusions from Table 5.3 are firstly, that numerical predictions are highly sensitive to assumptions on avoidance rates; and secondly, that the maximum predicted collision rates for any species[68] are of the order of a few tens per year, per development.

Table 5.17: Collision Risk Modelling (CRM) predictions taken from various UK offshore wind farm Environmental Statements

Wind farm	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	$0.048/d_d$ $0.076/d_d$ $0.052/d_d$
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	$4668/y_d$ $3176/y_f$ $93/y_a$ $47/y_b$ $23/y_c$ $4.7/y_g$ $0.93/y_e$ $77/y_d$ $4/y_f$ $2/y_a$ $1/y_b$ $0/y_c$ $0.1/y_g$ $0.02/y_e$ $427/y_d$ $21/y_f$ $9/y_a$ $4/y_b$ $2/y_c$ $0.4/y_g$ $0.09/y_e$ $74/y_d$ $0/y_f$ $1/y_a$ $1/y_b$ $0/y_c$ $0.1/y_g$ $0.01/y_e$ $2137/y_d$ $107/y_f$ $43/y_a$ $21/y_b$ $11/y_c$ $2.1/y_g$ $0.43/y_e$ $1710/y_d$ $85/y_f$ $34/y_a$ $17/y_b$ $9/y_c$ $1.7/y_g$ $0.34/y_e$ $114/y_d$ $6/y_f$ $2/y_a$ $1/y_b$ $1/y_c$ $0.1/y_g$ $0.02/y_e$ $3/y_d$ $0/y_f$ $0/y_a$ $0/y_b$ $0/y_c$ $0/y_g$ $0/y_e$

[68] excluding scenarios with zero avoidance,

Wind farm	Species/Taxa	Collision (mortality) rate (in units of number/time) for whole development
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/yb 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
Dudgeon - Greater Wash	Sandwich tern Common tern Razorbill Lesser black-backed gull Gannet	75/y_a 2/y_a <1/y_c 54/y_b 217/y_i
Dogger Bank Cryeke Beck[10]	Puffin Kittiwake Great black-backed gull Great skua Lesser black-backed gull Fulmar Gannet Razorbill	2/y_a 217/y_a 53/y_a 1/y_a 34/y_a 1/y_a 60/y_b 3/y_a
Dogger Bank Teesside A&B[10]	Kittiwake Great black-backed gull Great skua Lesser black-backed gull Fulmar Gannet Razorbill	134/y_a 58/y_a 1/y_a 33/y_a 1/y_a 68/y_a 6/y_a
East Anglia ONE[4]	Fulmar Gannet Kittiwake Common gull Lesser black-backed gull Herring gull Great black-backed gull	2/y_a 850/y_a 1056/y_a 41/y_a 394/y_a 230/y_a 496/y_a
East Anglia THREE[10]	Fulmar Gannet Kittiwake Lesser black-backed gull Herring gull Great black-backed gull	6/y_a 98/y_a 112/y_a 97/y_a 253/y_a 286/y_a

Wind farm	Species/Taxa	Collision (mortality) rate (in units of number/time) for whole development
Hornsea One	Gannet Kittiwake Great black-backed gull Lesser black-backed gull Herring gull Little gull Common tern Arctic tern Arctic skua Great skua	$54/y_a$ $31/y_a$ $127/y_a$ $22/y_a$ $64/y_a$ $10/y_a$ $8/y_a$ $47/y_a$ $9/y_a$ $1/y_a$
Hornsea Two	Gannet Arctic skua Great skua Lesser black-backed gull Great black-backed gull Little gull Kittiwake Common tern Arctic tern	$62.6/y_a$ $9.9/y_a$ $0.8/y_a$ $4.2/y_c$ $40.9/y_c$ $1.3/y_a$ $28.1/y_a$ $8.5/y_a$ $49.9/y_a$

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% and $_j$97%. [1]Two precautionary assumptions are used in impact assessment. First the annual mortality was calculated with the worst case 108 x 3MW layout (Rochdale Envelope). Second, a precautionary avoidance rate of 98% was used. [2]Collision morality 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]Collsion rates calculated using SNH CRM. [5]Collsion 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 sweep 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 term sp.). [10]Collision rates calculated using Band (2012)

The selection of appropriate avoidance rates for use in collision risk models is a key part of the assessment, as different bird species exhibit different behavioural responses (in this case avoidance) to wind turbines. Since there is a lack of data for the interactions between marine birds and offshore wind farms, use of avoidance rates is commonly based on values that have been derived for terrestrial species and onshore wind farms. Cook *et al.* (2014) focused on five species whose behaviours and distributions make them particularly prone to collision with offshore turbines (gannet, kittiwake, lesser black-backed gull, herring gull and great black-backed gull); they began their review of avoidance rates by offering three different scales of avoidance behaviour: macro, meso and micro. Macro refers to changes in flight direction and altitude that indicate avoidance of wind farm perimeter; meso refers to changes in flight direction and altitude that indicate avoidance of rotor swept zones in the wind farm; and micro refers to flight behaviour that indicates responses to single blade(s) within 10m of the rotor swept zone. Over time, the use of a considerable range of avoidance rates has been used in collision risk models. Using available data from the literature and in conjunction with the basic and extended Band model[69] (Band 2012), Cook *et al.*, (2014) recommended total avoidance rates for the

[69] The basic Band Model assumes that birds are distributed evening within the rotor-swept area of a turbine, while the extended Band Model uses a continuous flight height distribution to estimate collision risk at different points within the turbines rotor-swept area.

basic Band Model for all five species, but for the extended Band Model total avoidance rates were calculated for only three species and species-specific avoidance rates for only two.

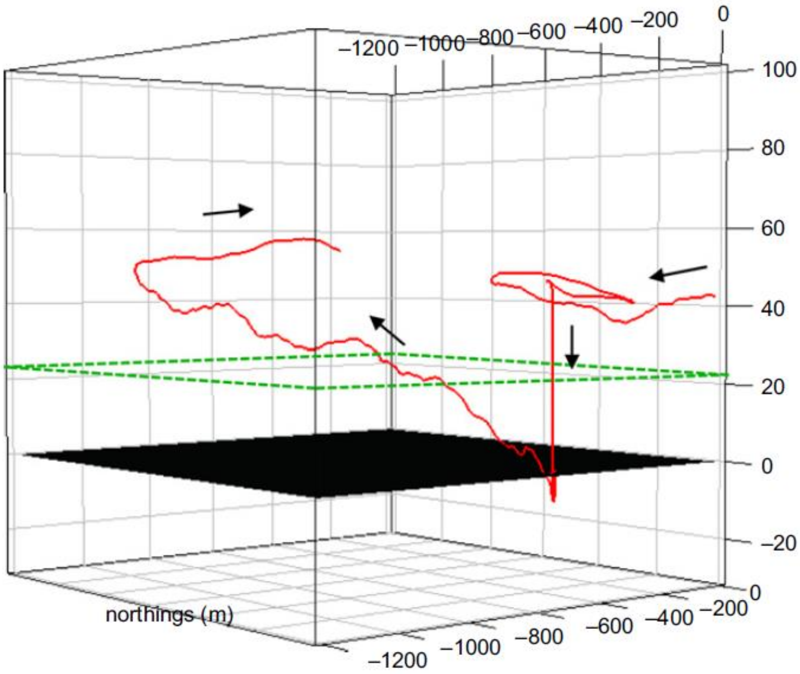
The Offshore Renewable Joint Industry Programme (ORJIP) was set up in 2012 by DECC, The Crown Estate, Marine Scotland and a number of offshore wind farm developers; its aim was to reduce the consenting risk for offshore wind farms through funding research projects designed to better inform consenting authorities on the environmental risks of offshore wind farms. A two and a half year project was initiated in March 2014 to improve the evidence base on bird collision avoidance rates; monitoring equipment (rangefinder observations and radar tracking) was installed at the Thanet offshore wind farm to monitor macro, meso and micro avoidance behaviours of the same key five species as looked at by Cook *et al.* (2014).

Flight height is also a key factor in predicting collision risk. Cook *et al.* (2012) reviewed available information on flight height and produced models based for a wide range of species. They relied primarily on estimated heights, as directly recorded flight heights were available from only two radar studies, one focusing on eider (in Alaska) and the second of migrating black-headed and lesser black-backed gulls in the Netherlands. They acknowledge other studies recording flight altitudes (e.g. Thaxter *et al.* 2011), but the small sample sizes involved do not allow generalizations about species flight behaviour to be made. The height/area where birds are most at risk is considered to be within the height envelope swept by the wind turbine rotors. For their analyses, Bradbury *et al.* (2014) and Cleasby *et al.* (2015) used 20-150m and 30-160m above sea level respectively; and concluded that the risk of collision was greater for birds flying at these heights.

From their literature review, 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; contrast this with 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, where only one collision event was recorded during observations of 1.5 million migrating waterfowl (Pettersson 2005). Hüppop *et al.* (2006a) noted the problems of quantifying collision rate by carcass collection offshore, and Chamberlain *et al.* (2006), in a review of collision risk modelling, pointed out that calculation of post-construction mortality rates has typically relied on corpse searches (Langston & Pullan 2003), using tideline searches for offshore and coastal wind farms (e.g. Winkelman 1992, Painter *et al.* 1999). There are potential biases in estimating mortality in this way due to a number of factors: searching efficiency, corpse removal by scavengers, injured birds leaving the area before death, ‘obliteration’ of birds struck by turbine blades (especially smaller species) which therefore do not reach the coast and, for coastal locations, corpses sinking or being washed out to sea.

Cleasby *et al.* (2015) tracked adult gannets from Bass Rock in relation to two potential wind farm locations in the Firth of Forth. They used a combination of data from GPS-loggers and barometric pressure loggers to track the three-dimensional movements of chick-rearing birds to estimate their foraging ranges, density at sea, flight heights during different activities and the spatial variation in height during trips. From these data they were able to estimate potential collision risk with each of the wind farm sites and to compare their results with collision risks predicted using flight heights reported from ship-based and radar-based studies (see Figure 5.27). It was estimated that gannets flew at a median height of 12m while commuting but increased their flight height during periods of active foraging (median height 25m). Previous ship based estimates of flight height for gannets were lower with fewer than 10% of flights exceeding 20m (Cook *et al.* 2012)

Figure 5.27: Five-minute section of a three-dimensional foraging track from a gannet breeding at Bass Rock, recorded using GPS and pressure differences



Notes: The dotted green line indicates that the bird spent most of this time above the minimum collision-risk height (22m above sea level)
Source: Cleasby et al. (2015).

Using the combined altimeter and GPS data and the basic (Band) model, with 99% avoidance rate, they further estimated that ~300 breeding adults could be killed per month, during the chick-rearing period as a result of collision with turbines at these two sites. The cumulative predicted mortality during the breeding season (mid-April to mid-September) each year is therefore estimated at ~1,500 adults. Using this method, predicted mortality was almost twelve times higher than that obtained using the overall distribution of flight heights estimated by observers at sea combined with GPS data; and it was almost six times that obtained by assuming that 5% of birds fly at collision risk height, based on observer and radar data. Given such high estimated mortality, the authors acknowledge the urgent need for further data not only on gannets, but on other high-priority species (e.g. gulls), most at risk from collision; this will enable a refining of collision-risk estimates and mortality threshold for long-term population viability. It will also benefit strategic monitoring at key sites to determine whether the predicted mortality (and hence the collision risk modelling estimates) are realized.

The causes of bird fatalities due to collisions with both onshore and offshore wind farms have been reviewed by Marques *et al.* (2014). They analysed species-specific, site-specific and wind farm specific factors and found that collisions with wind farms caused fewer bird deaths than collisions with other man-made infrastructure (e.g. power lines, buildings); worldwide estimates of bird deaths from collisions with wind farms ranged from 0 to ~40 per turbine, per year.

Since OESEA2, results from a number of DECC-commissioned studies which examined the potential interaction of bird species with offshore wind farms have been published. It is important to know and understand where birds forage in order to determine populations that might be affected by offshore wind farms and in particular to assess the risk of adverse impacts on relevant Special Protection Areas (SPA) and their interest features. Langston *et al.* (2013b) is the final report of a three year study (2010-2012) collecting adult gannet data from Bempton Cliffs; the birds were tagged to investigate their foraging ranges in relation to offshore wind energy development zones during chick-rearing and early post-breeding periods. Locations of tagged birds coincided with the Hornsea offshore zone, Dogger Bank zone, East Anglia zone and the Greater Wash Strategic Zone. Although this study had a relatively small annual sample size (i.e. there is a degree of uncertainty as to how representative the data are of year to year foraging activity by breeding gannets from this colony, especially in years of lower breeding productivity), the collective foraging range of the forty two tagged birds encompassed the full seaward radius around Bempton Cliffs, allowing reasonable confidence in the results that they represent the sea areas used by adult gannets, at least in seasons of good productivity.

Lesser black-backed gulls from a colony at Orford Ness, Suffolk, and great skua from colonies at the Hoy SPA (Orkney) and Foula SPA (Shetland) were tagged during a three year study by Thaxter *et al.* (2014). The aim of the study was to investigate movements and record flight heights in relation to operational, consented and proposed offshore wind farm areas. The use of offshore areas by lesser black-backed gulls showed individual, seasonal, sex-specific and annual variations. Individual, sex-specific differences and cross-breeding season variation in area utilisation were all also seen in great skua. Lesser black-backed gulls showed connectivity with the East Anglia zone and the Greater Gabbard offshore wind farm area; one individual was also recorded in the area of the Scroby Sands wind farm. Despite the apparent high numbers of birds interacting with operational, consented and proposed wind farms locations, the total time spent and spatial extent of overlap of these areas was more limited; the percentage of time spent in the offshore wind farm areas peaked at 4% in 2010 and the percentage of total area usage peaked at 14% in the same year (Thaxter *et al.* 2014).

Results of the DECC funded extension to the Wildfowl and Wetlands Trust (WWT) whooper swan tagging study looking at migration routes in relation to wind farm footprints were published by Griffin *et al.* (2011). This study included tracking data for three goose species, all of which winter in the UK but which follow different migration routes to separate breeding areas. Eleven offshore wind farms and 81 onshore wind farms were within 5km of the flight-lines for Whooper Swans tracked from NW England (Martin Mere), SE England (Welney) and SW Scotland (Caerlaverock) in 2009 and 2010; this included three offshore wind farms (Kintyre, Wigtown Bay and Solway Firth) where the planning applications have been withdrawn. Most intensive Whooper Swan movement in the vicinity of wind farms was over the consented West Duddon offshore site, the withdrawn Solway Firth offshore site and an onshore site. Whooper Swan tracks passed over all four of the operational/consented Cumbrian offshore sites: West Duddon, Ormonde, Walney and Barrow, as well as the Robin Rigg wind farm (in operation) on the Solway Firth.

Little is known about the flight lines taken by Bewick's swans migrating between south east England and the Low Countries of continental Europe. Bewick's in the UK have major concentrations in the south east of England; with three sites of international importance (Ouse Washes, Nene Washes and Severn Estuary) and three of national importance (Breydon/Berney Marshes, Dungeness/Rye Bay and Ranworth/Cockshoot Broads). In a study commissioned by DECC as part of the SEA process, Bewick swans were tagged in 2013/2014 (but technological issues preventing analysis from this year) and 2014/215, with preliminary results showing 12 of the 13 birds tagged in winter 2014/15 exiting Britain and appearing to cross the footprint of the R3 East Anglia offshore wind farm zone in the North Sea and the final bird passing within a few miles of the site (Griffin *et al.* in prep). Work is ongoing with this study, with further data downloads planned from functioning tags and the plotting of swan GPS positions within the UK in relation to weather observations from the closest stations to look at migration routes in relation to prevailing weather conditions.

To improve understanding of Bewick's swan[70] migration routes between south east England and the Low Countries (Section A1a7.6.3), a satellite-tagging study was commissioned by DECC. Bewick's swans were tagged in winter 2013/2014 and 2014/215. Preliminary results show 12 of the 13 birds tagged in winter 2014/15 appearing to cross the footprint of the R3 East Anglia offshore wind farm zone (Griffin *et al.* in prep). The results will also be interpreted in relation to weather data for relationships between migration routes and prevailing weather conditions.

Further work on flight altitudes and bird movements in relation to operational, consented and proposed wind farms, include tagging studies of adult lesser black-backed gulls from Skokholm and lesser black-backed and herring gulls from South Walney breeding colonies (Thaxter *et al.* in prep.). Preliminary lesser black-backed gull results show individual variation in habitat use (inland and offshore); birds from South Walney foraged up to 88km offshore from the colony and most birds (15 of 24 tracked) interacted with areas of operational, consented and proposed offshore wind farms; in contrast, lesser black-backed gulls from Skokholm foraged up to 210km offshore from the colony although typical trips were much shorter. With the cancellation of the proposed Atlantic Array offshore wind farm, there are few offshore wind farms within foraging range of the Skokholm colony during breeding. Altitude data recorded for lesser black-backed gulls showed that they flew higher over land than over sea, with substantial individual variation in bird flight height that might reflect specialisations in foraging habitat. Preliminary results from the South Walney herring gulls show birds using coastal areas near to the colony; only two birds flew within the areas of operational wind farms (Thaxter *et al.* in prep.).

The gannet work at Bass Rock (e.g. Cleasby *et al.* 2015) is continuing with a further 35 birds tagged in 2015. The aim is to improve on the characterisation of areas for foraging and for commuting. Immature birds were also tracked and preliminary results showed longer (greater distance from colony) foraging trips for immature than adult birds.

5.6.3.4.2 Wave and tidal stream and tidal ranges

Wet renewable devices present a collision risk to birds during construction and operational phases. The risk is generally considered greatest for birds whose foraging depths coincide with the depths at which tidal devices may be deployed. The potential impacts of wave and tidal devices on marine birds have been the topic of a number of papers (e.g. Grecian *et al.* 2010, Langhamer *et al.* 2010, Langton *et al.* 2011, Frid *et al.* 2011, Wade *et al.* 2013, Masden *et al.* 2013), with ICES (2010) also providing advice on collision risk as part of a general review of environmental interactions with marine renewable devices. Witt *et al.* (2016b) addressed the methodological approaches needed to assess possible effects of wave energy on biodiversity.

In 2012, Furness *et al.*, published a review of the potential sensitivity of seabird populations to the adverse effects from tidal stream turbines and wave energy devices. The Natural Environment Research Council (NERC) 2013 position paper[71] on the potential ornithological impacts associated with the construction, operation and maintenance and decommissioning of wave and tidal energy devices acknowledged uncertainties in determining the level of impact (at the population level) on birds from these devices and that while the potential for impact exists, a degree of uncertainty will remain, regardless of ongoing research or monitoring of test devices, until monitoring of results from larger installations become available.

[70] A bird with international conservation status at three East Anglian SPAs (see also section 4)
[71] This was part of NERC Wave and Tidal Consenting Position Paper Series

Given the limited deployment of wave and tidal stream devices in UK waters, empirical evidence also remains limited. Furness *et al.* (2012) provided vulnerability indices for birds interacting with tidal and wave devices. Using an approach similar to Garthe and Hüppop (2004), several species vulnerability factors (see Table 5.18) and conservation factors were scored. Interactions with tidal and wave devices were inferred rather than evidenced. Using the indices, species identified to be most vulnerable to adverse effects from tidal turbines are black guillemot, razorbill, shag, guillemot, cormorant, divers and puffin, while divers are the most vulnerable to wave devices. Furness *et al.* (2012) concluded that wave energy devices are likely to represent a lesser hazard to seabirds than tidal turbines, and both seemed likely to represent a lower hazard to seabirds than offshore wind farms.

Table 5.18: Vulnerability factors for tidal turbine (left) and wave devices (right).

Vulnerability factors for tidal turbines	Vulnerability factors for wave energy devices
Drowning risk – seabird vary in their susceptibility to drowning, e.g. some seem prone to get stuck in nets/traps, while others avoid. Differences likely to be caused by morphology, feeding ecology, behaviour, e.g. juveniles more prone to such mortality than adults.	**Risk of collision mortality due to structures** – some seabirds may be at risk of injury or death from colliding with wave energy devices either in flight or while swimming or diving.
Mean/maximum diving depth – depth deployments of tidal turbines uncertain and varies with design, but typically 30-50m below sea surface. Seabirds capable of diving to these depths likely to be at greater risk. Surface feeders at less risk. Scoring groups were: regularly dive to 2-3m but have max diving depth of no more than 5m; regularly dive to 5m but rarely below 20m; regularly to 20m but rarely below 40m and regularly to 30m and deeper[1].	**Exclusion from foraging habitat due to behaviour constraint** – seabirds may be prevented from foraging in important habitat maybe through being unable to land or take off easily where devices are present in the water, because other birds have been attracted to the area or because they need to spend their time avoiding devices rather than foraging
Benthic foraging – benthic foragers more likely to interact than seabirds that do not forage on the benthos.	**Benefit from roost platform** – under relatively calm sea conditions, devices may provide some seabirds with a resting platform; such an opportunity could extend their potential foraging area. E.g. cormorant and shag return to shore to dry their plumage after a foraging bout, having resting sites at sea could allow these birds to exploit areas further from shore.
Use of tidal races for foraging – few studies on the use of fast tidal flow areas by foraging seabirds; guillemots have displayed a tidal rhythm in foraging activity in early part of breeding season (but not chick rearing) in Orkney; Arctic tern and common tern in the Wadden Sea have also been recorded foraging selectively at stages of the tide and in geographical locations with relatively faster flowing (1m/sec) shallow (<10m) water	**Benefit from fish attraction device or biofouling** – devices will likely provide shelter for small fishes and so are likely to act as a fish attraction device, and also present surfaces onto which biofouling organisms will settle – both attracting foraging seabirds by providing locally high densities of prey.
Feeding range – being "central place foragers" breeding seabirds are constrained to return to the central place (nest site); during migration and winter, they are considerably less constrained. The distribution of predictable feeding hotspots may influence habitat quality; species with short feeding ranges will be more likely to be affected by the placement of devices than seabirds with greater foraging ranges.	**Disturbance by structures** – species differ in their reaction to structures; relates in part to the general responsiveness of species to disturbance and in part to their perception of the hazards represented by structures.
Disturbance by ship traffic – species differ in their reaction to ship traffic (deployment/maintenance activity); e.g. alcids can be disturbed by boats hundreds of metres away; divers are sensitive to approaching boats more than 1km away and scoters are particularly vulnerable to disturbance by boats.	**Disturbance by ship traffic** – considered the same as that for tidal devices

Vulnerability factors for tidal turbines	Vulnerability factors for wave energy devices
Habitat specialization – seabirds vary in the range of habitats they use, e.g. relating to water masses, and frontal systems, and whether they use these as specialists or generalists. Species can tend to forage over large marine areas, with little known association with particular marine features or feed on very specific habitat features such as shallow banks with bivalve communities.	**Habitat specialization** – similar to tidal devices

Notes: [1]See RPS (2010) and the description in OESEA2 (Table 5.11) for summary of dive depth behaviour. [2]the tidal flow rates reported by Schwemmer et al. (2009) for the Arctic and common terns (1m/sec) are relatively low in comparison to areas under consideration for deployment of tidal turbines (usually in excess of 4m/sec). Source: Furness et al. (2012)

The risks to seabirds posed by these devices in a particular area of open water are dependent on the foraging ranges of each species, especially the mean range within which most birds from a particular population will be expected to forage. For example, care should be taken to ensure devices are only located within the foraging ranges of birds from major colonies and SPA-designated areas if it can be established that the sites in question are of little importance or where risks to these species are assessed to be low. Placing devices within important foraging areas may mean that species are at elevated risk of collision with or entrapment within structures, construction and operational disturbance and indirect effects such as displacement of prey (RPS 2010).

Risk of collision is expected to be minimal as for many species of seabirds, including gulls, terns, kittiwakes, fulmars and skuas, their normal depth range would not allow them to encounter operating turbines. For some deep diving species, e.g. auks, shags, there is the chance of an encounter as these species regularly dive to depths of 45-65m. The critical issue is the relative swimming speed of the bird, and the ability to sense and respond to the turbine. A typical swimming speed for these species is of the order of 1.5ms-1. For comparison, the tip turning at 15rpm would be moving faster than this and so potentially be difficult for a bird to avoid. The possible interactions are further complicated by the possibility that diving birds may respond to the moving blades as potential prey and be attracted to their vicinity. Further work is needed to elucidate the scale of this phenomenon and to develop mitigation measures i.e. painting the blades (ICES 2010).

5.6.3.5 Collisions risk – fish and marine mammals

Worldwide, collisions with vessels are a potential source of mortality to marine mammals, primarily cetaceans. Whales are occasionally reported to be struck and killed, especially by fast-moving ferries but smaller cetacean species can also be impacted by propeller strikes from smaller vessels. In areas where cetacean numbers are depleted and vessels are numerous, ship-strike mortality can be a serious cause for concern as for example in the case of North Atlantic right whales during their seasonal migration along the U.S. coast. In the UK certain areas experience very high densities of commercial and recreational shipping traffic, some of which may also be frequented by large numbers of marine mammals; despite this, relatively few deaths are recorded as results of collisions (Hammond *et al.* 2008). Between 2000 and 2009, only 11 out of 1100 post-mortems on harbour porpoises and common dolphins identified collision as the cause of death (UKMMAS, 2010).

Wilson *et al.* (2007) reviewed the risks of injurious collisions between mobile species and wave and tidal stream devices. Mooring equipment such as anchor blocks are similar to natural seabed structures and hence pose few novel risks for vertebrates. Cables, chains and power lines extending up through the water will have smaller cross-sectional area than vertical support structures and so produce reduced flow disruption and fewer sensory cues to approaching animals. Instead of being swept around these structures, animals are more likely to become entangled in them. Seals may use floating devices as haul-out sites and risk of injury may be associated with getting onto/off the structures and any contact with exposed, moving or articulated parts. Cetaceans do regularly surface for air and collisions could either occur through animals swimming into them or the structures pitching down onto breathing animals in heavy seas. Collision risks for surfacing mammals will depend on how aware they are of the presence of the surface structures. Overall, the potential to cause collision has been associated most strongly with rotating turbines of tidal stream energy converters; this assessment is based largely on similarities between the velocity of rotor blades and those of approaching vessels implicated in cetacean ship-strikes.

A first assessment of the magnitude of risk to marine mammals posed by a tidal stream development was estimated by modelling encounter rates of harbour porpoises (Wilson *et al.* 2007). Information on distribution, size, depth preference and swimming speed was included in the model but the lack of any data to evaluate the ability of individuals to avoid coming into contact with devices led the authors to exclude consideration of avoidance or close-range evasion; hence encounter and not collision rate was modelled. It was predicted that in a year of operation, approximately 4 to 11% of the porpoise population would encounter a rotating blade. Albeit preliminary, these results supported the need for caution and for new research to quantify collision. The harbour porpoise encounter estimate was further revised by Wilson *et al.* (2014) for two Scottish sites with high potential for tidal stream energy development, where high resolution harbour porpoise abundance data from *ad hoc* surveys was used; encounter rates were found to be lower reflecting the lower abundance obtained in the surveys.

As part of the Marine Renewable Energy Strategic Framework for Wales (MRESF), WAG (2010a) carried out a desk-based examination of factors which may influence collision risk of marine mammals with wave and tidal stream devices. Discussions were consistent with the work by Wilson *et al.* (2007) and a similar conclusion was reached in that a detailed assessment of risks posed by tidal turbines is hampered by major knowledge gaps in several areas. It was noted that areas of high tidal energy are apparently important for different species of cetaceans and seals; better understanding of their distributions and densities in these environments, including knowledge of diving behaviour, is important for assessing encounter probability. Better understanding of sensory and motor capabilities and behaviour is important for quantifying evasion, quantifying collision risk and devising effective mitigation strategies. Field studies were carried out to improve the evidence base on the likely use by cetaceans and grey seals of high tidal-energy areas in Wales (WAG 2010b, WAG 2012).

The lack of empirical data to enable evaluation of the ability of animals to avoid collision with operational tidal devices continues to hamper predictions (Sparling *et al.* 2015, Thompson *et al.* 2015). To a certain extent, this reflects the limited deployment of tidal devices to date, but the technical challenge of monitoring animal behaviour and collisions in difficult conditions (e.g. high tidal flow, low visibility) is only now being addressed (Thompson *et al.* 2015b). The SeaGen tidal turbine in Strangford Lough was a key test case in this respect; an active sonar system was operated from it providing real time sub-surface sonar imagery of marine mammals and other large marine animals e.g. basking sharks, within 80m of the SeaGen turbine. Between March and September 2010, the active sonar system recorded 612 targets of which 227 triggered precautionary turbine shutdowns as a result of large animals coming within 50m of the turbine (although on closer inspection 22 shutdowns were believed not to be caused by marine mammals [Royal HaskoningDHV 2010a]). Monitoring indicated that both marine mammals and ‘other’ targets move past the turbine in close proximity; however, due to the requirement for precautionary turbine shutdowns information on how marine mammals interact with the turbine during operation was not collected. More recently, a licence has been secured to allow a short trial of unmitigated operation alongside near-field monitoring of seals but this has not yet been progressed (Thompson *et al.* 2015b).

Since the work by Wilson *et al*. (2007), modelling efforts have continued (e.g. Batty *et al.* 2012, Davies & Thompson 2011). These approaches were reviewed and compared by Lonergan & Thompson (2015) in an assessment of risk for seals; broadly similar results were obtained but the authors recognised that the outputs were far more sensitive to assumptions made about animals' ability to avoid collisions than any other factor. They concluded that until data on avoidance rates become available, further refinements of the models of encounter rates may be of limited value. Among the research requirements identified (Thompson *et al.* 2015), the need for empirical evidence to support collision models has been clearly identified.

Collision with the rotor blades of turbines of tidal devices can cause significant injury to fish. Although up to 50% of such collisions do not result in injury (Hammar *et al.* 2015), direct mortality of fish passing through turbines at tidal stream devices can potentially be high (Deng *et al.* 2011), and may be affected by the turbidity of the water, the design of the turbine, and the noise produced by the device. Hearing-sensitive fish, such as herring, may be able to detect and avoid tidal devices at distances of up to 300m; however for less acoustically sensitive species, wave and tidal devices are not likely to generate sufficient noise to trigger a response (ABPmer 2010). A modelling study conducted by Hammar *et al.* (2015) suggests that larger bodied fish are more at risk than smaller ones, particularly when encountering larger turbines, which may not be as easy for a fish to navigate an avoidance path around. Collision risk of wave devices is considered low, and unlikely to be any more significant than that of floating buoys or moored vessels (ABPmer 2010). Entrapment of fish within the reservoir of over-topping devices is a possibility, but anecdotal evidence has not identified this as a significant occurrence (ABPmer 2010). Entanglement in the mooring lines and ropes of surface deployed wave devices is a potential source of effects, particularly for large species such as basking shark. The tendency of fish to aggregate around artificial structures may act to increase collision risk (Freeman *et al.* 2013).

5.6.3.6 Effects of offshore lighting

Over a number of years, the potential effects of light on birds have been raised in connection with offshore oil and gas (e.g. Weise *et al.* 2001, Bruinzeel *et al.* 2009, Bruinzeel & van Belle 2010). 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 birds on cloudy nights is enhanced by fog, haze and drizzle (Weise *et al.* 2001). Bruderer *et al.* (1999) noted 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 (Regional Sea 2 and 3) is an important funnel for bird migration with an estimated 1-1.3 million seabirds possibly using the route annually (Stienen *et al.* 2008). Large numbers of species such as great skua and little gull, as well as terns and lesser black-backed gull, use the Strait of Dover to exit the North Sea.

Hüppop *et al.* (2006b) 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, 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 on the altitude of migrating birds and on seasonal and diurnal variability in migrating bird numbers, 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% of the 332 birds examined) had outwardly apparent injuries. Over 50% of the strikes occurred on just two nights 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.

There is little observational data on light effects from offshore wind farm developments, but behavioural responses and mortality of migratory birds have been reported from lighthouses and gas platforms in the southern North Sea (Hope Jones 1980, "Green light paper") and are commonly observed from vessels of all sizes.

There is very little information on the potential ecological impact of lighting on wave and tidal stream devices. Some installations are totally submerged while others may only protrude slightly above the sea surface. Lighting patterns will be based on IALA Recommendation 0-139 on the marking of man-made offshore structures. Navigational lights associated with devices may attract foraging nocturnal birds although any attraction would likely be short-lived if not associated with any foraging benefits for the birds (ABPmer 2009). Given the likely demonstrator scale of development rather than large scale arrays (over the currency of this OESEA), it is unlikely that lighting will have a significant ecological impact.

Lighting over the estuary during construction and operation of a potential Severn tidal range scheme could possibly represent a barrier to the migration and movement of fish in transit through and residing within the estuary (DECC 2010g).

5.6.3.7 EMF

A number of marine invertebrates are magneto-sensitive, but evidence of interactions with anthropogenic sources of magnetic fields is limited and often contradictory. Brown shrimp (*Crangon crangon*) has been recorded as being positively attracted to EMF fields of the magnitude expected around wind farms (ICES 2003) and the spiny lobster *Panulirus argus* has been shown to use a magnetic map for navigation (Boles & Lohmann 2003). Shore crabs (*Carcinus maenas*) were found to be less aggressive in the presence of an AC B field generated to match magnitude of windfarm cabling (Everitt 2008, as referenced in Gill *et al.* 2014). In contrast are the result obtained by Bochert & Zettler (2004) in a long-term study (up to three months) on the effects of exposure to static B fields of 3.7mT on a range of benthic animals; no difference in survival rates between experimental and control populations were found in the crustaceans, *C.crangon*, *Rhithropanopeus harrisii* (alien crab), *Saduria entomon* (isopod) and bivalve *Mytilus edulis* (mussel). Bochert & Zettler (2004) conclude that the static magnetic fields of power cable transmissions do not appear to influence the orientation, movement or physiology of benthic species. More recent evidence noted several significant changes in the behaviour of Dungeness crab (*Metacarcinus magister*) under laboratory conditions when subject to an EMF of similar magnitude to that expected from marine renewable energy installations (Woodruff *et al.* 2013). However, the change of behaviour was only significant when the responses were examined with respect to combined effects of EMF strength and source orientation, water flow direction and other tank effects; and it was noted that further study is warranted to fully understand if there is a direct correlation between EMF and behavioural change.

Controlled experiments have shown that EMFs appear to disrupt the transport of calcium ions in cells, which may be of importance to developing embryos. B fields of 1 100 FT have been found to delay embryonic development in sea urchins and fish (Cameron *et al.* 1985; Cameron *et al.* 1992; Zimmerman *et al.*1990). In addition, it has been found that high frequency AC EMF can cause cell damage to barnacle larvae and interfere with their settlement (Leya *et al.* 1999). However, this is conflicted by anecdotal evidence of benthic invertebrates living directly on top of DC (direct current) electrodes with no apparent effects (Walker 2001).

Many fish species are able to detect electric and magnetic fields (EMF) and it is a matter of concern that anthropogenic sources of EMF, in particular subsea cables, might be detected by and negatively influence sensitive species. Elasmobranchs possess an electrosensory system called the Ampullae of Lorenzini, an array of receptors that allow them to detect the weak electric fields produced by prey items of around 0.5μV/m (Gill *et al.* 2005). Consequently, they are most frequently linked with potential EMF effects. 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. Anthropogenic EMF may also affect elasmobranchs during seasonal migrations and reproductive behaviour, and the effect on juvenile sharks and rays in coastal areas is unknown and untested.

Available data assessing elasmobranch responses to subsea cable EMFs is limited. The first and only documented example of a marine fish responding to an emission from a subsea cable comes from evidence of shark bites on optical telecommunication cables (Marra 1989). Gill *et al.* (2009) showed that some species of elasmobranchs are affected by EMFs from undersea cables, with the behaviour of a number of species affected. The authors indicate that that the effect is only likely to be observed within a very small distance around the cable and it is unclear whether the effect is positive, negative or neutral.

Some teleost fish have been demonstrated to be EMF sensitive. Species present in UK waters include the plaice and the diadromous species European eel, Atlantic salmon, sea trout and river and sea lamprey (SNH 2010a). Migratory eels and salmonids are able to use the earth's magnetic field for orientation during migrations (Durif *et al.* 2013) and magnetic field detection has been demonstrated in a range of fish species, notably by Formicki *et al.* (2004), who found a number of species to be more attracted to nets on which a magnet was mounted than nets with no magnet. While there is a range of evidence to support the EMF detection abilities of these fish, and little doubt that highly mobile, migratory species will encounter anthropogenic EMF sources, evidence is limited as to whether such EMFs are likely to provoke a behavioural response (Öhman *et al.* 2007, SNH 2010a). Gill *et al.* (2012) reviewed the response of diadromous fish to EMF, particularly relating to marine renewable energy devices and found that more research is required to understand the consequences of fish responses. 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 interaction between anthropogenic EMF and marine mammals is not well understood. Understanding of how marine mammals experience and use either natural magnetic or electric fields is poor, but knowledge relating to anthropogenic sources is even less (Gill *et al.* 2014). Studies of deterrents to seal predation on salmon fisheries have identified strong responses to electric fields in certain pinniped species (PSC 2009, Burger 2010). In 2007, the Pacific Salmon Commission (PSC), and collaborators, conducted a series of tests to assess how Pacific harbour seals (*Phoca vitulina richardsi*) respond to very low electric fields and determine whether this technology could be used to deter seal predation on salmonids. Results from tests on captive and wild animals in aquarium and river environments respectively indicated that seals avoided an electrified zone of voltage gradient <0.32V/cm at surface with a maximum pulse width of 1 millisecond (ms) and frequency of 2.25Hz (Cave *et al.* 2008, cited in PSC 2009).

PSC (2009) report an extension of these experiments, with three different configurations (arrays) of electrodes tested across the width of the lower reaches of a river known to be a preferred foraging area for seals. Arrays included 3 and 4 cable configurations running perpendicular to the bank and an array of 17 elements oriented parallel to the bank spanning the width of the river. For each configuration, tests commenced at the lowest pulse width setting (1ms) and ramped up by 1ms increments to a maximum of 5ms (17 element array only). At the lower pulse width settings (1-2ms), seals that successfully passed through the array were not harmed or exposed to excessive stress. At pulse width settings in the mid-range (3ms), seals displayed more distinctive behavioural responses (avoidance of short-term discomfort or pain) while at the highest pulse width settings (4-5ms) seals exhibited more physiological responses (involuntary muscle contractions). In further field studies, seals were deterred from foraging in a test fishing gill net in a river habitat by using a pulsed, low-voltage DC electric gradient (Forrest *et al.* 2009a). These levels did not seem to affect the behaviour of salmonid fish, and catch rates of salmon were shown to be higher at nets protected by an electric field.

Burger (2010) report results from experiments on the responses of captive Californian sea lions (*Zalophus californianus*) to electric fields, with a view to wider applications as deterrents to predation in salmonid fisheries. A pulsed DC electric field was generated within a freshwater test pool (conductivity of 509µS/cm). Sea lions were able to detect an electric gradient introduced at a frequency of 2Hz at pulse widths that ranged from 0.08-0.29ms. Strong deterrence reactions without and with food present were exhibited at pulse widths from 0.08-0.32ms and 0.16-0.44ms respectively, both with a voltage gradient of 0.6V/cm.

WAG (2010a) review the studies on harbour seals in relation to potential effects from buried cables associated with marine renewable energy devices. Estimates of the electrical fields that will be generated in seawater from buried power cables bringing power ashore from marine renewable devices are orders of magnitude lower than those shown to induce responses in seals; therefore, it appears that there is no basis for expecting such strong exclusion effects demonstrated in those studies. Furthermore, consideration must be given to the differences in the environments where exclusion responses were observed and the marine environment relevant to this assessment. PSC (2009) noted that the impact of the electric field on seal behaviour deteriorated as river depth increased due to a weakening in the electric field strength at the water surface over the array, with seals often observed passing through the array during high tides. Despite this, certain caveats should be considered. Firstly, the seal exclusion trials used short pulse length electrical fields, and it was shown that seal sensitivity increased as pulses lengthened; seals might therefore be more sensitive to a continuous electrical field. Secondly, seal sensitivity and responsiveness to lower level electrical fields have not been studied and there may be effects at levels below those tested. It is not known why seals are apparently so sensitive to these electrical fields, whether they have specially adapted electrically sensitive organs, or if this is of any biological significance to them. WAG (2010) suggests the risk that electrical fields from power cables could affect seal behaviour must remain as a precautionary concern, and recommend that the issue should be more fully explored. The authors noted that they are unaware of any attempts to test for sensitivity to electrical fields in cetaceans.

The potential for EMF effects associated with wave and tidal stream devices are likely to be similar to OWF given the requirement for inter-field and export cabling. However, given the likely demonstrator scale of these activities, the magnitude of cabling and resultant potential EMF effects are likely to be reduced compared to OWFs. 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.

Further research is required to investigate the potential significance (if any) of artificial electric and magnetic fields for marine organisms. Currently, consideration of EMF during EIA process for marine renewable energy devices and their cable infrastructure consists of literature review and desk study but any modelling and assessment is hampered by the limited understanding of the biological response (Gill *et al.* 2014). Monitoring programs post-installation are often limited in scope and rely on the broad scale distribution of EM-sensitive species such as elasmobranches as evidence. This approach is limited as it often involves trawl surveys pre-operation and during operation of the renewable energy device, the trawls are unable to sample in close proximity to the device or directly over cables (due to collision or snag risk) (Gill *et al.* 2014). The 2010 SNH commissioned report (SNH 2010a) suggests that the precautionary approach regarding EMF could be restrictive to marine renewable energy developments, and offers that a more adaptive approach would be more suitable. Boehlert & Gill (2010) indicate that a before-and-after baseline assessment of EMFs associated with cable networks is needed. It is widely acknowledged that there needs to be greater research effort to determine the detectability by potential receptors of a range of fields emitted and to achieve a better understanding of the response and potential biological significance of detection.

5.6.4 Controls and mitigation

To reduce the risk of introduction and spread of non-native species posed by international shipping, controls are in place to minimise transmission via exchange of ballast water and hull-fouling. The International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM) was adopted by the UK in 2004; it has been ratified by 30 States, representing 35 per cent of world merchant shipping tonnage. It aims to prevent the spread of harmful aquatic organisms from one region to another, by establishing standards and procedures for the management and control of ships' ballast water and sediments. Under the Convention, all ships in international traffic are required to manage their ballast water and sediments to a certain standard, according to a ship-specific ballast water management plan. Eventually most ships will need to install an on-board ballast water treatment system.

The risk of introduction and spread of non-native species is also managed by the use of anti-foulant coatings on ships and energy devices. As with ballast water, anti-foulants are an international concern and are managed to prevent unwanted ecosystem effects. The International Convention on the Control of Harmful Anti-fouling Systems on Ships was adopted by the UK in 2001; it prohibits the use of harmful organotin compounds in anti-fouling paints used on ships and provides a mechanism to prevent the potential future use of other harmful substances in anti-fouling systems. The Convention entered into force on 17 September 2008. The convention was followed up by EC Regulation 782/2003 on the Prohibition of Organotin Compounds on Ships and transposed into UK law by The Merchant Shipping (Anti-Fouling Systems) Regulations 2009. Marine energy devices are not subject to this legislation, however the selection of anti-foulant systems is an important component of development environmental statements and should be aligned with country agency policy e.g. SNH.

To minimise or ideally avoid collision risk between birds and infrastructure associated with the implementation of the draft plan, a range of mitigation measures can be implemented, primarily at the project level. A description of these is provided in general terms, but in practice mitigation measures need to be adopted according to the site characteristics of each marine renewable energy development, since a measure that may reduce the risk for one species, may increase the risk for another. Considerations must include the diversity, abundance, and distribution of all species that occur in (and transit through) that area;

It is generally acknowledged that one of the most effective ways to reduce potential impacts on birds is to avoid siting offshore wind farms in areas of high bird abundance, or in areas particularly sensitive to life cycle requirements such as breeding areas, feeding areas and on migration routes. Strategic planning for siting offshore wind farms should be based on detailed sensitivity mapping of bird populations, habitats and flight paths. However, this should not replace other impact assessment requirements and local, site specific assessments remain essential for assessing risk of impact.

Various other forms of mitigating actions are available. Temporal activity planning may be effective; for example at night, when birds are more vulnerable to collisions, activities such as installation and maintenance could be avoided. Turbine shutdown on demand should be considered, i.e. where turbines are shut down/slowed down at times of high bird collision risk or when birds are detected within a safety perimeter (this requires real-time surveillance). Other mitigation includes increasing device visibility and the use of acoustic or laser deterrents. Although effective in the short term, the long-term use of auditory deterrents has proven to be ineffective due to habituation by birds to certain stimuli; laser deterrents may be a useful tool during night-time. Deterrents which can be activated by real-time surveillance systems are also useful, although they may have unpredictable effects on a bird’s flight path and would have to be activated at sufficient distance for an effective avoidance. For tidal turbines, shiny blades should be avoided, as diving birds mistake these for fish and the use of protective netting or grids may be effective.

With respect to avoidance and barrier effects of wind farms, turbine layout design is important and consideration should be given to minimising the total farm area by siting turbines close together; to grouping turbines so that there is no alignment perpendicular to main flight paths; and to providing corridors (up to a few km wide) between groups of turbines to allow passage by birds.

Enforcing vessel speed limits and establishing a code of conduct for vessels operating in areas of high seabird abundance or high sensitivity may mitigate against disturbance induced displacement of birds.

In 2015, the OSPAR Commission published guidelines (applicable to both existing and new offshore installations) aimed at reducing the impact of offshore installations lighting on birds in the OSPAR maritime area (OSPAR 2015d).

Potential mitigation measures to reduce the probability and severity of the effects posed by wave and tidal stream devices to marine mammals (collisions, avoidance, barrier to movement) have been outlined by Wilson *et al.* (2007) and WAG (2010a). A careful choice of location is currently the best available tool to help avoid or minimise the collision risk that has been identified between marine mammals and tidal stream devices; however, in most cases this requires targeted efforts to improve the evidence base of marine mammal use of any proposed development area at the appropriate spatial and temporal scale. The importance of ensuring marine mammal surveys are fit for purpose has been highlighted within guidance to inform marine mammal site characterisation requirements at Welsh wave and tidal stream energy sites

(Sparling *et al.* 2015). In addition to site identification, the selection of turbine design, turbine spacing and the size of array are important considerations (WAG 2010a).

Acoustic warning devices that alert marine mammals to the presence of tidal stream turbines have been proposed to help mitigate a collision issue should one prove to exist (Wilson & Carter 2013). However, given the high ambient noise in tidal streams, any sound emitted by the acoustic devices would need to be loud, raising concern that the acoustic devices themselves may cause extensive habitat exclusion and disturbance. This issue may be side-stepped if a method of ‘detect and deter’ was developed, instead of installing permanent acoustic alarms (Thompson *et al.* 2015b).

For fish and fish communities, the design and placement of rotors are key elements in minimising collision risk and potential behavioural disturbance. Avoidance of known spawning or nursery sites and migration routes of diadromous fish will limit impact at vulnerable life stages. Likewise, reducing the activity of devices at times of annual migration or spawning periods will limit impact. Unfortunately there is still a knowledge gap concerning detailed corridors of movement and likely depth preferences of a number of diadromous fish species and these may also vary between estuaries and between life-stage (Freeman *et al.* 2013).

Mortality of fish as a result of rotor blade strikes appears to be minimised at turbine speeds of 25-30rpm (Pelc & Fujita 2002) and adopting simple measures such as blunted blade edges is effective in reducing the incidence of laceration injury in the event of rotor strike (Hammar *et al.* 2015). Smaller turbines pose a smaller risk of collision than larger turbines, as the avoidance response required for escape is much less severe (Hammar *et al.* 2015). It is likely that larger fish are at greater risk from turbines strikes than smaller fish, with large, slow-moving elasmobranchs perhaps the most likely to incur injury.

The use of strong colours, high contrast patterns on moving parts, lighting at night, acoustic fish deterrents and bubble curtains around devices have all been proposed as methods to reduce risk (ABPmer 2010). Strobe and fluorescent lighting have been used as fish deterrents at power station cooling water extraction plants (McIninch & Hocutt 1987, van Anholt *et al.* 1999); and variable sound signals (with frequencies of 20-600Hz), close to the mouths of intake pipes have also been successfully used (Maes *et al.* 2004). A high level of deterrence of clupeid fish (*i.e.* herring, sprat) was achieved, with numbers of herring reduced by 95% and sprat by 88%. Deterrence was variable, however, and related to species type and hearing ability.

With respect to EMF, accepted mitigation measures include burying cables to a depth of 1-3m. This successfully isolates marine organisms from the very highest electric and magnetic fields but is ineffective in insulating the B field (and resultant iE field) (Gill *et al.* 2005). An industry standard AC cable, buried to a depth of 1m is predicted to create an induced electric field of 91µV/m at the seabed; this is within the boundary of emissions expected to attract and/or repel elasmobranchs (CMACS 2003).

5.6.5 Likelihood of significant effects

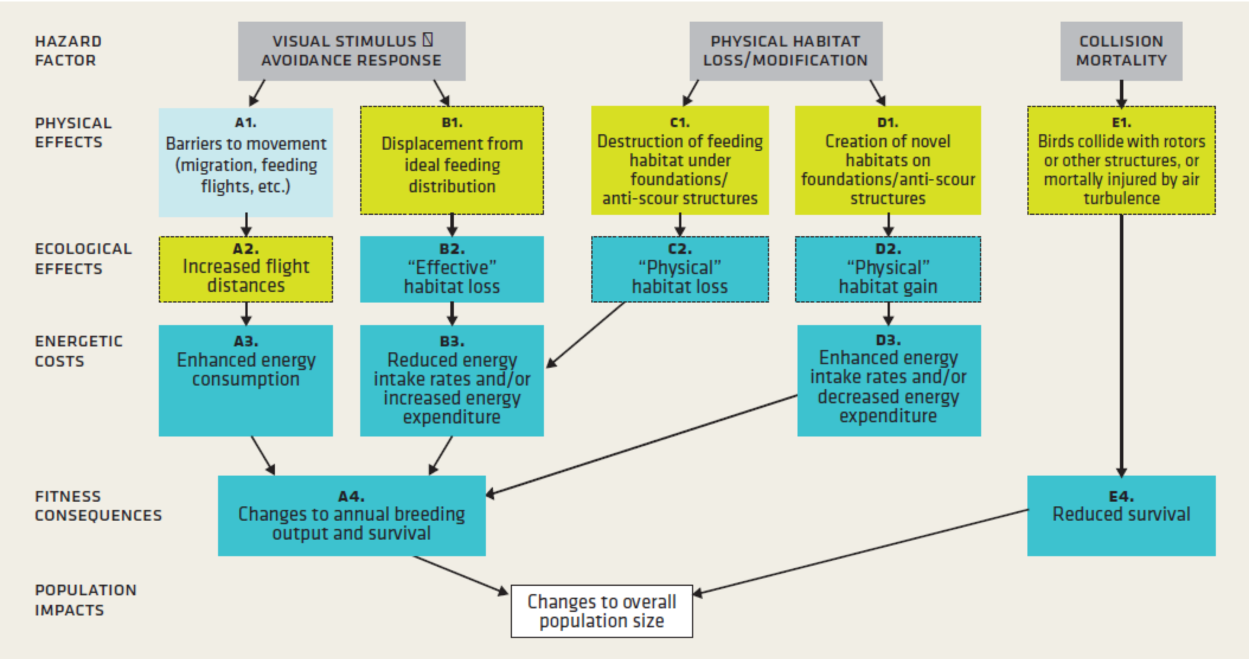
The following section considers the likelihood of significant effects, and potential for mitigation for each receptor and combines these across the different elements of the plan/programme.

Non-native benthic species have been recorded from offshore wind farms, primarily in the southern North Sea; however widespread species success and geographical population spread are not apparent. Since natural ‘islands’ are widespread and numerous in continental shelf areas, it is considered very unlikely that any of the offshore energy technologies or developments will result in any significant effect on benthic species.

For mobile species, potential effects of interactions with the infrastructure and support activities associated with the draft plan/programme, have been discussed under the headings of collision, displacement and barrier effects. However, these do not represent simple causative relationships. Their assessment is often complicated by subtle and unpredictable interactions between a number of processes: functional ecological processes (for example between behavioural modification and energetic cost); feedback processes (for example mortality resulting from wind farm collisions may reduce competition for resources, thus reducing the rate of natural mortality Maclean *et al.* (2007)); the importance of stochastic events, particularly to small populations (Maclean *et al.* 2007); habituation; and the presumed functioning of processes which are difficult or impossible to measure (as noted by Drewitt & Langston (2006), for example habitat loss causing a reduction in bird numbers in the area, which may then reduce the risk of collision).

This complexity is illustrated diagrammatically by what is known as "the Danish model[72]" (Figure 5.28). Although devised for birds, the principles are equally valid for other receptors/infrastructure interactions. The model describes the three major hazard factors of offshore wind farms to birds (visual stimulus & avoidance response, physical habitat loss or modification and collision mortality) and the various levels of effect; physical and ecological effects, energetic costs, fitness consequences, and the ultimate impacts at the population level. It distinguishes between measurable effects and processes that need to be modelled. There is a considerable range in the quantity and quality (confidence) of information relating to these various issues. Some (e.g. displacement and collision risks for birds) are the subject of considerable research effort; others (fouling) have been extensively monitored over a substantial time period; and some (link to vital rates) are relatively speculative.

Figure 5.28:"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)

[72] First published in a joint publication by Dong Energy, Vattenfall, The Danish Energy Authority and The Danish Forest and Nature Agency (Dong Energy *et al.* 2006) to described the offshore wind power in the Danish sector and the challenges faced at large scale developments.

Of the receptors reviewed, greater potential effects have been identified for birds which are therefore the focus of much of this section. First however, key points relevant to all other receptors are given:

For marine mammals, tidal stream devices have been identified as the element of greatest concern with respect to both collision risk and barrier effects but a lack of empirical evidence hampers efforts to evaluate the real magnitude of any potential effect. Collision risk is most strongly associated with rotating turbines but the behaviour of animals in response to these devices is largely unknown so that only 'encounter' risk can be reliably modelled to inform assessment. Given that suitable areas for exploitation of tidal stream resource are to a certain extent constrained to tidal straits and channels, the potential for barrier effects cannot be excluded.

Multiple factors likely to influence collision and behavioural effects have been reviewed; these are related to the specific characteristics of each species, device and locality. Therefore, modelling predictions and comprehensive risk assessments are best carried out for each deployment at the appropriate spatial scale and with specific knowledge of device characteristics. At the strategic level, the limited scale of development resulting from implementation of the plan allows the conclusion that any effect is unlikely to be significant at the population level.

The most likely sources of significant effect on fish are tidal energy devices. Collision and barrier effects risks apply particularly to migratory, diadromous species which are present in estuaries and river mouths at sensitive and critical stages of their life-cycles. Exact migratory routes will vary between species and possibly within species and so assessment at a local scale, using specific knowledge of the area of the proposed development and the devices to be installed, is required for more comprehensive risk assessments. Habitat change arising from the placement of tidal energy devices may also have significant effects on spawning or nursery aggregations of fish, particularly at sensitive habitats such as estuaries and bays. Such aggregations of fish are often associated with particular habitat conditions and will therefore be vulnerable to a change in environment.

The potential 'reef effect' introduced by underwater structures may result in variations in foraging opportunities for fish, birds, seals and cetaceans at the local scale but its wider ecological significance is unclear.

Several marine taxa have been identified as sensitive to electromagnetism but further research is required to explore the potential effects of EMF associated with offshore energy developments. Current evidence suggests that individual local effects may not be of a magnitude sufficient to warrant concerns at population or ecosystem level; it is however recognised that this assessment has low confidence due to limited evidence.

In terms of mitigation measures, the initial choice of location for device installation has been highlighted as the most critical factor for all receptors. A precautionary approach to facility siting in areas known to be of key species/habitat importance is therefore recommended unless evidence indicates otherwise.

For marine birds, the evidence has shown that the risks of collision and displacement effects are strongly associated with offshore wind farm developments. Much of the evidence reviewed focuses on the response of individual birds; however, to identify significant effects consequences must be assessed at the population level.

To quantify the potential magnitude of disturbance Maclean *et al.* (2009) recommend determining peak densities within the wind farm footprint (and buffer area) and then assuming the worse-case scenario, that all birds within are displaced. The magnitude of the impact can then be determined by quantifying the proportion of the regional, national or international populations hosted by the wind farm footprint and buffer zone (a 4km buffer zone was suggested).

On behalf of the Marine Renewables Ornithology Group (MROG), a two day workshop was convened by JNCC (JNCC 2015) to assess displacement impacts to seabirds from offshore wind farms and to identify and agree on key components and best practice for Displacement Assessment Framework (DAF). Overall they found that consistent empirical evidence for displacement from offshore wind farms remained relatively limited; likely due to both the inherent complexities of species distribution data (which has strong temporal and spatial variation) and to the fact that wind farm projects are not identical in scale, density or physical location. However, patterns did emerge from sites where results were available:

- Species that were largely displaced = mainly divers, scoters, fulmar, gannet, little gull, guillemot and razorbill
- Species that were consistently attracted = cormorant
- Species that were attracted or neutral = common, herring and great black-backed gulls
- Species with conflicting evidence = kittiwake, lesser back-backed gull

The outcome from the MROG workshop (in common with a number of other publication) was that at present there is a paucity of information on seabirds at sea to inform assessments as well as difficulties in both detecting a change in abundance (due to variability in baseline data) and in quantifying the consequences of displacement and/or barrier effects on mortality and/or productivity (JNCC 2015a). For any future DAF to be effective, they point out the need for common analytical approaches, better/more empirical evidence and clearer guidance; and they recommend that displacement/abundance data from individual projects should be comparable, with clear records of methods used and decisions made and that outcomes from assessments should be made readily available.

Among the many factors that may influence risk, several of them are species-specific; the large number of bird species (migrating and resident) that may encounter wind farms in UK waters introduces a considerable challenge to the assessment of risk. In this respect, this SEA recognises the contribution made by Furness *et al.* (2013) and by Bradbury *et al.* (2014) in producing species specific vulnerability scores. Bradbury *et al.* (2014) followed the methods of Furness *et al.* (2013) and others amending these to relevance in English territorial waters and updating with new data where this was available. Table 5.19 provides the population risk due to collision and displacement, by species, as calculated by Bradbury *et al.* (2014). The results tend to confirm the observation that collisions are more likely to occur if seabirds fail to avoid wind farms, whereas displacement is a function of avoidance (Furness *et al.* 2013). For example, herring gulls are most vulnerable to collision and score as ‘very low’ for displacement.

Table 5.19: Overall scores for marine bird species' population risk due to collision (left hand side of table) and displacement (right hand side of table) by offshore wind farms

Species	Vulnerability score to collision risk	Classification of risk	Species	Vulnerability score to displacement	Classification of risk
Herring gull	1470	Very High	Red-throated diver	32	High
Great black-backed gull	1143	Very High	Black-throated diver	30	High
Lesser black-backed gull	960	Very High	Commons scoter	24	High
Iceland gull	817	High	Great northern diver	22	High
Glaucous gull	817	High	Goldeneye	18	Moderate
Common gull	750	High	Scaup	16	Moderate
Mediterranean gull	542	High	Velvet scoter	16	Moderate
Gannet	512	High	Slavonian grebe	16	Moderate
Kittiwake	420	High	Eider	14	Moderate
Black-headed gull	400	Moderate	Goosander	14	Moderate
Sandwich tern	397	Moderate	White-billed diver	14	Moderate
Little gull	390	Moderate	Little tern	13	Moderate
Little tern	373	Moderate	Guillemot	13	Moderate
Arctic skua	327	Moderate	Razorbill	13	Moderate
Common tern	327	Moderate	Cormorant	12	Moderate
Great skua	320	Moderate	Shag	12	Moderate
Roseate tern	299	Moderate	Black guillemot	12	Moderate
Black tern	260	Moderate	Red-breasted merganser	10	Moderate
Black-throated diver	225	Moderate	Sandwich tern	10	Moderate
Red-throated diver	213	Moderate	Roseate tern	10	Moderate
Shag	208	Moderate	Long-tailed duck	8	Low
Great northern diver	200	Moderate	Great-crested grebe	8	Low
Red-necked phalarope	200	Moderate	Black tern	8	Low
Sabine's gull	200	Moderate	Common tern	8	Low
Cormorant	187	Low	Arctic tern	8	Low
Pomarine skua	187	Low	Puffin	8	Low
Long-tailed skua	163	Low	Black-headed gull	6	Low
Arctic tern	163	Low	Common gull	6	Low
Goldeneye	147	Low	Great black-backed gull	6	Low
Goosander	120	Low	Mediterranean gull	5	Very Low
Scaup	110	Low	Kittiwake	5	Very Low
Red-breasted merganser	107	Low	Sabine's gull	4	Very Low
Common scoter	96	Low	Little gull	4	Very Low
White-billed diver	93	Low	Herring gull	4	Very Low
Velvet scoter	88	Low	Little auk	4	Very Low
Storm petrel	75	Low	Gannet	3	Very Low
Leach's storm petrel	75	Low	Arctic skua	3	Very Low

Species	Vulnerability score to collision risk	Classification of risk	Species	Vulnerability score to displacement	Classification of risk
Eider	72	Low	Great skua	3	Very Low
Slavonian grebe	69	Low	Lesser black-backed gull	3	Very Low
Grey phalarope	67	Low	Balearic shearwater	2	Very Low
Great crested grebe	42	Very Low	Red-necked phalarope	2	Very Low
Fulmar	39	Very Low	Pomarine skua	2	Very Low
Guillemot	33	Very Low	Iceland gull	2	Very Low
Razorbill	14	Very Low	Glaucous gull	2	Very Low
Puffin	12	Very Low	Fulmar	1	Very Low
Black guillemot	10	Very Low	Cory's shearwater	1	Very Low
Little auk	8	Very Low	Great shearwater	1	Very Low
Long-tailed duck	0	Very Low	Sooty shearwater	1	Very Low
Cory's shearwater	0	Very Low	Manx shearwater	1	Very Low
Great shearwater	0	Very Low	Wilson's storm-petrel	1	Very Low
Sooty shearwater	0	Very Low	Storm petrel	1	Very Low
Manx shearwater	0	Very Low	Leach's storm-petrel	1	Very Low
Balearic shearwater	0	Very Low	Grey phalarope	1	Very Low
Wilson's storm petrel	0	Very Low	Long-tailed skua	1	Very Low

Source: Bradbury et al. (2014).

CRM are an essential tool to risk assessment but their interpretation may not be straightforward. Masden & Cook (2016) reviewed a range of avian collision risk models (not all related to offshore wind farms) to: raise an awareness of models available; highlight their strengths and weaknesses; qualitatively compare models and provide suggestions where future efforts should be focused to advance collision risk modelling. They identified ten distinct CRMs referring to birds and wind turbines, the earliest of which dated back to 1996 and concluded that while CRMs are useful tools in estimating collision risk and provide information on potential environmental impacts of wind farm developments, they have limitations, something that is not always recognised when interpreting their data outputs. Potentially the greatest limitation of CRMs is the uncertainty surrounding avoidance behaviour and the tendency to rely on assumptions to quantify bird behaviour; most models, while taking into account avoidance behaviour for example, assume a single value across all individuals within a species while a range would be more appropriate. The difficulties in improving on this are acknowledged (e.g. Cook *et al.* 2014). Further limitations of CRMs are they are "data hungry", and they are generally used in situations where data availability is limited, and there is often little opportunity for model validation (Masden & Cook 2016).

Despite this concern and the construction of a number of offshore wind farm developments, the evidence base for quantifying the rate and scale of displacement, barrier effects, and collision risk (in terms of bird fatalities) impacts of offshore wind farms on birds, or providing species specific data on factors influencing these potential impacts (including flight heights and avoidance rates) is sparse, which makes it very challenging to understand the wider implications of these effects at the population level (e.g. Masden & Cook 2016, Cook *et al.* 2014, Furness & Wanless 2014, WWT Consulting 2015, IMARES 2015, JNCC 2015).

Lack of empirical evidence is an even greater problem with wave and tidal stream devices; adaptive management should ensure that this situation will be improved prior to the deployment of full scale arrays. Tidal devices will only be sited at very specific locations, as determined by the available tidal resource (See Section 5.15). Therefore, the range of diving species potentially at risk from any particular development will also be limited by proximity of the development to seabird breeding colonies, as well as species specific diving ability in relation to tidal flow rates. Overall, wave devices seem to represent a lesser hazard to seabirds than tidal turbines and both are considered a much lower hazard than offshore wind farms.

Bird species at most risk from tidal range schemes are likely to be waterbirds which rely on intertidal habitats for feeding which may be significantly impacted by such schemes. Those SPAs and associated waterbird species potentially vulnerable to tidal range schemes in England and Wales will include: The Wash SPA; Thames Estuary and Marshes SPA; Foulness (Mid-Essex Coast Phase 5) SPA; Humber Estuary SPA; Duddon Estuary SPA; Morecambe Bay SPA; Mersey Estuary SPA; Bae Caerfyrddin/Carmarthen Bay SPA (see Section A1a.7)

The overall potential impacts to marine birds from offshore oil and gas, gas storage and carbon dioxide storage are considered negligible given the range of controls and mitigation measures in place. These include assessments required at project specific level, mitigation of impacts required for exploration and appraisal activities and the installation of new developments, with operational control of chemical use and discharge, flaring and venting, oil spill mitigation and responses, and guidelines associated with lighting.

The spatial distribution of potential effect is related strongly to the distribution and relative sensitivities of individual bird species. The offshore wind and marine renewable industry remains relatively young, with appreciable technological development expected in for example, turbine size, rotation speed, foundation structure, spacing and potentially rotational axis. A firm base of information is required to inform risk assessments and adaptive management.

Although there is a lack of empirical data, there is a general consensus from various studies that those species at highest risk of collision with wind turbines are gulls (e.g. herring, lesser black-backed, greater black-backed) gannet and kittiwake – with this risk potentially leading to measurable effects on breeding populations, if colonies for these species lie close to offshore wind farms (e.g. Furness & Wanless 2015).

Combining the assessment of spatial distribution of “priority” species with that of sensitivity e.g. Bradbury *et al.* (2014), Furness *et al.* (2013) and Langston (2010) and areas of potential resources for future development, this would indicate that:

- In Regional Sea 1, fulmar, kittiwake and storm petrel are of relatively low sensitivity; auks, gannet, gulls, Manx shearwater, terns and migratory waterbirds are of moderate sensitivity
- In Regional Sea 2, the most sensitive species are divers and gannets (mainly distributed along the Flamborough front); and, to a lesser extent, auks in the outer Thames and along the East Anglian coast; sandwich tern in the Greater Wash, and migrating waterbirds.
- In Regional Sea 3, terns in particular sandwich tern are the highest sensitivities with migratory waterbirds, gull species and Balearic shearwater of moderate sensitivity.
- In Regional Sea 4, gannet, lesser black-backed and herring gull, shearwaters and auks are all of moderate sensitivity. Storm petrel are of relatively low sensitivity.

- In Regional Sea 6, cormorants are of high sensitivity with terns, auks and Manx shearwater of moderate sensitivity. In Liverpool Bay, red-throated diver and cormorant are of high sensitivity with common scoter, auks, gulls and waterbirds, including swans and geese of moderate sensitivity.

The potential for birds to be impacted cumulatively through displacement, barrier effect and collision, in relation primarily to OWF, has received attention in recent years; methods for assessing such potential effects have been the subject of a number of studies and workshops, and continue to be developed, e.g. NRC (2007), Hüppop *et al.* (2006b), Maclean *et al.* (2007), Maclean & Rehfisch (2008), Norman *et al.* (2007) and King *et al.* (2009).

The Danish Energy Agency (2013) investigated using a model based approach to assess the cumulative effects on bird populations by evaluating the extent to which displacement from an area (in this case the Horns Rev wind farm area) could potentially impact red-throated diver at a population or sub-population level,. The study was performed on three scenarios of offshore wind farm developments: one reflecting the existing status and two future scenarios with medium or high development rate.

The endpoint information used for the scenarios was the total number of birds in the population after 10 simulation years; bird death was set as a result of displacement (a bird having a negative energy balance) while collision with wind turbines was not considered. Primary results of the three scenarios showed a detectable but very small impact of the wind farm scenarios on the number of extant birds; even scenario 3 where 15,000km^2 were classified as wind farms, resulted in less than 2% change in the population levels (see The Danish Energy Agency 2013 for full details). Limitations of the model acknowledged by the authors included the limited knowledge on the biology of the red-throated divers in this flyway population, the uncertainties in population size estimates, the limited relevance of density estimates (from Danish waters only) and the simple assumptions regarding habitat quality. This study and the caveats in the modelling used, indicates the challenges faced when trying to assess cumulative impacts.

In 2007, at a COWRIE workshop on the cumulative impact of OWFs on birds it was agreed that population viability analysis (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 were concerns over the information dependency and the assumptions inherent in population modelling, further development of PVA for a range of key sensitive bird species (red throated diver, common scoter, gannet, lesser black-backed gull and common tern) was supported. A DECC-funded PVA study on the pink-footed goose population potentially affected by wind farms off the East Anglian coast and eastern Irish Sea (WWT Consulting 2008b) 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%; if 10,000 birds are killed each year however, the risk of significant population decline increased 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 Assessments (CIA = Cumulatives Effects Assessment) 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 and, guidance on ornithological CIA for offshore wind farm developers was produced by COWRIE in 2009: *Developing Guidance on Ornithological Cumulative Impact Assessment for Offshore Wind Farm Developers*– see King *et al.* (2009) and OESEA2 for a SEA contextual summary of this.

King *et al.* (2009) noted that CIA was particularly relevant in relation to Round 3 given that the nine development zones could contain multiple projects each comprising hundreds of turbines. By identifying the unresolved cumulative impacts on birds as a key issue, the Crown Estate promoted their early identification as a way of expediting the consenting process in relation to Round 3, with zonal appraisal and planning for this Round (a non-statutory strategic planning process) enabling a more strategic approach to the identification and assessment of cumulative impacts compared to previous rounds of development. King *et al.* (2009) made a number of recommendations on the methods and techniques which could be applied to CIA of offshore wind farms (based on Maclean & Rehfisch (2008)) including:

- Selection of species for consideration
    - Production of a list of species potentially at risk of cumulative impacts in Round 3
- Selection of projects for consideration
    - Projects that have been consented but which are yet to be constructed
    - Projects for which application has been made
    - Projects that are reasonably foreseeable
    - Non-wind farm projects subject to EIA
    - Existing projects which have yet to exert a predicted effect (i.e. an effect that is not covered in the baseline)
- Consideration of relevant population and reference area
    - The default boundary of the CIA study area for defining regional populations should be considered as the relevant Round 2 strategic area, Round 3 zone or equivalent, unless there is reliable evidence to support the definition of an alternative discrete biogeographic region e.g. area incorporating onshore breeding colony, Regional Sea etc.
    - Depending on the reference population(s) identified, impacts may need to be considered at different population scales at different times of year

For collision risks and displacement, the effects should be assessed by summing the impacts from each component project and in some cases, further population modelling may be required. Disturbance and barrier-effects accrue in a non-linear manner and these should, therefore, firstly be considered in a qualitative manner making best-use of available information. Significance of a cumulative impact on a species should include a consideration of its life history parameters. Alternately, consideration should be given to life history parameters and habitat/resource use flexibility when defining a species' sensitivity with long lived species and specialists considered more sensitive (King *et al.* 2009).

Latterly, publications in this area have included the *Cumulative Impact Assessment Guidelines: guiding principles for cumulative impacts assessment in offshore wind farms*, published in 2013 by RenewableUK, where they highlight the challenge of assessing cumulative impacts, for example due to the uncertainty of project-level impacts, including bird collisions and displacements, which are compounded by a number of projects potentially contributing to the same impact. The aim of the document was to provide a framework of guiding principles that develops a consistency of approach in areas prone to uncertainty in a cumulative assessment, rather than providing guidance as setting an expectation of standards; the focus of the principles is on producing meaningful assessments (RenewableUK 2013).

The Natural England Commissioned Report "*Development of a generic framework for informing Cumulative Impact Assessments (CIA) related to Marine protected Areas through evaluation of best practise"* was published in 2014; this provides a detailed review and evaluation of methods for conducting CIA both within and beyond the marine environment and building on this, it develops a generic CIA framework and provides clear guidance on the approach which could be adopted for robust and comprehensive CIAs for all projects affecting marine protected areas (MPAs).

In 2015, the *Framework for Assessing Ecological and Cumulative Effects (FAECE)* was drawn up to determine how to deal with the cumulative ecological effects of the development of offshore wind farms in the southern North Sea (Rijkswaterstaat 2015b). The document describes a six step process for assessing cumulative effects of a proposed activity:

- Step 1 – Identification of pressures from activities to be assessed (e.g. disturbance by light, sound, habitat loss)
- Step 2 – Identification of sensitive species and habitats (e.g. those species that could be affected by the pressure from activities under consideration – certain bird species are more susceptible to colliding with rotor blades of turbines)
- Step 3 – Inventory of other relevant activities with effects (all other relevant activities in or in the vicinity of the plan are identified – for highly mobile animals (birds) the area within which relevant effects could occur are large – only those activities that lead to cumulative effects should be considered)
- Step 4 – Determination of the cumulative effects of all activities (two models are available for quantifying collision mortality in this framework: the Bradbury model (Bradbury et al. 2014) and the Band model (Band 2012)
- Step 5 – Assessment of cumulative effects (the preferred standard for assessing cumulative mortality for birds is the potential biological removal (PBR) – this being the measure of the maximum number of individuals of a species that may be removed from the population, in addition to natural mortality and emigration, without the population undergoing a structural decline. As long as the PBR is not exceeded, there will be no significant effects73.
- Step 6 – Reduction of cumulative effects (if adverse effects cannot be ruled out, mitigation measures should be taken to reduce the effects on the species)

For birds (i.e. seabirds, coastal breeding birds and migratory birds) the combined, cumulative effects of collisions and displacement, have been modelled for all wind farms considered operational in 2023 in the southern North Sea. The calculations took account of habitat loss resulting from the presence of the wind farms and shipping traffic in combination with bird collisions with wind turbines. Results are presented in Table 5.20.

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[73] The potential unsuitability of using PBR for assessing effects of wind farms (e.g. in that it does not identify sustainable levels of additional mortality, because of inadequate knowledge about density dependence and that PBR requires the use of a recovery factor, which is set based on opinion rather than determined by empirical evidence (e.g. Green 2014) – is noted

Table 5.20: Calculated bird deaths from southern North Sea[1], in relation to PBR

Species	Bradbury	Band[2]	Habitat loss	PBR
Gannet	840	2,600	100	5,245
Lesser black-backed gull	2,300	**14,000**	160	7,560
Herring gull	1,200	**5,800**	57	4,184
Great black-backed gull	800	**4,700**	78	4,144
Kittiwake	3,200	5,900	730	16,473
Guillemot	450	13	3,500	26,641
Razorbill	31	29	550	7,129
Great skua	14	12	3	120
Bewick's swan		58		131
Red knot		650		6,099
Sanderling		380		1,770
Curlew		540		901
Black tern		23		43
Starling		17,000		139,577

Notes: Information from Table 4 and 7 from Rijkswaterstaat (2015b) combined to show the collision results using the Band model and Bradbury et al. (2014) and habitat loss. [1]The calculations apply to the populations of the whole of the southern North Sea. [2]The Band model assumes a 3MW capacity wind turbines and relatively rapidly turning rotor blades. [3]Bradbury, which contains less detailed wind turbine parameters, is based mainly on expert estimates on the behaviour of seabirds, in addition, it cannot be used for migrating landbirds.
Source: Rijkswaterstaat 2015b, IMARES 2015.

Based on the Band model results, Rijkswaterstaat (2015b) noted that mortality caused by collisions exceed PBR in the lesser and greater black-backed gull and herring gull but for the vast majority of species the cumulative effects do not appear to be ecologically significant. Although the mortality rates were modelled predictions based on assumptions regarding future turbine density, the exercise is useful in identifying species that may be at risk.

In the Belgian part of the North Sea, a zone of 238km^2 was reserved for offshore wind farms; three were operational in 2015 and eight are expected to be operational by 2020, involving >500 turbines. Brabant *et al.* (2015) used ship-based surveys and radar data applied to the Band (2012) model, to predict the cumulative impacts from these developments and predicted up to 1,046 seabird mortalities per year. Results from further extrapolation to the wider North Sea, indicated that the cumulative impact of a realistic scenario of 10,000 turbines across the North Sea (based on the goals set by the European Union) might have a significant negative effect at the population level for lesser and great black-backed gull, with 7,636 and 6,000 collisions per year respectively. The authors acknowledge the results are subject to large uncertainties and many underlying assumptions need better validation (Brabant *et al.* (2015).

Considering the recommendations of King *et al.* (2009), particularly those relating to appropriate spatial scales for ornithological CIA and the results from recent CIAs, including the framework of Rijkswaterstaat (2015a,b & IMARES 2015), it is recognised that there are significant challenges in the conduct of CIA of the marine renewable elements of the draft plan/programme. The information presented above identifies key areas and sensitivities of birds in relation to OWF and wave and tidal (although limited) development; consideration of this, in combination with the findings and recommendations below, will assist in the appropriate siting of OWFs wave and tidal devices and minimising the risk of cumulative effects arising. CIA for developments needs to consider activities at an appropriate scale including those in relevant neighbouring waters. See also Section 5.16.

Examples from cumulative assessments at large regional scales (e.g. southern North Sea) suggest that population levels effects from this SEA are unlikely; large uncertainties and many assumptions underlay these assessments, meaning confidence is relatively low. For any new offshore renewable developments, the extent of any potential transboundary impact on bird, fish and marine mammal populations utilising waters bordering the UKCS from this SEA plan/programme also remain unclear, with assessment relying on current available frameworks.

5.6.6 Summary of findings and recommendations

Considerable uncertainty surrounds our understanding of the potential ecological effects of the physical presence of the infrastructure associated with energy developments; this is true across all elements of the draft plan but particularly so in the case of offshore wind and marine renewable developments.

This SEA recognises the critical importance of site identification as a mitigation measure but once a site has been carefully chosen, monitoring and targeted studies are key to successful management and provide the best opportunities to improve the knowledge base.

Given the controls and mitigation proposed, it is highly unlikely that the implementation of the draft plan will result in a significant ecological effect from the introduction and spread of non-native species or from interactions with mobile species (collision, barrier effect and displacement) as presented in the evidence. For some species, effects will be incurred by single individuals but even in the case of offshore wind farms and marine birds, it is highly unlikely that a population level effect will take place over the life of this SEA. It is acknowledged that these conclusions are based on limited available evidence, including uncertainties in relation to bird distribution, abundance and behaviour and how these may vary spatially and temporally.

The potential application of vulnerability scores to collision and displacement and the classification of this risk (i.e. very high, high, moderate, low very low) for species (e.g. Furness *et al.* 2013, Bradbury *et al.* 2014) and the production of resulting species sensitivity maps to offshore wind farms (Bradbury *et al.* 2014) are noted and it is recommended sensitivity mapping should be used in conjunction with other impact assessment requirements and local, site specific assessments and should not be seen as a replacement for these.

King *et al*. (2009) and Rijkswaterstaat 2015b have identified species potentially susceptible to cumulative impacts for Round 3 development zones and the southern North Sea respectively and both of these are useful for site-specific environmental assessment of potential future developments – bearing in mind the caveats on the use of PBR.

The nature and uses of the range of estuaries and embayments in which tidal range developments have been and may be proposed vary widely; similarly there is a wide diversity in the type and location of installations to exploit tidal range. Consequently it is recommended that site specific assessments are undertaken before decisions can be taken on potential leasing and the desirability and acceptability of individual projects, and that successive tidal range proposals should consider the potential for local, regional and wider far-field effects, with particular regard to endangered diadromous fish and waterbirds.

5.7 Physical presence and other users

Assessment Topic	Potentially Significant Effect	Oil & Gas	Gas Storage	Carbon Dioxide Storage	Offshore Wind	Tidal Stream	Tidal Range	Wave	Assessment Section
	Interactions with fishing activities (exclusion, displacement, seismic, gear interactions, "sanctuary effects")	X	X	X	X	X	X	X	5.7.2
	Other interactions with shipping, military, potential other marine renewables and other human uses of the offshore environment	X	X	X	X	X	X	X	5.7.2, 5.15

5.7.1 Introduction

Interaction between offshore energy installations and other users of the marine environment is a prime concern for stakeholders. Issues relate to the potential or actual exclusion from areas which may be relatively isolated and widely separated in relation to oil & gas, CCS and gas storage (e.g. 500m safety zones around surface installations and some subsea infrastructure) or much larger for offshore wind (e.g. between <10km^2 and 305km^2 to date) and other wet renewables (there have been no commercial scale developments in the UK to date, for example the MeyGen tidal stream development is estimated to cover ~3.5km^2). The installation of renewables may not necessarily lead to exclusion as the density of devices may be low (>1,000m between devices in some instances), however the nature of certain activities (e.g. aggregate extraction, bottom towed fishing gear) is such that interactions with cables may be an issue, as are safety issues relating to the maintenance of obstacle free areas (e.g. for commercial shipping, aviation). Tidal range developments may vary significantly in size and differ in that they are typically shore connected impoundments, either forming a hard physical boundary or having dedicated navigational locks. Those tidal range options considered in the Severn tidal feasibility ranged between 86 and 87km^2 for tidal lagoons, with barrages impounding areas of between 62 and 550km^2 (DECC 2010k). The latest UK proposals include the Swansea Bay and Cardiff lagoons which cover 11.5km^2 and 70km^2 respectively.

An overview of other users of the marine environment is given in Appendix 1h and this section is a consideration of the potential for interactions between the offshore energy infrastructure covered by the draft plan/programme and these other users. Interactions between shipping, navigation and fishing activity with offshore renewables probably represent the greatest potential for conflict. The interaction of multiple users of the marine environment and the role of marine planning in activity management is discussed in Section 5.15. Policy directions given in the Marine Policy Statement (MPS) and regional marine plan policies (where available) are discussed with reference to specific activities below.

5.7.2 Sources of potentially significant effect

5.7.2.1 Navigation

Navigational risks associated with the installation of offshore energy infrastructure are well-recognised. With regards to oil and gas (and by association also gas storage and CCS given they largely fall within the same regulatory regime), there is a long history of risk assessment as part of the initial block licensing process, and subsequent exploration and production activities. Anatec (2012) undertook a strategic consideration of the potential navigational effects relating to offshore wind farms (OWF) which included stakeholder consultation and a dedicated steering group, with strategic issues identified as including: wind farm project site boundary and structure alignment, radar implications (vessel detection), congestion and displacement, emergency response demand/provision and potential for restricted access, effects on adverse weather routes, access and transboundary effects. A number of suggested actions were made in relation to these which were presented to the Nautical and Offshore Renewable Energy Liaison (NOREL) group and many of these issues are discussed below.

Guidelines have been issued on the assessment of navigational risk for offshore renewables developments (e.g. MCA 2013, MCA Marine Guidance Note (MGN) 371 (M+F)). 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 what is ALARP (As Low As Reasonably Practical).

Offshore wave and tidal device deployment is not currently on the same scale as offshore wind and the likely spatial extent of development for the associated technologies over the lifetime of the current draft plan is expected to be at a demonstrator or small scale rather than in the form of large commercial arrays. Their impact on navigation is therefore currently less extensive than for offshore wind. For tidal stream devices mounted on the seabed, location within deeper waters should mitigate their impact on shipping (e.g. AECOM & Metoc 2009), however, both wave and tidal devices could form a potential hazard both during their construction and operational phases and are subject to the same offshore hazard regulations and assessments as for offshore wind (e.g. EMEC 2009, Halcrow 2006). The NOREL group, chaired by the Department for Transport (DfT), provides a forum for Government, developers and stakeholders to discuss navigational issues. Guidance on renewables developments (primarily tidal stream but there are also partly or fully submerged wave devices) in relation to vessel under-keel clearance was issued by NOREL in 2014 such that minimum depths could be set whereby vessels could still transit sites without deviation, or conversely, where deviation would be required (for a worked example see MeyGen 2015). No set figure for under-keel clearance is provided, but the guidance indicates how a maximum safe height of a device above the seabed may be calculated based on a study of vessel types and drafts in the area of interest, and the specific design of any device and site specific characteristics (i.e. water depths, variations in sea level due to the state of the tide). Water depths vary greatly in the resource areas identified for wave and tidal devices, however it is likely that should devices be deployed in the shallowest parts of these areas (e.g. 5-10m depth – see Section 2.7.6), then under-keel clearance could be significantly reduced. Charting requirements, notices to mariners and aids to navigation, in addition to risk assessment as part of activity consenting, would be required for any deployment of such devices.

Under the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) O-139 recommendations for the marking of offshore manmade structures (IALA 2008, revised 2013), wave and tidal devices extending above the sea surface must be marked in accordance with the marking regulations for OWF, and the level of marking should be decided after risk assessment. Appropriate navigation buoys (with lighting visible for 5nm) at the corners of arrays and above sub-surface devices which still pose a hazard to surface vessels is required; active or passive radar reflectors, retro reflecting material, racons and/or AIS transponders are also expected to be fitted as the level of traffic and degree of risk requires (e.g. if specific structures are not considered to be sufficiently radar conspicuous from all seaward directions). Fog signals may also be required. The Scottish marine renewables SEA (Faber Maunsell & Metoc 2007) assessed the impacts and mitigation measures associated with wet renewables and recommended that a detailed review of shipping activities and consultation with local port, harbour and lighthouse authorities be undertaken as part of the site selection for any project development.

MCA MGN 371 requires 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 Offshore Renewable Energy Installation (OREI) Environmental Statement. However, if deemed necessary in order 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 and difficulties caused to mariners or emergency response services using the site area and its environs. Those difficulties which could contribute to a marine casualty and lead to injury, death or loss of property, either at sea or amongst the population ashore, should be highlighted; as should difficulties 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. All OREI generators and transmission systems should be equipped with control mechanisms that can be operated from a central control room or through a single contact point. Development EIA 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). 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 (e.g. through the Emergency Response Co-operation Plan (ERCoPs) process – also see below in relation to helicopter based SAR. All of the above need to be addressed to the satisfaction of MCA prior to consenting of a development.

MGN 371 also indicates that an EIA should consider whether any features of the OREI, could pose any type of difficulty or danger to vessels underway, performing normal operations, including fishing, or anchoring; OREI features include auxiliary platforms outside the main generator site, mooring and anchoring systems, inter-device and export cabling. Dangers would include clearances of wind turbine blades above the sea surface[74], the burial depth of cabling[75], the mooring spreads of tethered devices which may be large and extend outside of any sea surface safety zone etc.

Specific guidelines on navigation risk assessment (NRA) for offshore renewables developments have been produced by the MCA (2013) – note this is an update to the DTI (2005) guidance on NRA for offshore wind. 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. The FSA is required to: estimate the "Base Case" level of risk based

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[74] 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.

[75] See East Marine Plans Policy CAB1, which indicates that preference should be given to proposals for cable installation where the method of installation is burial.

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 development in place; and with or without the identified hazards which are caused or changed by the introduction of the development, 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 as "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 and Emergency Response Risk". This considers both the tolerability of individual risks, and of societal concerns.

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 *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 (ES) accompanying the development application. In practice, few offshore wind developers to date have made use of the potential to incorporate operational 50m safety zones around devices. Wave and tidal devices may be considered differently in that they may be partly mobile and have tethered moorings which may not make the safety zone approach taken for offshore wind appropriate (DECC 2011a).

Developers are also 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 be noted that guidance (MCA 2013) requires that all vessel types are covered in NRA, and so AIS and shore based radar techniques may not be comprehensive enough on their own to understand the full range of vessels in an area, so visual and other methods may need to be used.

The MCA (2013) NRA methodology notes that levels of navigational risk associated with offshore renewables developments and their tolerability are likely to be dependent on a number of variables. These include the size of the water space, its bathymetry and hence the sea room available for manoeuvring, and the variety of marine operations taking place in the water space. The spatial scale of existing Round 3 leases is relatively large and future lease areas may be of a comparable scale. Any lease area is likely to include a wide range of shipping traffic densities. In addition, although there is an established methodology for FSA of individual developments (MCA 2013), 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). Several studies have been undertaken to understand how major shipping routes have changed in relation offshore wind, as described below.

A NRA for the Wave Hub site off Hoyle, north Cornwall (Halcrow 2006) calculated, on the basis of existing shipping information, a risk of collision of a vessel with one of the devices (both in a powered and drifting scenario) as 1 collision per 169 years (a conservative estimate as it assumes a collision of every ship entering the site). The risk of ship to ship collision in the area was actually reduced - from 1 in every 77 years to 1 in every 94 years - by the installation of the devices, due to vessels tending to navigate either side of the deployment area. The study also recommended a 500m safety zone around each device and a movement of the whole deployment zone 4km to the east to reduce both impact on navigation and potential collision risk.

For the MeyGen development in the Inner Sound of the Pentland Firth (MeyGen 2015), operational risks were regarded to be very small (frequency of 1 collision per 18,400 years, and much lower frequency for shallow draft vessels) mainly due to the minimum potential draft of 8m over the operational turbines. Installation activities carry a greater risk due to vessel presence, however the imposition of a safety zone to ensure vessel safety, together with notices to mariners and other consultation is considered to reduce the risk to tolerable (see above for context).

The NRA undertaken for the Tidal Lagoon Swansea development (Anatec 2014) acknowledged a number of potential navigation and safety related effects, most of which could be reduced in scale through mitigation measures. Potential issues identified included:

- Increase of vessel to vessel collision risk and vessel to structure allision76 risk
- Displacement and changes to transit routes of fishing vessels, recreational vessels and tugs
- Impacts on navigable water depths and effects of wave reflection
- Impact on SAR and pilot operations
- Impacts from lighting (potential to create confusion)

The nature of these sources of effect varies depending on project phase (construction, operation, decommissioning), but in general, standard mitigation includes the provision of additional aids to navigation, extensive notification of works, use of safety zones where appropriate (including around sluices and turbine housing for the duration of operations), maintenance of access to ports, additional hydrographic survey and dredging, guard vessels in construction areas and also the movement of a pilotage area further from the lagoon walls. This is in addition to mitigation provided through adherence to guidance including MCA MGN 371, IALA lighting and marking recommendations and vessel compliance with the Convention on the International Regulations for Preventing Collisions at Sea (COLREGs). In almost all instances, Anatec (2014) concluded that the effects described above could be reduced to being "minor adverse" on adoption of the above mitigation, or "moderate to minor adverse" for vessel allision.

Numerous NRAs have been undertaken for offshore wind farms granted planning permission since OESEA2; these include Gunfleet Sands Extension, Kentish Flats 2, Race Bank A, Dogger Bank Creyke Beck A & B, Dogger Bank Teesside A & B, Rampion, Blyth Offshore Wind Test Site, East Anglia One, Hornsea Project One (Heron & Njord), Galloper Wind Farm, Triton Knoll, Walney 3, Dudgeon East, Burbo Bank Extension and Westermost Rough A, all of which are available through the Planning Inspectorate website.

As well as the navigational risk discussed above, the physical presence of OWF, wave and tidal devices has additional potentially significant implications for other aspects of ports and shipping, such as displacement and increased journey times. A DECC report of AIS tracking data of ship navigation around OWF (DECC 2010h) presents information on the changes to vessel routes

[76] the striking of a vessel with a stationary object.

before and after the construction of the Barrow, Thanet and Greater Gabbard developments. The report showed that at the Barrow OWF, NW/SE shipping into Morecambe Bay that previously passed through the site had been displaced to the south (Figure 5.29), with the width of the navigation corridor reducing from 60% of the tracks within 1nm of the mean to 80% for the Stena Line ferries. The shipping in the vicinity of Barrow OWF is dominated by ferries which have adjusted their position to achieve a safe clearance of 0.5-2nm. A study was commissioned as part of OESEA3 (Anatec 2016) to understand the main changes to commercial shipping routes following the development of offshore wind in English and Welsh waters for a wider range of sites. The study covered the three major areas of wind farm construction and operation to date: the East Irish Sea, the Humber and Wash and the Thames Estuary. AIS tracks for vessels were considered in advance of the construction of each wind farm so that areas with multiple build out of wind farms over time could be reviewed for the individual and additive effect of OWF construction, noting that in some cases the data preceded the wider deployment of AIS. A number of changes in specific routes were identified, either directly as a result of wind farm construction (including cumulatively) or indirectly resulting from other development (see Table 5.21). Changes in the major routes were also plotted as areas containing the 90th percentile of shipping activity. Generally it was concluded that:

- For case study areas in the Irish Sea, route changes resulting from wind farm construction were consistent with the navigational risk assessment undertaken for specific developments.
- Where major route changes were minor or not apparent, OWFs had typically been constructed in areas outside of major shipping routes, thus avoiding major effects on commercial routes.
- Understanding of small vessel movements is improving with AIS coverage, but it is variable and far from comprehensive.

The studies of major changes in shipping routes for each area are shown in Figures 5.29-5.33 below, together with a summary of the route changes. looking A consideration of potential cumulative effects of OWF deployment on navigation routes in the southern North Sea led to suggestions for a wider set of routes by the Southern North Sea Offshore Wind Forum (SNSOWF), these were included in the NRA document for Hornsea Project One (SMartWind 2013b). If these were taken to accurately reflect the changes which could result from construction of all wind farms presently consented or in-planning, then in anticipation of future wind farms being located in this and other areas such as the east Irish Sea, there is the possibility that further measures could be necessary to ensure ship safety and to maintain commercial routes. This could include future routeing measures, or alternative approaches could be adopted such as used in the Netherlands, whereby major routes are maintained as “clearways” within which development cannot take place, nor within a 2nm buffer (Dutch Ministry of Infrastructure and the Environment & Ministry of Economic Affairs 2014).

In addition to the results of this study, it should be noted that the MMO used the 90th percentile routes as the basis for its East Marine Plans PS2 policy map. This policy indicates that developments should not be authorised if they encroach on these routes unless there are exceptional circumstances. This is presently only applicable to the East Marine Plan areas; however the desired consistency with the MPS may lead to this being a policy which is more widely adopted. With these factors in mind, and recognising that maritime traffic distribution can change, it is recommended that primary navigation routes are refined and reviewed periodically, with the results made available to developers, and that this is part of the review process undertaken as part of the statutory marine plan process.

Table 5.21: Summary of commercial shipping route changes

Area	Summary of route changes
East Irish Sea	The majority of routeing changes within the area are linked to RoRo or passenger vessel movements (e.g. Fleetwood to Larne, Heysham to Belfast). These may be the result of offshore wind farm development or localised operator/vessel changes. The most frequent area where changes were noted included the approaches to the river Mersey (port of Liverpool) for vessels bound to the Isle of Man, the Republic of Ireland or Northern Ireland. Other infrastructure impacted on vessel routeing decisions (i.e. South Morecambe and Calder Gas Fields) but could not be demonstrated to significantly impact the routeing in isolation. Changes were generally noted as minor route alterations or increased passing distance (0.6-0.9nm).
	The development of the Douglas Platform in 2006 and the Liverpool Bay Traffic Separation Scheme (TSS) in 2009 have formalised traffic routeing in Liverpool Bay. Although the TSS was developed for a number of traffic management issues, Gwynt y Môr OWF was in the early stages of planning pre-2009 and may therefore have contributed to its implementation, and has further dictated traffic movements given its proximity to the southern boundary of the TSS following its construction and commissioning. It was noted that smaller, more inshore OWF located in shallow waters have not impacted commercial vessel movements post their commissioning.
Humber and Wash	The Humber TSS was established in 2009 solely due to a combination of general traffic increases in the area, the deep water anchorage and proposed OWF (Humber Gateway). Vessel traffic altered into more defined routes following the implementation of the TSS. Generally, route changes within this area have been noted as increasing closest point of approach (CPA, directly associated with development of a wind farm) or minor route adjustments (cumulative), due to changes within the wider navigable area. There are Round 1 wind farms within the southern study area in close proximity to The Wash that are nearshore and therefore out with areas where commercial navigation generally occurs. However when Round 1 developments are considered in combination with Round 2 developments these have caused some isolated vessel displacement as well as increased CPAs for the main commercial vessel routes in the area.
Thames Estuary	The Thanet OWF is an example of where traffic has been significantly altered, but not significantly impacted around an offshore wind farm development. Traffic prior to the development of Thanet OWF was generally unrestricted. Post development (which includes the implementation of a north cardinal buoy to the north of the site) the traffic has become more organised into denser routes and resulted in minor re-routeing for some vessels. The north cardinal buoy[77] has also had notable positive effects by ensuring that most traffic maintains a 1nm passing distance from the development boundary. A number of commercial vessels were noted to have been displaced when assessing the pre and post AIS data. However, the actual number of vessels requiring alterations was considered to be insignificant with the majority of commercial vessels remaining within defined deeper water channels, thus avoiding the shallower water area within which London Array was constructed.

Source: Anatec (2016)

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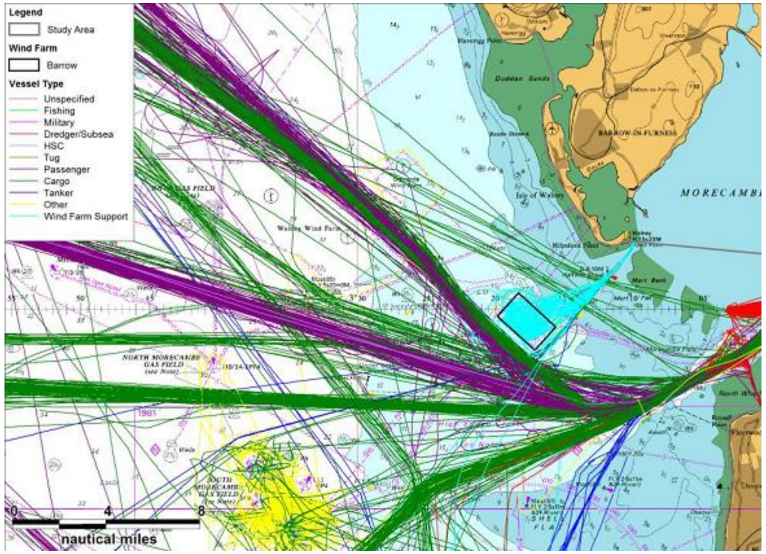
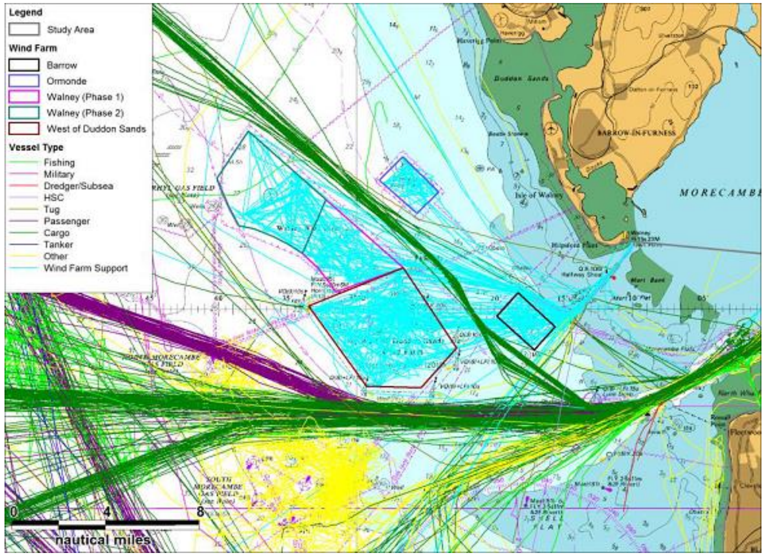
Figure 5.29: Vessel AIS track and route changes following OWF construction: East Irish Sea (north)

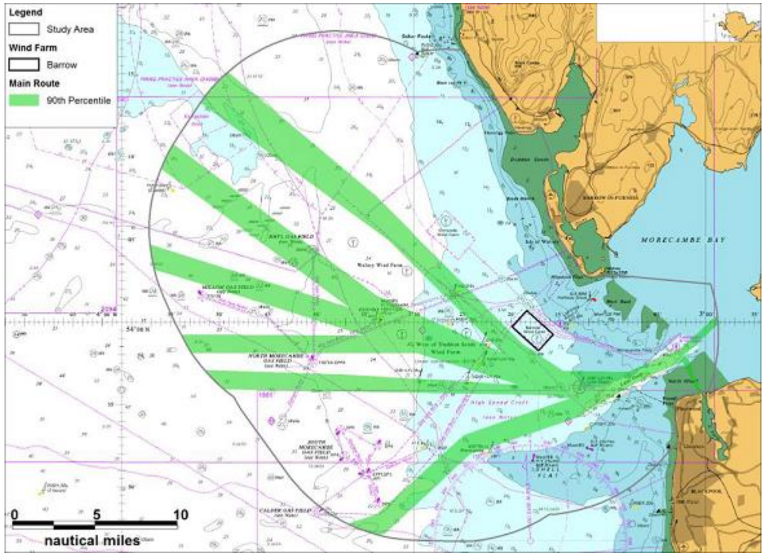
February 2010

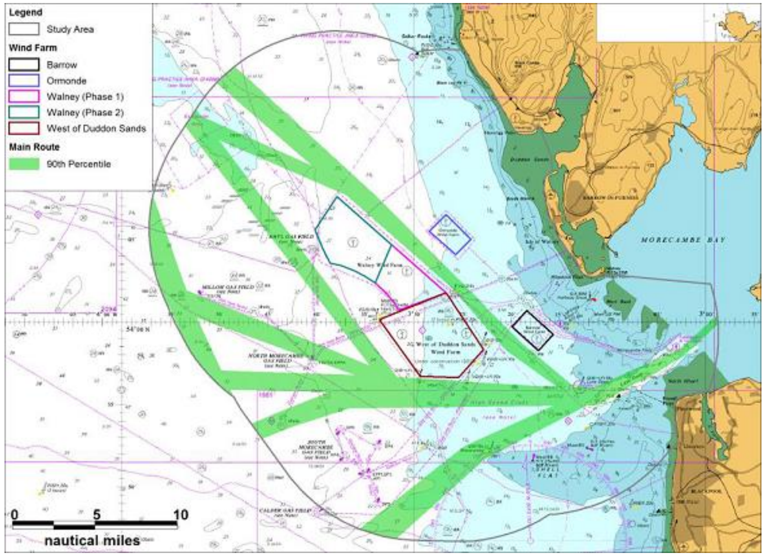


January 2015



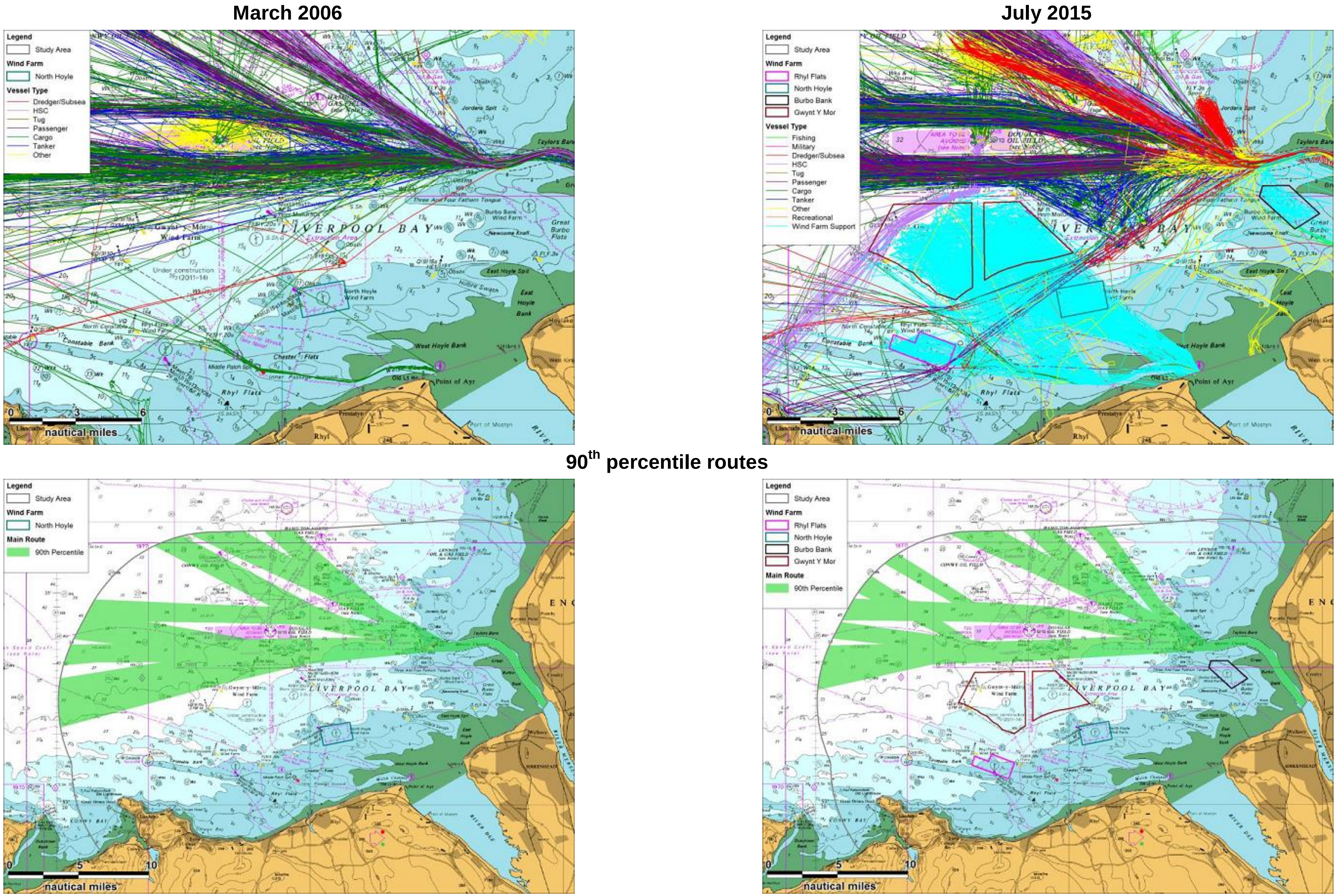
90th percentile routes





Source: Anatec (2016)

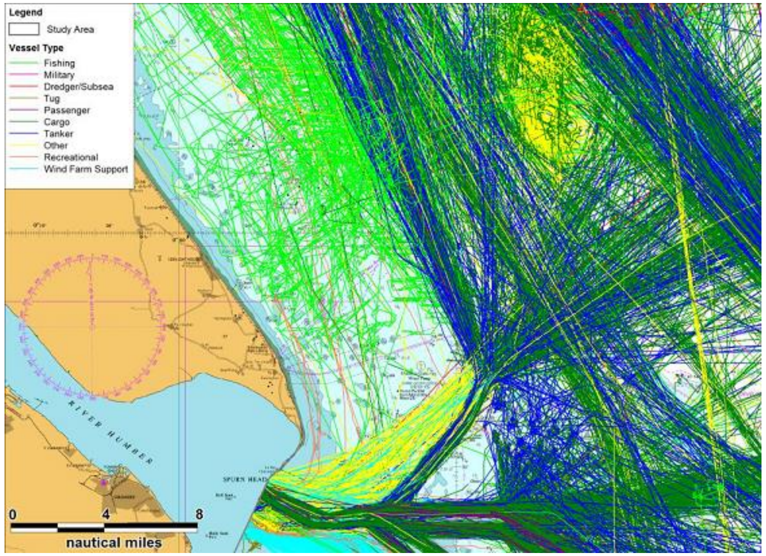
Figure 5.30: Vessel AIS track and route changes following OWF construction: East Irish Sea (south)



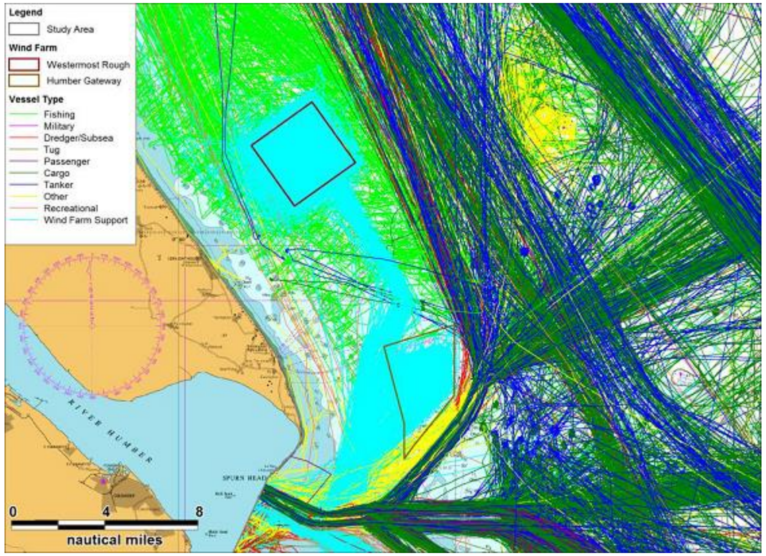
Source: Anatec (2016)

Figure 5.31: Vessel AIS track and route changes following OWF construction: Humber and Wash

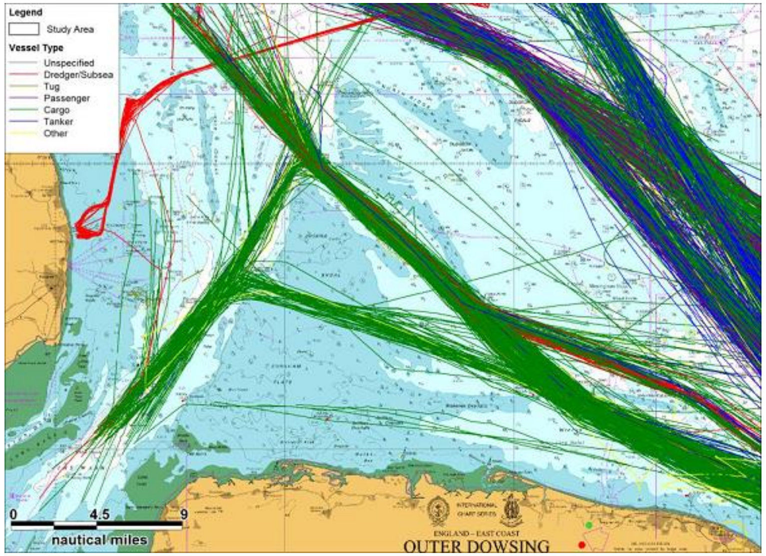
June 2013



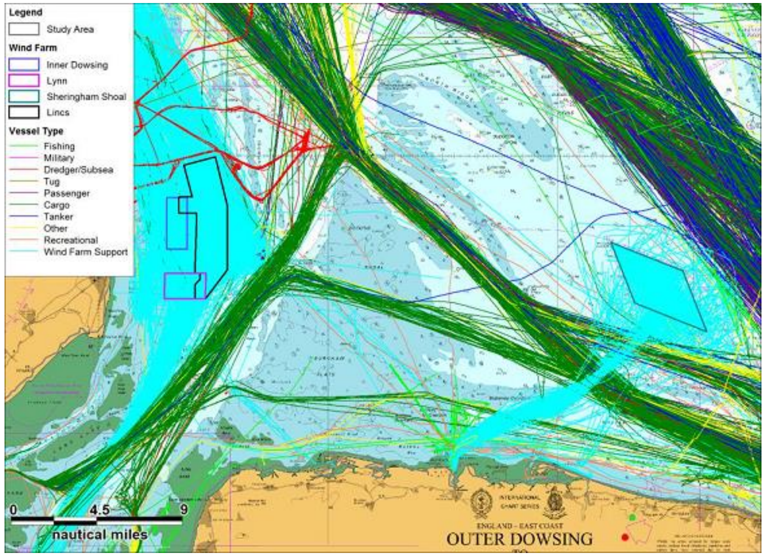
July 2015



April 2006



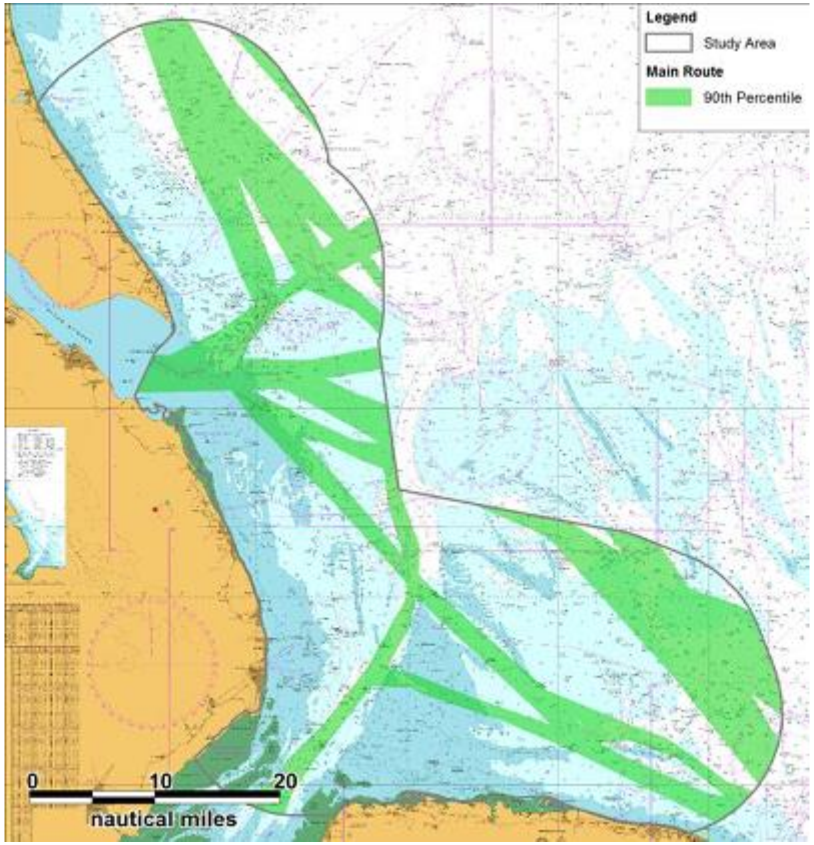
June 2013



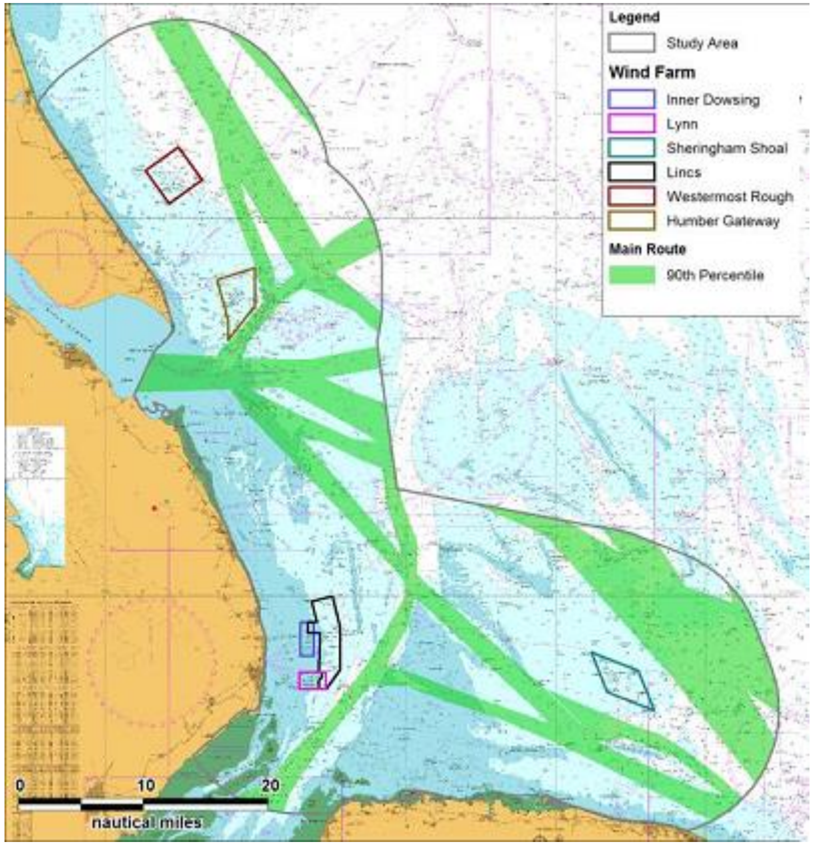
Source: Anatec (2016)

Figure 5.32: 90th percentile shipping routes: Humber and Wash

April 2006



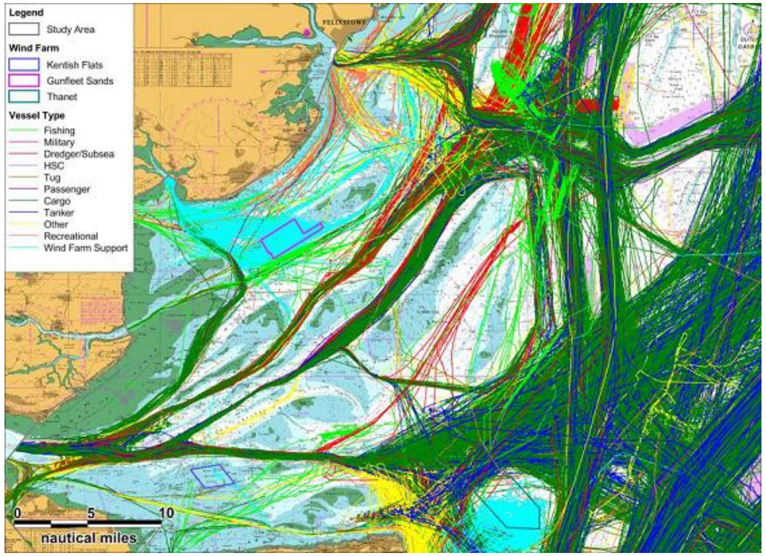
July 2015

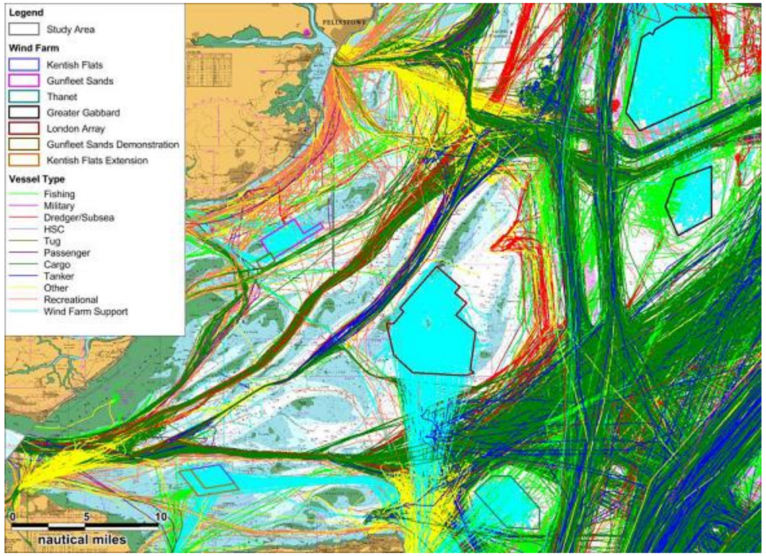


Source: Anatec (2016)

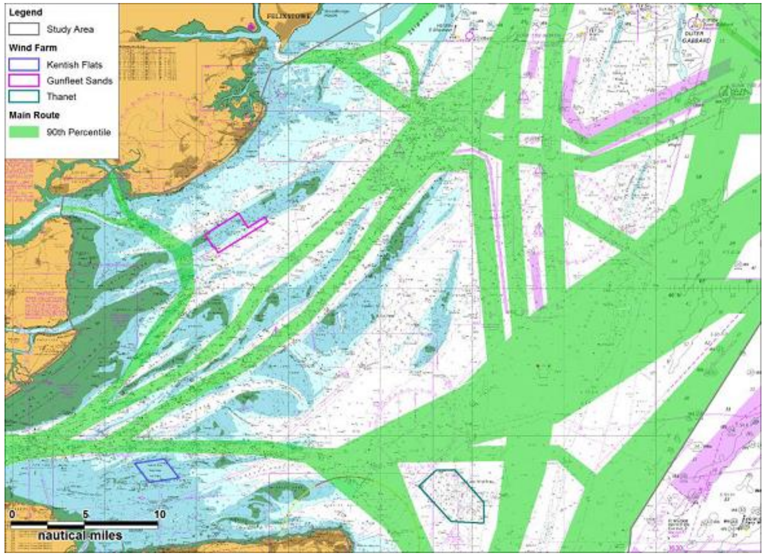
Figure 5.33: Vessel AIS track and route changes following OWF construction: Thames

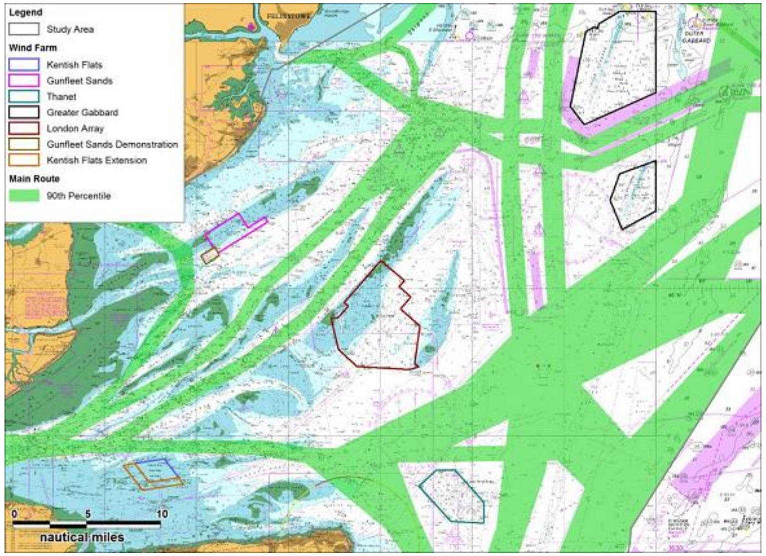
May 2009 **October 2015**





90th percentile routes





Source: Anatec (2016)

The number of vessels recorded as intersecting OWF developments increases in areas with higher traffic densities and a variety of different types of shipping (DECC 2010h). At Greater Gabbard, Burbo Bank, Scroby Sands and Kentish Flats the vessels tracked inside the OWF were all fishing vessels (see below), recreational craft, lifeboats, harbour pilot vessels or small passenger/inland waterways vessels. This interaction of cargo ships (and other vessels) with OWF developments and the displacement of vessels in all directions is partially addressed at several OWF sites with the introduction of traffic separation schemes (TSS). At Greater Gabbard (Figure 5.33) the introduction of the TSS has helped manage routeing in the vicinity of the wind farm, with the east traffic lanes located between north and south developments separating traffic by direction to minimise the risk of head-on encounters (DECC 2010h). An updated TSS scheme exists at the Humber Gateway OWF site, partially to assist port traffic management and safety and partially to move traffic away from the OWF. The routeing measures on approaches to the Humber were updated in 2009. This means that the subsequent impact of the OWF on traffic will be much reduced. Similarly the introduction of a TSS scheme at the Gwynt y Môr OWF site due to a combination of routeing issues (e.g. in relation to the Douglas Field) has resulted in routeing that avoids the OWF site.

There are a number of 'pinch points', which are either constrained locations within UK waters where there are currently high densities of shipping or areas of navigational importance such as turning areas. Often these constrained locations have strong tides and heavy seas and as such may be candidate areas for tidal stream/wave development. Care needs to be taken that when siting these devices, areas of high vessel activity and limited manoeuvrability are not compromised. Similarly caution needs to be extended to siting devices in the entrance to estuaries/harbours where they may either restrict access or produce a hazard risk especially in areas prone to bad weather conditions.

The potential displacement of vessels around large arrays of devices, during installation, operation and decommissioning phases may increase journey times and distances. The location and size of the development, size of safety exclusion zone and type of journey will all determine how much disruption occurs, with increased journey distances resulting in increased fuel consumption, associated increased greenhouse gas emissions and costs to the shipping operator. There is the potential issue that an increase in the number of obstacles in the vicinity of approach routes to ports will have indirect effects on the ports themselves, through higher insurance premiums for vessels manoeuvring in these areas and therefore potential displacement of vessels to easier access and cheaper ports. A number of North Sea and Irish Sea ports experience high numbers of days where fog is an issue for navigation. The construction of OWF and other obstacles in the vicinity of port approach routes and associated constriction of vessels into set channels and routes would increase the collision risk and may deter vessels from the ports. Long term reduced access to ports, potentially exacerbated during installation and decommissioning would have an effect on trade opportunities. In view of the strategic importance of this sector, regional marine plans are identifying policies which seek to ensure that appropriate consideration and weight is given to the safeguarding of port approaches.

Tidal range developments have the potential to significantly impact access to ports and therefore trade opportunities. The presence of a barrage would affect the environmental conditions of an estuary and potentially alter the water levels and sediment deposition patterns affecting the available water depth for navigation. Changes to tidal velocities and vessel size restrictions posed by lock dimensions are also likely to affect access to specific ports. The Severn barrage feasibility study (DECC 2010i) outlined potential impacts on Bristol, Cardiff, Newport and Sharpness ports of the construction of the Cardiff to Western barrage, with for example a predicted reduction in employment of 2,100 people at Cardiff port alone and a reduction in GVA (gross value added) of £1.3bn over the 40 year evaluation period for all affected ports (DECC 2010i). Shipping channels should be maintained where they may be affected by tidal range projects.

In view of the high degree of correspondence between draft, unpublished MCA "OREI 1" primary navigation routes (see Section 5.15) and other vessel traffic data[78], generic indications of risk tolerability given in MCA 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 (see Section 5.15); however it is also understood that any such restriction would need to be compatible with relevant marine plan policies. This buffer width is based on the "high" to "medium" risk threshold of the shipping route template[79]; and a larger buffer may be required where additional factors (such as traffic density and tidal set) increase the local risk. It is noted that the identification of primary navigation routes is based primarily on AIS data which currently has limited coverage. The information collected by the system may vary between 20nm and 350nm depending on a number of factors, including the strength of the transmitter (e.g. whether AIS-A or AIS-B), atmospheric and sea state conditions and visibility/height of receivers – an average range of 40nm may be expected (MMO 2014). Moreover, it is noted that not all vessels carry AIS; AIS-A is required for larger vessels (gross 300 tonnes or more on international voyages or 500 tonnes or more not on international voyages) and all passenger ships; AIS-B is targeted at the fisheries and recreation sectors.

There is no requirement for recreational vessels to carry AIS, but all fishing vessels >15m in length must carry AIS. Also see Section 5.7.2.2 and Appendix 1h for a discussion of fisheries Vessel Monitoring Systems (VMS) and Inshore Vessel Monitoring Systems (I-VMS). For small fishing vessels and most non-commercial vessels, including recreational craft, the navigational risk of offshore wind farm developments would be largely mitigated by a coastal buffer zone which is recommended to address several ecological and spatial conflict concerns (see Section 5.15.3 for more detail), however it is realised that for wave and tidal devices this will not be possible in many cases. In addition, the recommended air gap of 22m between blade tip and sea surface should prevent any possibility of collision with the turbine rotors (also see 5.7.2.6 below). Further guidance on navigation in the vicinity of OREIs is provided by MCA Marine Guidance Note MGN 372 (M+F) – Offshore Renewable Energy Installation (OREIs): Guidance to Mariners Operating in the Vicinity of UK OREIs. In addition to the above recommendations, those included in Anatec (2012) are considered to be largely ongoing.

Subject to the above considerations and recommendations, the judgement of this SEA is that sufficient regulatory control and guidance exists at the consenting and operational stages to manage navigational safety risk effectively, and that regional level marine policy relating to the importance of navigation, shipping and port activities, and identifying areas of particular interest to commercial and other navigation interests, will improve both the understanding of navigational use and also provide a consistent policy steer. Away from the primary navigation route network, there is no clear basis or requirement to spatially constrain offshore wind farm development on grounds of navigational safety. The consideration of smaller craft, many of which relate to fishing and recreation interests, are starting to be covered by National and

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[78] See the 2008 AIS data compiled for OESEA, subsequent MMO data available for 2012 and 2013, data provided as part of a technical report undertaken for this SEA (Anatec 2016) and also those shipping routes identified in policy PS2 of the East Marine Plans.

[79] As background, the MCA Template for assessing distances between wind farm boundaries and shipping routes (Annex 3, MCA Marine Guidance Note MGN 371 (M+F)) integrates 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.

regional policy. This may not directly relate to navigational risk assessment, but does include the potential consequences of displacing such vessels, which may in turn increase risk (e.g. by displacing recreational users into busier shipping lanes).

5.7.2.2 Fisheries

The distribution of fishing effort around the UKCS, described in Appendix A3h.13 of the Environmental Report, is based on independent analyses of VMS and logbook data, consultation with fisheries stakeholders and various published reports. Important fishing grounds to be considered when siting offshore installations are listed in Table 5.22. 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. Areas of deeper water and those of great local importance (which are more difficult to identify) are described in the text below. The information presented in Table 5.22 should be considered alongside the various maps presented in Appendix A1h, as these better illustrate the locations of the areas described.

Table 5.22: Important UK fishing grounds for consideration

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.
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.	High density of static gear in the north.
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 and selected sites offshore. Static gears dominate between Start Bay and Salcombe.
The Bristol Channel and north coast of Cornwall.	Mobile gears offshore, with most static gear effort inshore.
Between the west coast of the Isle of Man[80] 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.

[80] The territorial waters of the Isle of Man support important fisheries particularly for shellfish. The waters to the east, south and west of the island are some of the most heavily fished in the region.

Area	Primary gear type(s)
Waters off the east Cumbrian coast extending south and west from approximately to Whitehaven to 12nm offshore.	Primarily 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).	Primarily 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 and around the north coast of Lewis.
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.

Outside of the areas of high effort and value from a UK context as listed in Table 5.22, 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 every port throughout the UK and those in remote and rural areas are likely to be most sensitive. At region- and site-specific levels, early consultation with relevant Inshore Fisheries Conservation Authorities (IFCAs) (England and Wales), or Inshore Fisheries Groups (IFGs) (Scotland) and fishermen, will facilitate the identification of these locally important areas. In addition to those areas cited in Table 5.22, there are many areas in waters exceeding 60m water depth which are of very high fishing effort of considerable value in UK. 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; these include numerous discrete areas of particularly high effort, notably along the continental shelf margin, where both mobile and static gears are heavily used. 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.

During discussions with representatives of the fishing industry and fisheries management organisations, it was noted that extensive inshore fisheries take place throughout most UK waters to approximately 25nm offshore, and that through the activities of IFCAs the 0-6nm zone is generally quite well understood. The 6-12nm zone, however, is an area of typically high fishing effort but is less well understood - many foreign vessels operate in this area. Offshore installations 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 fish by distance from home port, availability of sheltered waters and substrate type. Displacement from favoured grounds may have important economic implications resulting from increased steaming times (and fuel use) potentially required to reach alternative sites. Renewable installations, such as OWFs and wave and tidal developments tend to be constructed in shallower, inshore waters, and therefore are more likely to be focal points for physical interactions with the fishing industry. Wave and tidal developments tend to be close to shore, and are on a much smaller scale than OWFs. Consequently, the main risk posed to fishing vessels by wave and tidal devices is likely to be of collision, although snagging of gear on seabed-mounted devices is a potential risk which can be minimised by accurate marking of their locations on marine charts. Tidal barrages and lagoons may have significant barrier or habitat effects on inshore fish, particularly migratory, diadromous fish and juvenile or spawning fish that are found in bays and estuaries inshore. Impacts on fish species will clearly have a direct effect on the fishing industry and these ecological effects have been discussed further in Section 5.6. However, development in inshore areas may restrict access for local, small-scale fisheries, including recreational sea angling, which will have regional economic and social impacts.

The Scottish Marine Renewables SEA (Faber Maunsell & Metoc 2007) and the SEA of Offshore Wind and Marine Renewable Energy in Northern Ireland (AECOM & Metoc 2009) described potential spatial impacts of construction, operation and decommissioning of offshore renewables on fishing. These include, for example, the displacement from fishing grounds during the construction and decommissioning phases with the implementation of temporary safety zones of 500m and potentially permanent safety zones of 50m around the array area during operation. As well as excluding fishing from the development area there may also be added pressure of other vessel traffic being diverted and impacting on fishing operations (Halcrow 2006). It is also noted that new subsea cables may make areas less attractive for mobile fishing methods (i.e. beam trawls, bottom otter trawls), displacing vessels operating such gear over a swathe of approximately 300m for each device array (assuming three export cables each separated by 100m) (AECOM & Metoc 2009).

These predicted effects have been reflected in a Crown Estate report examining changes to fishing activity following the construction of six OWFs (Robin Rigg, Walney 1 & 2, Ormonde, Barrow and Burbo Bank) in the eastern Irish Sea, as reported by locally active fishermen (Gray *et al*. 2016). Vessel Monitoring System (VMS) data revealed significant reductions had occurred at sites since 2007, although this was associated with a decline in Irish Sea Total Allowable Catches (TACs) and a comparable decline in the wider region. However, fishermen consulted as part of the report all claimed to have reduced effort or stopped fishing altogether within the OWFs during the construction period, with only a small number returning post-construction. The majority of these fishermen claimed the OWFs had a greater impact on their fishing opportunities than quota management. Reasons given for a lack of confidence in fishing within turbine arrays included the risk of snagging cables or support structures and losing equipment, and the danger of engine failure while surrounded by turbines. Nevertheless, fishing activity was reported within OWFs, with some fishermen claiming to operate demersal trawls in cable-free corridors between turbines. Observations of fishing activity within the Barrow offshore wind farm, as described during stakeholder discussion, reveal trawling to be considered hazardous although potting activities are carried out safely.

Loss of access to fishing grounds at OWFs can be partly mitigated. Blyth-Skyrme (2010a) provides a summary of mitigation measures that might be considered, which can be broadly divided into four categories. A brief discussion of each follows below.

Pre-construction options to limit impacts on commercial fishing

Pre-construction options may consider the siting or design of offshore developments to avoid, or reduce impact on, particular fishing grounds. The identification of important areas at an early stage, similar to the "core fishing grounds approach" as proposed by the MMO (MMO 2014), and pre-emptive analysis of local fishing activity, such as that carried out in the Co. Down Wind Resource Zone off the coast of Northern Ireland (Seafish 2013), will allow and encourage early consultation and decision-making.

Co-location of Marine Conservation Zones (MCZs) and OWFs would exclude fishing from a single combined area rather than from two separate, potentially larger ones and Blyth-Skyrme (2010b) identifies the potential effects on the fishing industry. The positive effects include minimizing social and economic impacts, supporting engagement efforts of developers with the industry and potentially supporting MCZ conservation objectives (with possible knock-on benefits for fishermen). The disadvantages are the limiting of grounds within OWFs that might otherwise be targeted, as well as the concern that fishermen could miss out on compensation for losing these opportunities. Clarity would also be needed over the responsibilities of developers to both co-location with MCZs and additional compensation related costs to the fishing industry. Broadly, collaborative planning between developers and other stakeholders, including the fishing industry will allow pre-emptive mitigation of sources of potential concern.

Other design and procedural measures that could be taken to facilitate co-existence between industries included:

- Provision of seabed maps showing accurate and precise locations of hazards
- Identification of cable-free corridors within arrays that may be suitable for trawling
- The use of concrete mattresses to protect cables rather than rock dumping
- Clearing debris left on the seabed following construction operations

Supporting the existing fishery activity

Support for existing fisheries might include providing financial assistance to allow fishermen to operate within OWFs. This might include assistance to purchase new or modified gear, support for maintenance costs, provision of safety equipment or support for insurance for fishing within windfarms. Establishing fuel subsidy schemes for fishermen affected by displacement and promoting local fisheries and regulating access to fishing within developments are other ways in which the industry might be supported.

Enhancing stocks of targeted species and associated habitats

Promoting or enhancing stocks of commercial fish species, through direct seeding of wild or hatchery seed, or the release of large, broodstock animals (most likely, shellfish), has been considered, although this may also happen naturally. The potential effects of offshore structures on fish assemblages have been the subject of numerous studies. It is generally expected that the 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 been noted for oil platforms (Løkkeborg *et al*. 2002, Soldal *et al*. 2002) and offshore wind farms (Reubens *et al*. 2014, Stenberg *et al*. 2015) and was the subject of a RAG commissioned study (Linley *et al.* 2008). It is not fully understood to what extent reef effects might increase commercial fish stocks outwith the vicinity of offshore structures, although reef effects are unlikely to be significant at a strategic level, in view of the limited spatial area affected by habitat alteration. Reubens *et al*. (2014) noted that, while juvenile cod and whiting were attracted to turbines and OWFs, there was no evidence that this translates into a regional-scale increase in recruitment (and thus fishing these locally elevated populations might act to deplete the community at a greater rate).

Developing new fisheries or non-fishing opportunities

Finally, options to develop new fisheries or other activities, would encourage and support the efforts of fishermen to adapt to new opportunities, perhaps by providing maintenance support (such as acting as safety patrol vessels at developments), or industrial (surveying, commercial diving) or recreational (angling, diving) support. Commercially valuable decapod crustaceans such as edible crab and European lobster have been associated with the artificial reefs provided by man-made structures such as shipwrecks (Hiscock *et al*. 2010, Krone & Schröder 2011), oil and gas platforms (Southgate & Myers 1985, Pradella *et al*. 2014) and OWFs (Emu Ltd 2008, Leonhard & Pedersen 2006). As such, the opportunities for new targeted fisheries for these species may exist around and within OWFs, particularly if artificial reef effects can be enhanced through design and selection of materials (Hooper & Austen 2014). Syvret *et al*. (2013) describe the potential for shellfish cultivation, particularly of blue mussel, to co-locate with OWFs in Welsh waters. The potential for long-line or net bivalve or algae aquaculture within OWFs is also discussed by Blyth-Skyrme (2010a).

The effects on of offshore developments on fishing activities depend on the scale of fishing interests in the area, willingness to fish within the areas, the space available for displacement of fishing into other suitable areas and the management regime of fisheries in that area. At a strategic level, caution is required with regard to the siting of major expansion of offshore infrastructure to ensure fishing activities and skills of local cultural and economic importance are not inadvertently lost, through the prevention or significant hindrance of fishing activity for a generation during the lifetime of the developments.

5.7.2.3 Military activity

Potential disruption to military activities may occur during the installation, decommissioning and operation of a renewable energy site. Current military practice and exercise areas (PEXAs) are mapped in Figure A1h.12 and are considered further in Section 5.15. Those areas which are considered to represent a significant constraint to offshore energy (and potentially other activities) are listed as danger areas (i.e. where live firing takes place); these may be used by the army, navy or air force. The latest UK Integrated Aeronautical Information Package (IAIP)[81] indicates the vertical limits and types of activities which take place within specified air force danger areas. The majority involve supersonic flight and air combat training at altitude (e.g. 5,000ft-66,000ft), thus plan-related activities would not interact with such danger areas due to vertical separation. Some activities however, in a number of danger areas (in English and Welsh waters, danger areas D513/513B/513C, Druridge Bay; D412, Saxton; D207, Holbeach and D307, Donna Nook) involve live firing or bombing within a vertical range which meets the surface and so may present some exclusion. Other danger areas used by the navy and army may also present potential development constraint to draft plan/programme activities and in some circumstances activities may not be able to take place within such zones. Early consultation with the Ministry of Defence (MoD) is advised and may result in an acceptable solution to siting.

A number of other PEXAs are located along the coast and offshore where, with dialogue with the MoD, development may acceptably take place. For offshore oil and gas, CCS and gas storage subject to licensing under the *Petroleum Act 1998* or *Energy Act 2008*, licence conditions may be imposed which include informing the MoD of the timing and type of operations proposed, often significantly in advance of any work taking place (e.g. 12 months, see DECC 2014f). In particular, DECC have informed prospective applicants in successive licensing rounds of which UKCS blocks may be subject to restrictions due to military interests. More recently, the MPS has amplified the above text, indicating that, "*Marine activities should not prejudice the interest of defence and national security and the MoD should be consulted accordingly",* and that*, "Marine plan authorities, decision makers and developers should consult the MoD in all circumstances to verify whether defence interests will be affected."*[82] The first regional marine plans further indicate that developments would not be authorised unless agreed approval had been granted by the MoD for activities to be undertaken (see policy DEF1). The

[81] http://www.nats-uk.ead-it.com/public/index.php%3Foption=com_content&task=blogcategory&id=165&Itemid=3.html
[82] MPS Section 3.2.

Scottish National Marine Plan, whilst for the purposes of this SEA is largely only relevant to oil and gas, CCS and gas storage, further emphasises that developments which interfere with radar (see below) and other national defence systems may be prohibited without mitigation (policy DEF 1).

Offshore wind farms have the potential to interfere with defence interests through interference with radar which facilitate the UK Air Surveillance and Control Systems (ASACS). Previously MoD policy did notallow any wind farm development take place within 74km of ASACS radar if it would be in the direct field of view; however in June 2011 an agreement between the MoD and wind developers led to the procurement of a TPS77 radar that provided mitigation from the effects of wind farms located at Remote Radar Head (RRH) Trimingham. Following on from this, further sites have been modified, or have agreed to be modified (Figure A1h.13) to broaden this mitigation and commissioning trials and optimisation of these continues (DECC 2015g). The potential for effects from offshore wind farms are still noted, for instance in relation to East Anglia 3, the MoD raise a concern about the wind farm being in line of sight of RRH Trimingham. Mitigation is available, for instance through application of a Non-Auto Initiation Zone (NAIZ), which is a available through the TPS77-type radar at Trimingham but which is also subject to detailed modelling and operational assessments to bring the effects to within acceptable levels (Cyrrus Limited & Royal HaskoningDHV 2015)

Marine planning has clarified the UK's position in relation to safeguarding military interests and this is now being amplified through regional marine plans. Concerns remain regarding the potential effect of offshore energy on defence interests from all aspects of the plan, however well established methods are in place to provide for mitigation including: the identification of practice and exercise areas on charts, dialogue with the MoD and developers including the MoD being a statutory consultee on planning applications and collaborative efforts such as on radar effects, and early identification by the licensing authority (e.g. DECC in relation to oil and gas licensing) of where there are MoD interests and potential constraints.

5.7.2.4 Aviation

The potential impacts of wind farms (onshore and offshore) on aviation have been documented by the DTI (2002), CAA (2013) and in DECC (2015g). Offshore energy installations may affect aviation activity principally in two ways: through interference with primary surveillance radar (PSR) used in air traffic control and military air defence radar, and/or through creating an en route obstacle. Offshore wind farms are the most likely aspect of the draft plan to be the source of potential effects as they can cause unwanted returns on surveillance radar at some distance from radar locations and/or shadow objects; they can be relatively large obstacles in terms of height (e.g. the latest Vestas V164-8.0 MW turbine has a blade tip height of 187m) and are also likely to occur in relatively high numbers.

The Aviation Plan (DECC 2015g) aims to develop mitigation measures to reduce the impacts of wind farms on aviation to acceptable levels. It is administered by the Aviation Management Board which takes responsibility for delivering the plan and securing funding for work to take place. The Aviation Investment Fund Company Limited (AIFMCL) was set up under the plan, led by RenewableUK, to bring together wind energy developers to help develop mitigation for radar issues. To date £3 million has been provided through the AIFCL with additional contributions from DECC, The Crown Estate, Marine Scotland and offshore wind developers at a project level. Despite a number of mitigation measures having been developed for military radar (e.g. TPS77 radar standard, see above[83]) and PSR (Project RM), there is presently no single technical solution to radar issues and work is therefore ongoing to test and improve these mitigation techniques. A number of work streams are therefore ongoing through the Aviation Plan, and project specific assessment, mitigation and dialogue through the planning process will continue to be required to establish acceptable wind farm locations, layouts and agreements on collaborative efforts to reduce impacts, which has proven successful to date.

Wind farms have the potential to cause physical obstruction to low flying aircraft, and guidelines relating to aviation issues and wind farms are detailed in CAA policy document CAP764 which informs much of the discussion below. Other than for military purposes, as discussed above, low flying aircraft could include helicopter traffic en route to offshore oil and gas installations and in their final approaches. Helicopters typically travel at an altitude above wind turbines, for example in the southern North Sea outwards flights tend to be in the altitude range 2,000-3,000ft and inbound flights in the range 1,500-2500ft to ensure safe vertical separation between helicopter traffic, but traffic must also keep a safe distance (at least 500ft) from any structure, including wind turbines. Maintaining this distance could become problematic where the icing level (0˚ isotherm) and low cloud is at an altitude which prevents aircraft travelling at heights which maintain a safe vertical separation from a wind farm. A number of Helicopter Main Routes (HMRs) have been defined over UK waters, largely relating to the oil and gas service sector and are detailed in the latest UK AIP (see Figure 5.34 – note the mapped area relates only to English and Welsh waters which are within remit of the draft plan/programme for renewable energy). HMRs are therefore concentrated over areas within the major hydrocarbon basins of the UK, namely the southern, central and northern North Sea, and in the East Irish Sea (Morecambe Bay). With the exception of much of the northern North Sea, water depths in these areas are also relatively shallow and have also been prospective for offshore wind energy; this means that helicopter traffic is already a consideration of wind farm applications and assessment. Whilst the HMRs do not have any statutory basis, the CAA has indicated that there should be a 2nm obstacle free buffer (i.e. 4nm corridor) for these routes, which could be increased if there was the potential for a reduced air traffic service.

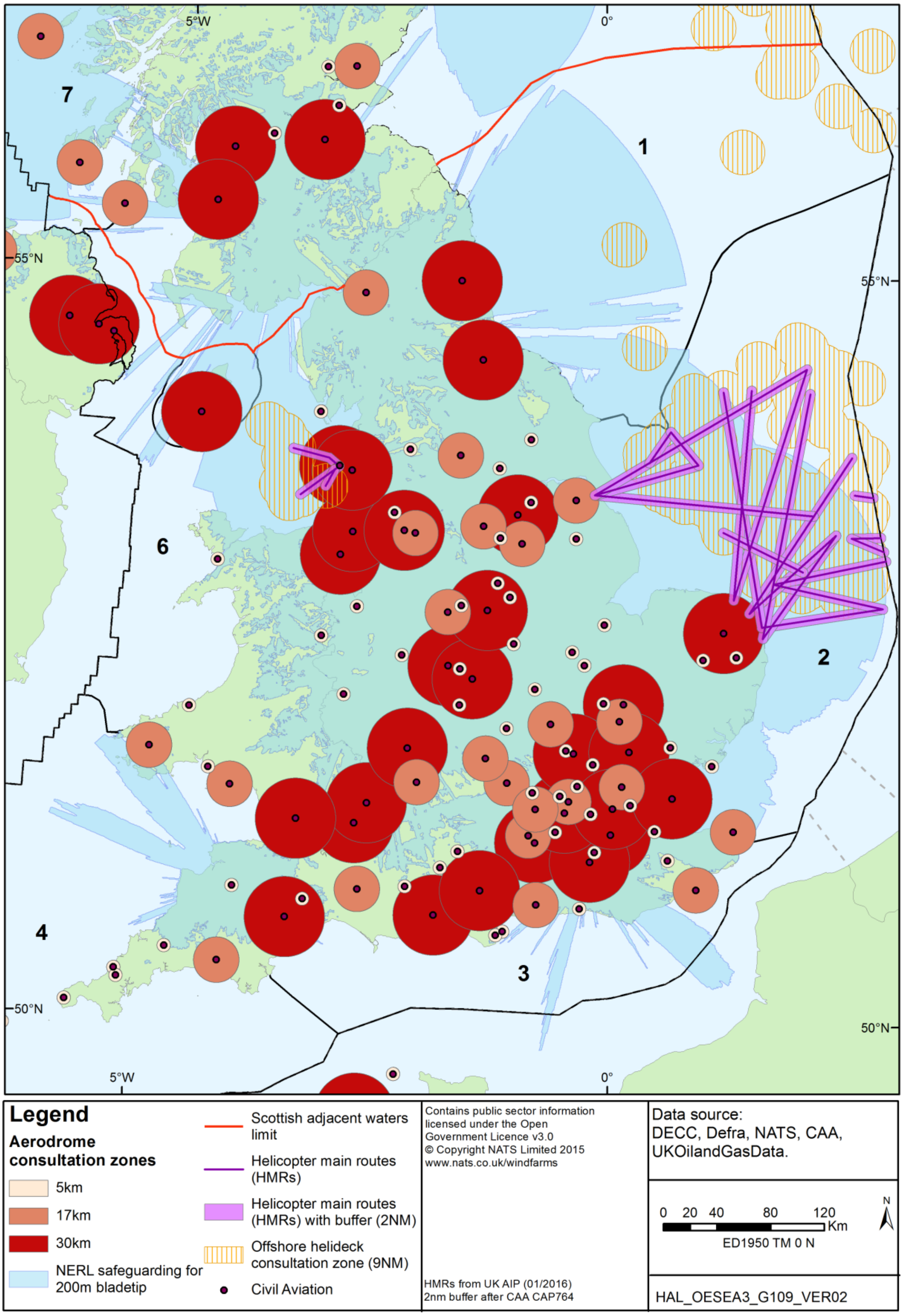
Additionally, consultation zones with a radius of 9nm are established around offshore installations. These are not development exclusion zones but present a space around each installation within which consultation with helicopter and installation operators should take place. This area allows for space within which low visibility approaches and missed approaches can be safely made, and encompasses 360˚ around an installation. Approach procedures typically commence at 8nm distance, with final approach starting at 5-6nm distance and a minimum flight height of 200-300ft is reached within 2nm of the helideck; any obstacle within 9nm of a helideck may therefore affect operations, particularly where low visibility flight operations are routine.

Consultation with helicopter and installation operators provides the opportunity to mitigate potential effects of wind farm obstructions should they fall within part of those areas (HMRs, consultation zones) described above. For example, consultation during the Hornsea Zone 1 and 2 planning process allowed for acceptance that a deviated route around the wind farm would be taken during periods where helicopters could not overfly the area due to

[83] Installed through agreements reached between the MoD and wind developers, the TPS-77 allows for the creation of a three dimensional Non Automatic Initiation Zone (NAIZ) to prevents false returns and allow continued tracking of aircraft over the NAIZ. The latest Aviation Plan (DECC 2015g) indicates that trials are ongoing to optimise the performance of these radars against specific wind farms. The latest updates may be found in the minutes of the Aviation Management Board: https://www.gov.uk/government/groups/aviation-management-board-aviation-advisory-panel-and-fund-management-board

meteorological conditions (see Smart Wind 2013c). No other Round 3 wind farms which have been consented or are in the planning process have been inside an HMR.

Figure 5.34: Areas identified by the CAA within which there may be potential constraints for wind deployment



DECC, made an assessment of the potential constraints turbines of a certain elevation within 9nm of an installation could present to helicopter operations within consultation zones, and also the potential airspace likely to remain around a platform for missed approach procedures given the available wind data, the results of which were deemed acceptable by helicopter operators.

In order to identify wind turbines as potential obstructions to aviation interests, particularly those which are low flying, guidance on markings and lightings is provided in a range of policy and guidance documents (e.g. CAA CAP764, and also MGN371 in relation to Search and Rescue (SAR) operations), and also in legislation (e.g. the *Air Navigation Order 2009*, also refer to CAA document, CAP393). There is a statutory requirement for lighting of any wind turbine located in territorial waters and greater than 60m in height above highest astronomical tides (HAT);although the CAA may specify additional lighting, the Regulations require at least one medium intensity light visible in all directions, with only peripheral turbines having the requirement in larger farms. Analogous to shipping navigation interests (above), offshore wind farms are typically charted in the UK AIP, this allows for the issuing of Notices to Airmen (NOTAM) in the event that turbine lighting has failed (CAA 2012). Most recently, the MoD (2014) have provided guidance on the lighting of offshore wind farms, which includes both visible and infra red lighting. The guidance also includes a lighting standard developed through a multi-lateral air-sea trial to satisfy both navigational and aviation requirements. The standard exceeds that of other CAA, MCA and Trinity House requirements and the MoD place new emphasis on lighting due to SAR interests[84]. Requirements on markings of wind turbines in relation to helicopter based SAR have also recently been updated through changes to Emergency Response Co-operation Plans (ERCoPs), including marking of turbine blades with hover reference marks at 10m, 20m and 30m distance from the nacelle, and also with blade tips marked in red. More generally, ERCoPs allows for the creation of plans for specific OREIs in relation to SAR.

The potential for interference with aviation operations remains a concern as the number and size of turbines in UK waters continues to rise; work is ongoing to ensure that effects of wind turbines on aviation interests can be successfully mitigated. Experience has indicated that, to date, large wind farms can be compatible with aviation interests. Future offshore wind farms using fixed foundations are likely to continue using the shallow southern North Sea and East Irish Sea areas, with the possibility of existing wind farms also being extended. Conversely, the deployment of turbines at greater distance from the shore has the potential to avoid a range of other user interests, including of aviation – see Section 5.15 for a discussion. While costs may be prohibitive for commercial scale deployment in the immediate term, the potential to deploy tethered turbines in a cost-effective manner may be possible in the 2020s (see ETI 2015, Section 5.15).

5.7.2.5 Dredging and aggregates

Dredging and aggregate extraction have the potential to be impacted through exclusion from prospective areas by the construction of offshore energy infrastructure. The depths at which certain technologies covered by the draft plan/programme are likely to be deployed during the currency of this SEA are technically and economically limited (see Section 5.15), and for wind farms in particular, siting has concentrated on shallow areas and sand banks which are also favoured for aggregates extraction (particularly in Regional Sea 2). The potential area of suitable aggregate resource is large (e.g. see Appendix 1b and 1h), however licensed areas or those defined as exploration or option areas are more geographically restricted (see Figure

[84] Note that SAR in UK waters is now undertaken commercially, see Appendix 1h.

A1h.29), and the actual area of seabed dredged is small. Both the licensed area and area dredged has declined significantly in the last 15 years (see Appendix 1h).

Aggregate supply, which is concentrated in the south and south east, with smaller areas in the Irish Sea and Bristol Channel/Severn, is strategically important to the UK, and a level of safeguarding of these resources to provide a consistent supply is indicated in the MPS and East Marine Plans (policies AGG1-2). These policies indicate that proposals, which would include activities associated with the draft plan, are unlikely to be permitted in licensed, application, exploration and option areas unless there are exceptional circumstances[85]. Additionally, assessments for new developments must consider (presently just in the East Marine Plan areas), the potential impact on wider prime aggregates resources (policy AGG3), also see (MMO 2013c). Aggregates areas are considered further in Section 5.15 as part of an overall spatial appraisal of constraints on plan related activities.

5.7.2.6 Tourism and recreation

The potential for conflict between recreational users of the marine environment and offshore energy installations is predominantly derived from exclusion, the potential for collision risks (e.g. to recreational sailing) and visual intrusion. The tourism industry is socially and economically important to the UK and the coast in particular has been a popular destination for British holidaymakers of all age groups (see Appendix 1h). Its importance is recognised in the MPS (Section 3.11), including its sensitivity to seasonality, which has been regionally defined in a number of plan policies (TR1-TR3) for the East Inshore and Offshore Marine Plans. In addition to potentially transient effects from construction including noise and visual intrusion (largely from nearshore pipe or cable installation and landfall), longer term effects may be derived from physical obstruction to recreational sailing activities and changes in landscape or seascape character – the latter is discussed in Section 5.8.

The Royal Yachting Association (RYA) has developed an atlas of cruising routes, general sailing and racing areas around the UK (described in Appendix 1h). The atlas identifies areas of use, indicative routes and intensity of use, however confidence in actual use is generally low (see Anatec 2012). The RYA is in the process of updating the atlas and augmenting it through the use of AIS data to examine the passages of recreational craft, while recognising the limitations of this system for small vessels which may not have AIS installed – local knowledge is therefore important at the development level. An RYA (2015) position paper identifies the concerns of recreational craft users, which include displacement (e.g. physical exclusion through loss of recreational routes, interference with racing areas and potential loss of and access to sheltered harbours and anchorages) and enhanced collision risk derived from wind turbine blades and subsea infrastructure such as tidal stream devices and cable protection materials. Note that for offshore wind, RYA (2015) indicate a minimum rotor tip air draft of 22m above mean high water springs would minimise potential collision risks[86] with rotors, guidance which has been taken into account in current UK offshore wind farm design.

The potential effects of tidal range devices differ from offshore wind, wave and tidal stream devices, in that they will be shore connected, and potentially in close proximity to harbour approaches, or in the case of barrages, introduce changes to how certain areas are navigated. Additionally, changes in water levels, speeds and also morphological changes due to alterations

[85] Note that such circumstances can include the licensing of an area by DECC for oil & gas activities, subject to agreement with the leaseholder.
[86] Also note that RYA (2015) indicate that to date there have been no recorded life threatening incidents involving recreational craft reported to HM Coastguard.

in sedimentary process (see Sections 5.4 and 5.5) have the potential to affect navigation generally (as above) including recreational users (e.g. as identified by DECC 2010i,j).

Many of these issues are reflected elsewhere in navigation guidelines (e.g. in relation to lighting and charting) and also in national policy including the MPS, Energy NPS EN-3 and regionally in the East Marine Plans with regards to the requirement for proposals to consider the effects of developments on recreational craft and their activities, and to minimise and mitigate against any effect. The RYA cruising routes and sailing areas are considered further in Section 5.15 in relation to wider potential spatial interactions and constraints to future renewables deployment in UK waters.

5.7.3 Controls and mitigation

The range of controls and potential mitigation options to avoid significant effects from plan/programme activities on other users of the sea and coasts are described above and in Appendix 3. These encompass legislation, assessments required as part of the consenting processes, guidance, best practice liaison and stakeholder engagement, and marine spatial planning which in due course will cover all UK waters. As a consequence it is considered that with appropriate siting and liaison, significant effects on other users from plan/programme activities can be avoided.

5.7.4 Summary of findings and recommendations

The primary issues for other users of the marine environment relate to navigation risk and the interactions of fishing activities with marine devices, although it is recognised that poorly sited developments can have significant effects on other users, including coastal tourism and recreation.

Exclusion and displacement as a result of offshore development reduces the remaining area available for other users to operate in. As navigation routes, and grounds for fishing, aggregate dredging and other activities become excluded from areas of offshore development, other areas may come under increasing pressure from multiple potential users and competition between users will be concentrated in the smaller space available. While each individual offshore development may only result in a relatively minor route adjustment or displacement, the cumulative effect of several such developments can lead to significant displacement and barrier effects. For industry, and particularly small-scale industry activity such as inshore fisheries, the combination of an enforced route adjustment, coupled with exclusion from all or part of a favoured fishing ground, could have a significant and damaging economic impact.

The seas around the UK contain important navigational routes for international shipping. The English Channel and the southern North Sea in particular support high levels of vessel traffic between the UK and the continent; the Irish Sea is also important. Offshore developments in UK waters may affect vessels travelling to or from the UK across administrative boundaries. Any resulting route alterations may have effects on ports currently supporting vessels traversing these routes.

Monitoring data of existing OWF suggest that regular users of the area adapt to altered routes and in busy areas the introduction of a traffic separation scheme can significantly reduce any risk of accidental collision. Whilst individual risk assessments have concluded that, in keeping with guidance, the effects of individual developments, and cumulative/transboundary effects are acceptable, for some areas such as the southern North Sea and east Irish Sea, the imposition of further large wind farms has the potential to lead to significant changes in shipping activity and a requirement for some form of additional routeing. The MMO has a duty to keep the marine plans under review, and it is understood that a review for the East Marine Plans could take place as early as 2017 (three years following publication), by which time a number of the Round 3 wind farms should either be operational or under construction (see Figures 5.31-5.33). It is recommended that a key part of this review is to further analyse AIS and other shipping data and to consider whether stronger policy wording (i.e. the creation of "clearways") where further development cannot take place is required. Further routeing measures can be referred to the IMO for adoption by individual Governments. Any such routeing would require engagement and agreement for all waters of the British Isles as well as international coordination for transboundary routes since there are wind farm and other development proposals in the waters of adjacent states.

As wave and tidal developments are currently at demonstrator scale, the spatial extent of commercial scale arrays of these developments and the implications for navigation are difficult to ascertain, although regulations on charting, lighting and navigational aids mean that they are unlikely to be any more of an issue than OWF developments. The displacement of shipping and subsequent impact on the cost of shipping and port revenues is potentially significant, and should be taken into account when siting arrays of wet renewable devices.

The effect of offshore installations on fishing activities are more complex, with negative effects of the exclusion of large areas and potential displacement to other areas and therefore intensification countered by positive effects on fish stock numbers, seabed disturbance and reef effects. At a strategic level the siting of major renewable energy developments (especially ones covering large areas or multiple arrays in close proximity) needs to consider fisheries implications (and potential mitigation for them) and avoid any areas of significance.

5.8 Landscape/seascape

Assessment Topic	Potentially Significant Effect	Oil & Gas	Gas Storage	Carbon Dioxide Storage	Offshore Wind	Tidal Stream	Tidal Range	Wave	Assessment Section
	Potential effects of development on seascape including change to character (interactions between people (and their activities) and places (and the natural and cultural processes that shape them))	X	X	X	X	X	X	X	5.8

Note: [1]outline assessment only

5.8.1 Introduction

There are three principal considerations for an assessment of the likely impacts of offshore energy activity on the seascape/landscape of UK waters and coastlines:

- the limit of visual perception from the coast (i.e. are the devices or installations visible and what influences their visibility)
- the individual characteristics of the coast which affect its capacity to contain a given development
- how people perceive and interact with the seascape, and what changes in character may be introduced by certain developments

Prior to the development of offshore renewables, offshore energy developments in UK waters have primarily been 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 (e.g. former fabrication and maintenance yards such as that at Nigg and Ardersier, terminals), and shipping and helicopter movements. Drilling activity and production platforms have in the most part been too far from shore to be visible, notable exceptions being Beatrice in the Moray Firth, exploration wells sites off Dorset and Cardigan Bay, structures in the east Irish sea and those associated with the Cromarty Firth rig support industry.

The more recent development of offshore renewables, namely offshore wind farms (OWFs), has led to a greater consideration of landscape/seascape issues as they are relatively large (160m blade tip for a representative 3.6MW turbine, though up to 190m for larger units), and numerous (for example Gwynt y Môr contains 160 turbines), and until recently technically limit in the depths to which they could be deployed and therefore favouring shallow nearshore sites. In the UK, OWFs have therefore largely been coastal phenomena, however the more recent Round 3 developments are largely located further offshore, and significant cost reduction in fixed and floating foundations makes sites further from shore more desirable, and there are typically fewer constraints in these areas (see Section 5.15).

Tidal stream and wave developments remain at demonstration scale to date, and it is not envisaged that large commercial scale deployments will take place within the currency of this SEA. The technical resource, and therefore locations where such devices may influence landscape, is spatially restricted (see below). Tidal range developments will interact with any landscape they are set within, both directly as they are coastal connected, and indirectly through any other potential changes they may generate (e.g. shipping pattern and type and for larger barrage projects, intertidal extent).

For some developments, particularly offshore wind, there is the potential to mitigate coastal effects through siting further offshore, whereas others are shore connected or have a largely nearshore resource, and therefore are inherently visible within the landscape/seascape. Offshore oil and gas, gas storage and CCS installations will typically be small, isolated, distant from shore, and perhaps entirely subsea.

The following sections therefore concentrate primarily on potential effects from offshore wind deployment, but also consider the potential location of other renewables deployment in relation to landscape designations and other features.

5.8.1.1 Planning policy context

The planning policy and wider context of landscape/seascape is set out in Appendix 2. Key areas of UK policy are outlined below.

The Marine Policy Statement (MPS) arising from the *Marine and Coastal Access Act 2009* states that all coastal landscapes should be considered in the preparation of marine plans, not just those which are protected through designations, which is broadly complementary to the tenets of the European Landscape Convention (see Appendix 1c). The East Inshore and Offshore marine plans include a seascape specific policy (SOC3), which states:

Proposals that may affect the terrestrial and marine character of an area should demonstrate, in order of preference:

- that they will not adversely impact the terrestrial and marine character of an area
- how, if there are adverse impacts on the terrestrial and marine character of an area, they will minimise them
- how, where these adverse impacts on the terrestrial and marine character of an area cannot be minimised they will be mitigated against
- the case for proceeding with the proposal if it is not possible to minimise or mitigate the adverse impacts

The East Inshore and Offshore marine planning process involved the commissioning of a methodological pilot study for seascape assessment, which was developed by Natural England and formalised in, *An approach to Seascape Character Assessment*, published in 2012. It is anticipated that this methodological approach will be replicated for the other marine plan areas as they are undertaken, and the assessment for the east and south marine plan areas has, amongst other sources and best practice, paid attention to this guidance.

Planning policies, for instance The National Planning Policy Framework and the Energy National Policy Statements (e.g. EN-1 and EN-3), exact the highest degree of protection to "most valued" sites (i.e. statutory designated areas such as Ares of Outstanding Natural Beauty (AONBs)), but do not propose that development should be precluded within them where project design would not conflict with the interests and features for which the sites are designated. More generally, they state that all developments should be well designed and in keeping with the scale and character (modern and historic) of the local area. Linked to this topic is that of the historic environment (e.g. listed buildings, UNESCO world heritage sites (WHS), scheduled monuments), where their setting is considered to be relevant to their designation or appreciation[87], guidance for which has been produced by Historic England (2015).

5.8.2 Consideration of the evidence

In view of the first bullet in the introduction above, the following considers the limit of visual perception of offshore energy installations from the coast, which primarily relates to offshore wind but is applicable to other offshore structures. The potential sources of effect from submerged or partially submerged devices are also considered. The visibility of structures at distance from the coast is dependent upon a series of compounding factors including atmospheric/meteorological conditions (haze, precipitation, fog), the chromatic contrast of structures at sea and their surroundings (i.e. sea and sky), the arrangement/complexity of offshore activities, and also the structure height (dipping height) of offshore objects which may be above the level of a given horizon.

5.8.2.1 Curvature of the earth and theoretical visibility

The curvature of the earth influences the visibility of offshore structures but is negligible except at very long distances – for instance an observer of height 1.5m would still see the top of a structure 160m in height, 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 (after Scott *et al*. 2005):

$$d = \sqrt{2rh1} + \sqrt{2rh2}$$

(Where: d=visible distance, r=radius of the earth (7,430km accounting for atmospheric refraction), h1=height of observer, h2= height to top of structure).

For example, the sum of the height of an observer at 50m (+1.72m for average height of person) in addition to the height of a structure (160m) gives 217.2m. The resulting maximum theoretical viewable distance would be 57km. DTI (2005) guidance in relation to wind farms considers that effects are likely to arise when the nacelle becomes visible at the horizon, as it is debatable as to whether blade tips can be distinguished by the human eye at such long distances. For 5MW and 10MW turbines with nacelle heights of 112m and 115m, and blade tip heights of 175m and 190m respectively, the visible distance is theoretically around 10km greater for blade tips than nacelles. Other factors are locally important, including screening by embankments or vegetation, and increased elevation can also allow for a greater view of the horizon which can diminish the scale of the view that includes offshore structures, however this reduction may still cause an effect, for instance, if in a designated landscape (White Consultants 2016)

Table 5.23 indicates the “worst case scenario” of theoretical visibility for wind and marine renewable devices from a range of viewer heights which are available at the coast, or within 10km of the coast, around the UK (also see MMO 2014d).

[87] For instance, “essential setting” and “”significant views” are identified in Wales in relation to registered Historic Parks and Gardens.

Table 5.23: Theoretical maximum viewable distance due to curvature of the earth

Viewer height (m)	Viewable Distance (km) Wind turbine nacelle (115m ASL)	Tidal stream structure (10m ASL)	Surface wave device (3m ASL)
1.7 (sea level)	46	17	12
9	54	25	19
22	60	31	25
100	80	51	46
150	89	60	54
250	102	73	66
500	128	99	93

Note: based on a turbine of 160m to blade tip with a rotor diameter of 90m (i.e. central nacelle height of ~115m). Lower values of 9, 22 and 100m are based on typical viewing heights stated in White Consultants (2009).

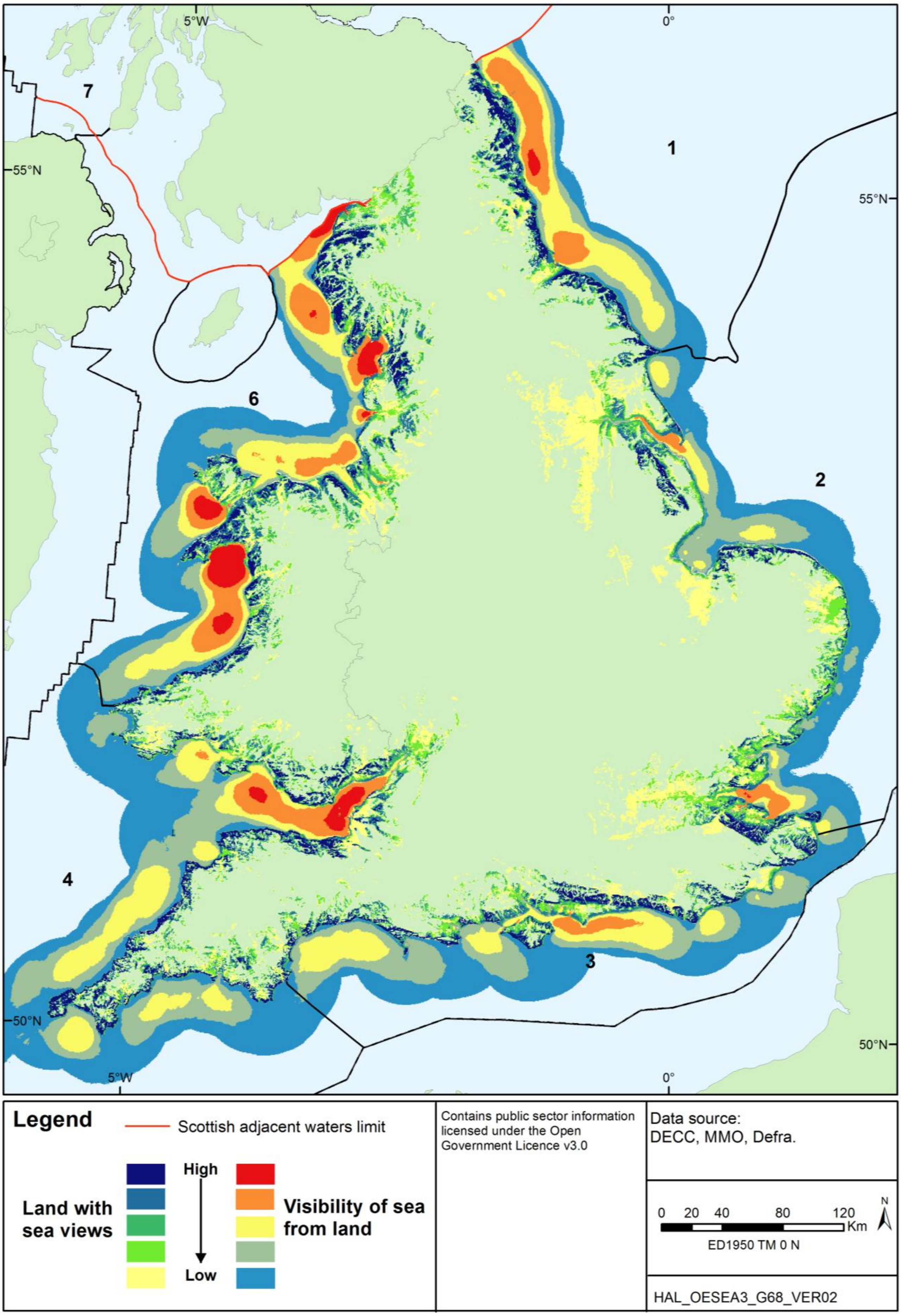
At a project specific scale, seascape studies consider the zone of theoretical visual influence (ZTVI) around a development, which is the extent of the potential visibility of a development. Digital terrain models and GIS tools are utilised to perform this calculation which takes into account, amongst 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 2005b).

As part of evidence gathering for the marine plans, viewshed analysis (Figure 5.35) was undertaken for the coast of England and Wales indicating land with sea views and sea visibility from land, based on methods used in MMO (2014d). This work can inform strategic level considerations of visual effects, however is limited as a more detailed understanding of the visual influence of individual developments can only be gained through a Seascape and Visual Impact Assessment (SVIA).

5.8.2.2 Contrast, lighting and navigational markings

The atmosphere is thickest at the horizon and appears lighter there, darkening overhead. Structures which are white and light grey (typical of wind farms) will contrast least, though certain devices requiring high contrast navigational markings will contrast more. Tall structures may be silhouetted by sunset or sunrise (White Consultants 2009) and therefore certain viewing aspects are more greatly affected than others.

Figure 5.35: Land with sea views and sea visibility from land, England and Wales



Lighting of renewables devices and other offshore installations must meet both Trinity House and CAA standards for marine navigation and aviation respectively, in addition to other requirements, for instance in relation to military activity. 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 could be viewable from a greater distance. Navigational lighting requirements for gas storage, including for carbon dioxide, will be analogous to those for oil and gas installations. 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. Those devices (typically tidal, though potentially also wave) which are completely submerged may still require identification buoys depending on their position in the water column. The level of marking will be decided after risk assessment. Appropriate navigation buoys (with lighting visible for 5nm) would be required at the corners of arrays and above sub-surface devices. With regard to wind farms, aviation lighting on the nacelle may appear to flash as turbine blades pass over them. Guidance on markings and lighting is provided in a range of policy and guidance documents (e.g. CAA CAP764, and also MGN371 in relation to Search and Rescue (SAR) operations), and also in legislation (e.g. the *Air Navigation Order 2009*, also refer to CAA document, CAP393). There is a statutory requirement for lighting of any wind turbine in territorial waters greater than 60m in height above highest astronomical tides (HAT), and though the CAA may specify other lighting, the Regulations require at least one medium intensity light visible in all directions, with only peripheral turbines having the requirement in larger farms. As the pace of rotational movement in each turbine may differ in any given farm, and the orientation of the blades for each turbine will be different, this may generate a sequence of irregular light flashes as the blades pass in front of the lights.

The MCA Marine Guidance Note (MGN) 371 outlines considerations which need be taken with regard to operational safety and emergency response in areas used by offshore renewable energy infrastructure (OREI), which is augmented by CAA CAP764, MoD (2014) and guidance relevant to Emergency Response Co-operation Plans (ERCoPs) – see Appendix 1h and Section 5.7 for more information).

MGN371 contains a number of recommendations, including for design requirements. Issues outlined in this paper which may influence the appearance of devices from the shore and at sea include:

- Wind turbines should be individually marked with characters which can be identified at 150m from vessels or 500ft from aircraft overhead
- Identification characters should be illuminated but baffled to prevent excess light pollution
- High contrast markings on the blades at 10m, 20m and 30m distance from the nacelle, and also with blade tips marked in red (updated using 2014 ERCoPS guidance)

5.8.2.3 Haze and meteorological factors affecting visual range

The above methods of determining viewable distance and visibility fail to take into account haze and meteorological conditions which might further limit visual range. Visibility affected by haze is the barrier to visual acuity brought about by atmospheric aerosols (Husar & Husar 1998). 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 5.24 indicates the maximum likely viewable distance at which the outline of an object can be made out given a range of UK specific coefficients. Scott *et al.* (2005) point out that this visual range is not the same as visual significance, though it will influence significance. The acuity of an individual's eye and the number, form and lighting of viewable objects will vary this distance (Husar & Husar 1998).

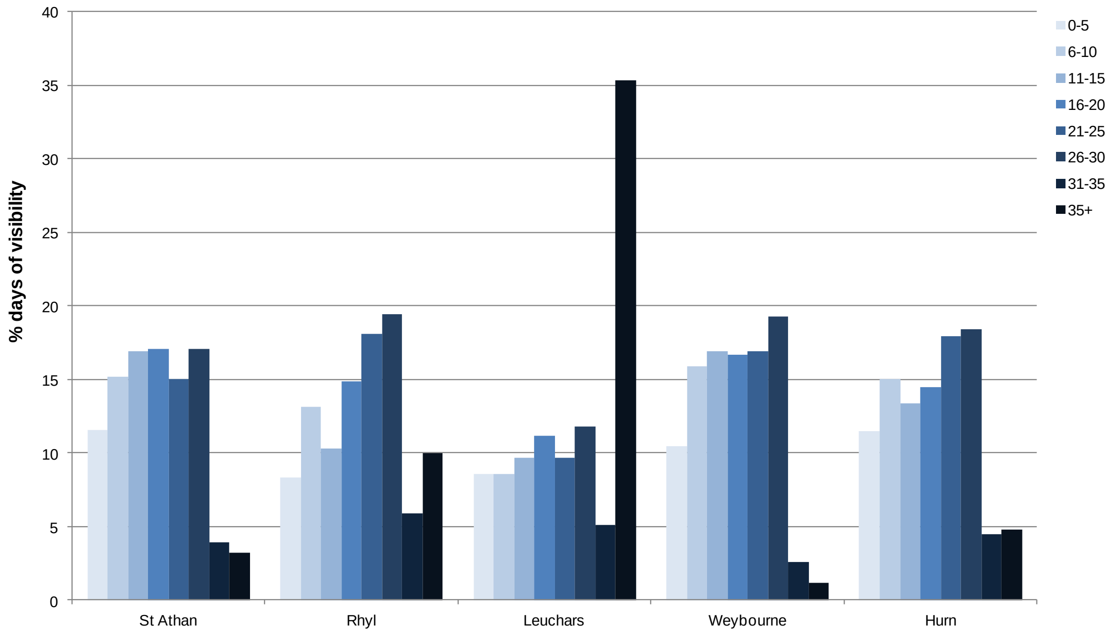
Table 5.24: The influence of haze on viewable distance

Applicable area and season	Haze coefficient (e)	Visual range (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).

The above 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. Figure 5.36 indicates the percentage of days where visibility falls within a range of distances over a 10 year period. With the exception of Leuchars, the majority indicate visibility is primarily 30km or below. The percentage average of days for all locations where visibility is within each of ranges is given in Table 5.25. White Consultants (2016) note that the methods used to collect this data may not provide an accurate view of visibility, as it does not take account of the varying conditions that may exist at certain distances offshore.

Figure 5.36: Percentage of days visibility for distances 0-35+ km over a 10 year period



Source: after White Consultants (2009, 2016)

Table 5.25: Distribution of percentage days visibility for coastal weather stations over a 10 year period

Station	Visibility distance (km)							
	0-5	6-10	11-15	16-20	21-25	26-30	31-35	35+
St Athan	100	88.4	73.2	56.3	39.2	24.2	7.1	3.2
Rhyl	100	91.7	78.6	68.3	53.4	35.3	15.9	10
Leuchars	100	91.4	82.8	73.1	61.9	52.2	40.4	35.3
Weybourne	100	89.5	73.6	56.7	40	23.1	3.8	1.2
Hurn	100	88.5	73.5	60.1	45.6	27.7	9.3	4.8
% Average for all	100	89.9	76.3	62.9	48	32.5	15.3	10.9
% Average without Leuchars	100	89.5	74.7	60.4	44.6	27.6	9	4.8

Source: White Consultants (2016)

Rainfall incidence, sunshine hours and propensity for fog provide additional meteorological factors in determining relative visibility of offshore structures (see Appendix 1f for a consideration of these). White Consultants (2016) note that turbines located 30km from shore may be visible only on limited occasions when haze and precipitation are low and sunshine remains bright.

5.8.2.4 Activity specific considerations

Offshore wind

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 for offshore wind farms (also see above). Considered in the context of nine SVIAs undertaken for various Round 1, 2, 3 and demonstrator scale projects, the maximum distance where a low magnitude of effect was found to occur is approximately 31.8km, with an average of 28.7km (White Consultants 2016). 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 (White Consultants 2009). Based on a further consideration of wind turbine size and SVIA results, the maximum and average ranges of low magnitude effects were not appreciably different for smaller (3-6MW) and larger (6-8MW) units (White Consultants 2016), and a trend was also noted that fewer larger turbines were considered more acceptable than many smaller ones.

Thresholds for significance based on distance from the shore for a range of turbine sizes are shown in Table 5.26. The threshold of significance used in this case is based on a ”worst case” scenario definition in DTI (2005), which is highly precautionary in judging moderate adverse effects as significant (White Consultants 2009, 2016). This is based on a series of wireline images and the judgement of professional landscape architects with experience in offshore wind farm visualisations. The images used an elevation of 22m, which corresponds with much of the coasts of east England and elsewhere in the UK. In most cases the threshold of no significance for medium sensitivity receptors was ~24km, and beyond 24km for high sensitivity receptors or 15MW turbines in all cases. Further conclusions of the work were that for high value and high sensitivity coastlines, a distance of 30km from the coast (the limit of visual acuity) could be attributable to developments for a range of sizes (e.g. 3.6MW to 15MW), whereas distances for areas of medium value and sensitivity may be in the order of 13km (3.6MW turbines), 20km (4-8MW turbines) or 20+km (10-15MW turbines).

In practice development scenarios will vary for each individual wind farm and also the variables determining visibility for individual wind farms. The visibility of structures from the coast, or their intrusion on sites designated for their visual qualities, does not necessarily preclude development in planning (see: NPS (EN-1) and the MPS), and any consideration of coastal “buffers” is too generalised an approach to take into consideration the many anthropogenic and natural variations along the coast and the variety of development scenarios which might take place (e.g. device type and design, array orientation). The application of indicative buffers has been used to inform this strategic level consideration in the absence of any future leasing and project plans, subject to development specific assessments being made. All marine plans in English and Welsh waters are due to be drafted within the currency of this SEA, and therefore further locational policy or guidance may be expected in the coming years.

Table 5.26: Thresholds of significance for a representative 500MW wind farm scenario (at 22m asl)

Turbine size (MW)	Distance from shore 13km	18km	24km	35km
3.6	Moderate and moderate/large	Small and small/moderate	Small	n/a
5	Moderate and large	Moderate and moderate/large	Small and small/moderate	n/a
7/8	Moderate and large	Moderate and large	Small	Very small
10	Large	Moderate and large	Small and small/moderate	Very small
15	Large	Moderate and large	Moderate	Very small

Source: White Consultants (2016)

Windfarm siting in the UK to date has largely taken place at or within 8km of the coast (present average 9.4km), with a few farms (e.g. Dudgeon and Race Bank) being located over 20km from shore. Areas of the East Irish Sea and southern North Sea presently have the highest concentration of OWFs in UK waters (see Figure 5.39 below). Turbine capacities of operating farms generally range from 2-3.6MW, with a height to blade tip in the order of ~160m. In English waters, the bulk of Round 3 proposals have been made in the southern North Sea (Regional Sea 2), generally for wind farms at greater distance from the coast, though comprising more numerous and larger (up to 7MW) turbines. These wind farms (e.g. Dogger Bank Creyke Beck, Hornsea Project One, East Anglia Two) are too distant to be perceived from coastal locations, but have the potential to alter the character of areas further offshore.

The Round 2 SEA (BMT Cordah 2003) considered that seascape issues became significant within a distance of 8-13km, but that the distance from the coast at which development was acceptable varied due to differences in the quality of the seascapes being considered. Similarly, though made as part of a wider range of considerations relating to the possible impacts from offshore wind, it was recommended in OESEA and OESEA2 (DECC 2009, 2011e) that developments should generally take place out with 12nm (~22km) from the coast (i.e. in offshore waters). Much like the recommendation made for Round 2, this was indicative and subject to a site specific consideration of potential effects (including on seascape) which may result in developments being more acceptable either closer to the coast, or further away. Landscape and seascape issues have been considered as significant for those Round 3 zones within viewable distance of the coast (Rampion, Navitus Bay, Atlantic Array). Whilst effects on landscape were identified for Rampion, the Secretary of State indicated that with agreed mitigation their effects were not significant enough to refuse the application. A greater number of landscape issues associated with Navitus Bay was the principal reason for the refusal of planning consent[88], and a number of significant seascape effects were identified for the Atlantic Array, though this was withdrawn for reasons other than landscape effect (White Consultants 2016).

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 and both its operational schemes are around 23km from shore, with another under construction at 85km distance. 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, and more recently Horns Rev 3 is located 20km from the shore and proposes to use 50 8MW turbines.

The deployment of offshore wind energy in Germany, in conjunction with other renewables, has increased considerably in recent years. The first operational wind farm in German waters was the Alpha Ventus, a testing site 45km from Borkum Island. The site originally consisted of 6 5MW turbines, though has been upgraded to 12. An additional 2.28GW of installed capacity was connected in 2015, an additional 7 sites are in pre-construction or construction phases, and another 19 are consented – all but one site lies between 42 and 110km offshore (White Consultants 2016). In Germany, seascape assessments are only required with developments within 50km of the coast. Of those projects mentioned above, almost all are at a distance of at least 35km from the coast, with the vast majority being further offshore than that (average 52.6km), which should all but eliminate visual disamenities of turbines for shore based receptors, though will obviously change the character of the North Sea and Baltic Sea from passenger ferries, recreational craft and other commercial ships.

Considering all European countries, the average distance of offshore wind farms from the coast has been steadily increasing. Those farms installed in 2008 were on average 10.5km from the

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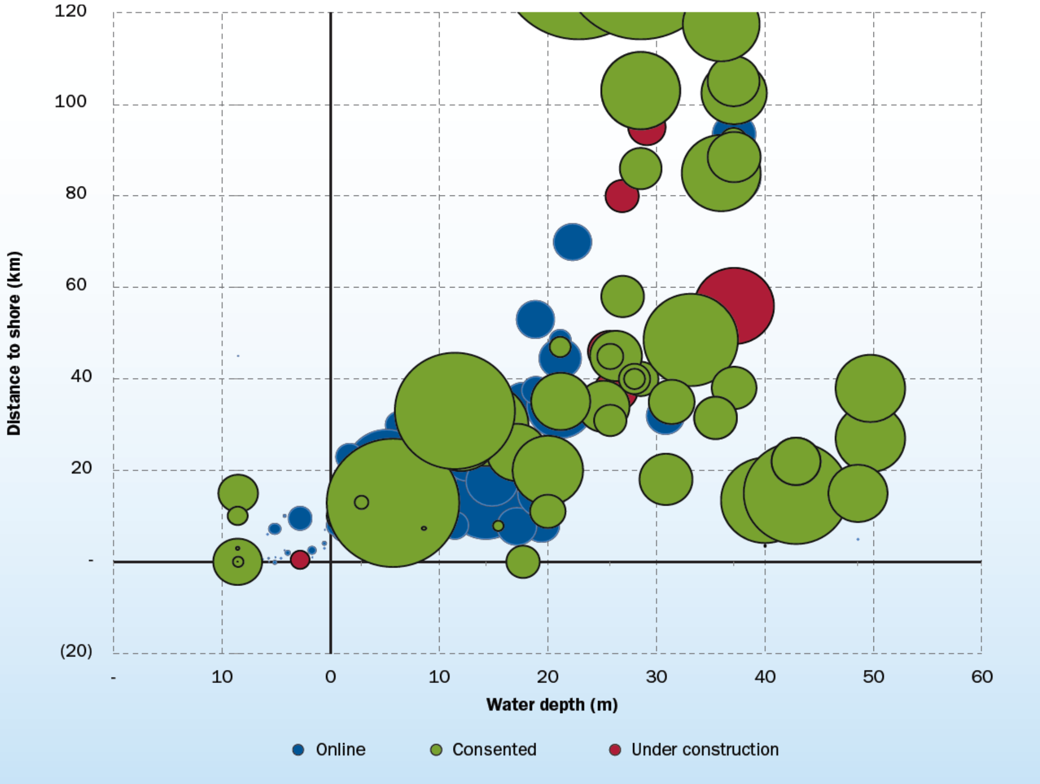
[88] http://infrastructure.planninginspectorate.gov.uk/projects/south-east/navitus-bay-wind-park/

coast, rising to 12.8km in 2009, 29km in 2012, 32.9km in 2014 and 43.3km in 2014 (EWEA 2016) (Figure 5.37).

Figure 5.37: Average European wind farm distance to shore in km



Source: EWEA (2016)

The lifetime of a wind farm may be in the order of 25 years, after which repowering may be an option. This could involve fewer, larger turbines as opposed to just the upgrading of turbine generators, blades etc. and so any OWF may be considered to have a long-term effect on landscape/seascape, and in time may come to be a significant component of landscape and seascape character.

Wave and tidal stream

The draft plan/programme considered in this SEA would allow for the progression of leasing/licensing of areas of the seabed for wave, tidal stream and tidal range technologies that will introduce a number of new visual components into seascapes. Seascape studies currently available for such technologies include those contained within the SEAs for marine renewables in Scotland (Faber Maunsell & Metoc 2007) and Northern Ireland (AECOM & Metoc 2009).

Very little work has yet been completed studying the impacts that wave and tidal devices may have on seascape. Indeed, the present demonstration phase of wave and tidal devices has led to a wide range of contrasting designs, the impacts of which will become more apparent as they progress towards commercial viability and are deployed in larger arrays. In an attempt to anticipate the level of impact a number of national scale studies for Wales, Scotland and Northern Ireland, have conducted assessments based on a few generic structure types. The same assessment criteria for landscapes and seascapes as used previously for offshore wind will apply to these devices, and as such, site specific and device specific impacts will need to be considered at the individual development level. The smaller vertical component of open water wave and tidal devices will make them less obtrusive at a closer distance to the shore compared with offshore wind.

The Wales regional seascape study (CCW 2008b) considered the possible impacts from tidal current and wave devices of a scale and form thought probable in the next 10 years, with tidal stream represented by vertical columns projecting from the sea surface (10x3m), and wave by broad, flat objects (3x400m) – e.g. similar in form to the Seagen tidal and Pelamis wave devices. Seascapes generally displayed less sensitivity to the wave scenario than to the tidal one, though in both cases headlands and areas with restricted or focussed views (e.g. along estuaries) recorded high sensitivities. It should be noted that this exercise only looked at a single scenario for each technology (which were not well defined) and seascape unit, and the impacts of particular wave and tidal designs may differ significantly from these. Similar scenarios for wave and tidal devices were considered by the Scottish Government in its marine SEA (Faber Maunsell & Metoc 2007) and in the Northern Ireland offshore energy SEA (AECOM & Metoc 2009), though recognising that surface point structures may also be wave devices, (e.g. the Aquamarine clam).

The Scottish study defined ten seascape types which could be attributed to specific study areas, for which a sensitivity score was then attached for linear, point and shore connected structures. The study outlined that the least sensitive seascapes were those that offered open and expansive views, while those with a large vertical component were of moderate sensitivity. In keeping with CCW (2008b), Faber Maunsell & Metoc (2007) and AECOM & Metoc (2009) regarded linear wave devices to have less of an effect on broad, open seascapes compared with point structures, primarily as linear structures may follow the natural movement of the sea and be partially hidden by wave motion. The more enclosed and complex seascapes found in the sounds and fjords of Scotland’s west coast were regarded as having the highest sensitivity to wave and tidal devices. Some devices such as the Openhydro open centre turbine are designed so that they have no surface component, and therefore visual impacts would be largely restricted to those occurring during deployment, monitoring and maintenance, and subsequent decommissioning, though any local substation would constitute surface infrastructure if it is required. Depending on the position of the device in the water column (i.e. whether it is at sufficient depth to be avoided by the draft of most vessels), these may be marked with buoys and navigational lighting (Faber Maunsell & Metoc 2007).

The Seagen tidal stream device in Strangford Lough, Northern Ireland, was an individual demonstrator project which is visible as a point surface structure, reaching 10m above sea-level. The Environmental Report for this development (Royal Haskoning 2005) indicated that the device would be visually obvious at all stages of development, which would affect views from land, particularly Portaferry, and the open seascape offered during ferry crossings. The requirements to use paints providing suitable contrast and lighting for navigation were highlighted as restrictions in making the device less visible, and that mitigation options were minimal. Visual impacts were considered most significant during maintenance as the turbine blades would be exposed above the water surface, though this is a temporary, but intermittent activity. Similar tidal stream devices are therefore likely to pose a transient visual impact proportional to the amount of time required for maintenance. Visual impacts present for the life of many submerged developments are therefore likely to be restricted to any local substation that may be required above water and associated landfall.

The operational lifetime of individual wave and tidal stream devices is uncertain, however individual farms may be in the order of 25 years, after which repowering may be an option. Any wave or tidal stream farm may be considered to have a long-term effect on landscape/seascape.

Tidal range

A seascape study was undertaken as part of the SEA for the Severn Tidal Feasibility Study (DECC 2008, 2010c) in addition to that already completed for a hypothetical inner barrage between Lavernock Point and Brean Down by Land Use Consultants (2007). Specific impacts (e.g. on individual AONBs, National Character Areas and viewing locations) for the Severn are presented in these reports, though only generic impacts are considered here as these may be more widely applicable to other estuaries considered for tidal range technologies in the UK. Barrages would alter the character of a given estuary due to land-use change associated with new infrastructure, for instance power cables and onshore development associated with the barrage (access roads and buildings), with significant effects predicted during construction and decommissioning (DECC 2010c). Any tidal barrage would be visible at all points in the tidal cycle and would block views in both directions on its landward sides. Secondary effects include the potential loss of intertidal habitat (and also associated fauna and flora), a reduction in the extent of intertidal areas at low tide, changes to water clarity and also shipping routes.

DECC (2010c) state that for the Severn tidal barrage, uncertainty surrounded what form intertidal areas would take following a change in sedimentation regime of the estuary, and how long it would take for such a new regime to become established. Therefore the consideration of landscape/seascape impacts of such structures is more complex than the more simplistic consideration given to other forms of offshore activity, and the Severn Tidal SEA recommended that local level, design stage visual assessment would be required to minimise impacts. Similar effects may be generated by lagoons, though some of these may be exacerbated at low tide as, depending on specifics of development design, more of the embankment structure would be exposed. Barrages may also be multi-use structures, incorporating a road crossing which could have its own street lighting that would be visible at night, in addition to the movement and lights of vehicles.

For any tidal range device, the imposition of a lagoon or barrage walls represents a long-term change. The lifetime for most tidal range proposals exceeds 100 years, and after this period repowering may be possible, or else the bulk of the structure may be left *in situ*.

Offshore oil & gas, gas storage and carbon dioxide storage

Carbon dioxide transport and storage facilities may have few visual components in the marine environment visible from coastal locations, and any associated structures may be restricted to the landfall of pipelines or increased, or new, port facilities at the coast and any associated tanker traffic. Gas storage operations may have similar impacts, having both onshore and offshore facilities. The Gateway Gas Storage project was the first proposal in UK waters to suggest for the use artificial salt cavern construction to provide gas storage capacity. The proposal included offshore facilities 24km from the coast and 20 wells, each with a monopod topside facility of dimensions 14x14m, reaching 50m above the seabed. It is uncertain whether this will be typical of the size, design and orientation of future developments of this type, and the results of the seascape study for this development (see Gateway Gas Storage 2007) may not generally be applicable to other locations, though provides an indication of how such facilities and offshore wind farms visually interact.

Though typically at some distance from the coast, a number of oil and gas facilities may be placed towards the coast in the near future. Many new oil and gas activities require only temporary surface infrastructure, as on completion many wells are tied-back to existing facilities. When this is not the case, longer term visual impacts may come in the form of jacket-type installations or FPSOs (which may be ship-shaped), and transient support vessel and aviation traffic. At night, any flaring and lighting from support vessels and rigs may also be visible from shore.

The operational lifetime of individual oil and gas developments will vary widely depending on the size of the resource discovered, production rates, and at what point economic recovery is no longer possible. Historically, large fields have had significant life spans (e.g. the Forties Field started production in 1975 and continues to produce oil), whereas smaller fields using tie-backs may have a lifespan of 10-25 years. Installations can be considered to have a medium- to long-term effect on landscape/seascape. Gas storage sites may have a long service life as they maintain both inject and withdraw gas depending on demand. CO_2 storage sites will have a life limited to the storage capacity of the formation and injectivity rate – the reverse of that for oil and gas production. Therefore the life of such installations will be similarly variable.

5.8.2.5 Seascape sensitivity

Assuming that a development is visible from the coast, a number of factors can be considered to determine the overall significance of the effect, which includes the sensitivity of the receptor or seascape and the magnitude of change. Aspects of landscape/seascape "value" are also of relevance which can be informed by the location of designated areas (landscapes such as Areas of Outstanding Natural Beauty (AONB), National Scenic Areas (NSA), National Parks, or other conservation features such as World Heritage Sites (WHS), scheduled monuments or landscapes of historic interest – see Figure 5.38 for an overview of designated areas), but a wider range of sites may help identify valued landscapes, including recreation value and conservation interests. Value is also locally variable, with stakeholders having differing views on what may be valued (LI & IEMA 2013), for example see Devine-Wright & Howes (2010).

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

The degree to which an offshore development alters or harmonises with a given landscape/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 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). Aspect influences structure visibility during sunset and sunrise, as they appear silhouetted against the sky.

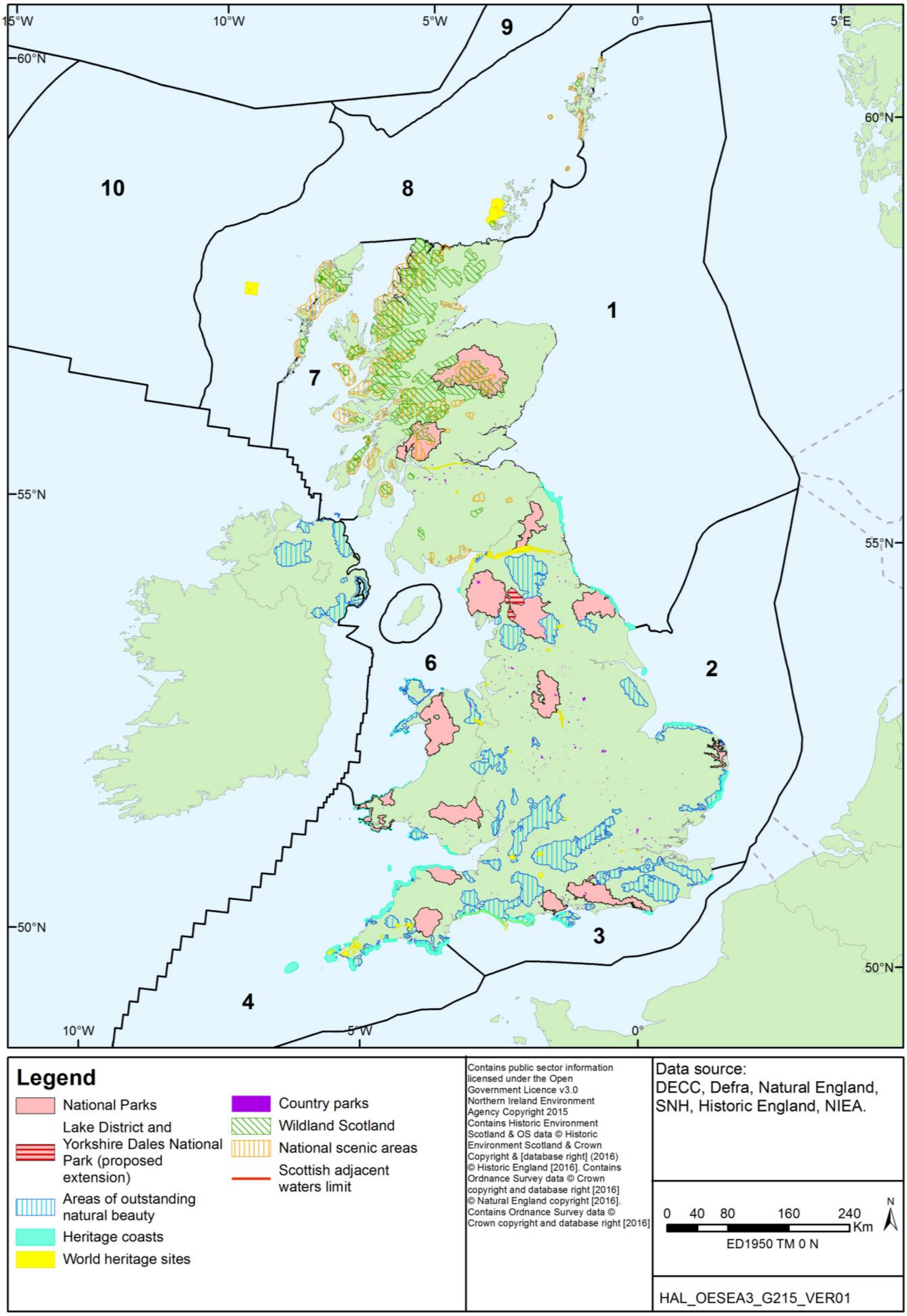
Outside of scale, form, aspect and exposure, seascape sensitivity is greatly influenced by the level of coastal development, and this can be highly variable within regional scale seascape units. Urban and industrial settings, areas where other forms of mechanical movement are present (e.g. ships, cars), 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 however, cumulative impacts must also be considered (DTI 2005).

Sensitivity is not just a measure of the compatibility of wind farms with coastal landscape, 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 is more complex. Income losses from tourism and recreation activity were a common source of potentially significant effect related to the landscape effects of the Rampion and Navitus Bay developments, and this is also recognised in the overarching NPS for energy (EN-1), MPS and policy TR1 of the East Marine Plans.

Many of the factors influencing perceived aesthetic (landscape/seascape) quality are relative and subjective concepts which are bound by any given individual's attitude, perceptions, and *a priori* or *a posteriori* knowledge about offshore energy developments or indeed environmental/energy issues more generally. Prior knowledge or experience of offshore wind farms may take a variety of forms however, and Ladenburg (2009) found that those people with experience of wind farms sited far from the shore were generally more positive about the visual impacts of future developments than those with experience of nearshore wind farms, and that demographic and use of areas which would be visually altered by wind farms affected attitudes to offshore wind (Ladenburg 2010).

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 "wise use" ideas falling within the umbrella of sustainable development. In each case, the inherent quality or naturalness of some landscapes are valued more than others, as recognised in statutory designations and the use of "value" in landscape/seascape studies. Wilderness may often have more to do with perception than any ecological understanding, for instance 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. In Scotland, a map of wild land areas was published in 2014 by SNH, with the areas developed following consultation on previously defined "core areas of wild land". Four physical attributes were considered to define wild land: perceived naturalness of the land cover, ruggedness of the terrain, remoteness from public roads, ferries or railway stations and visible lack of buildings, roads, pylons and other modern artefacts (see Appendix 1c). At a 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 (e.g. compared to that afforded under the *Land Reform Act* in Scotland), which helped to produce a public more constrained in their movements and range of permitted activities (Macnaghten & Urry 1998).

Figure 5.38: Principal landscape or landscape related designations in the UK



It is not just “wild” places where visual intrusion is regarded as deleterious, for the countryside or cultural aesthetic may be regarded to be 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 European Landscape Convention, and by association with certain cultural World Heritage Sites (e.g. the Cornwall and West Devon Mining Landscape).

A Countryside Commission (1993) report, though now dated, 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 81.5% of the population in England and Wales are urban dwellers (2011 census data, ONS 2013) it may be presumed that for many people, experience of the countryside is an important occasional relief. Surveys of awareness and attitudes to renewable energy, specifically onshore wind, indicate that people are generally in favour of the use of renewables, including wind power, and that the general population perceives advances in renewables as necessary (possibly linked with perceptions, knowledge relating to climate change, depleting hydrocarbon reserves). More recently (and considering a range of potential sources for a particular opinion, not just landscape issues), DECC launched a tracking survey to understand and monitor public attitudes to its business priorities in 2012, including for renewable energy. It was found (DECC 2016d) that support for renewables was high (75-80%), with specific support for offshore wind (73%) and wave and tidal (73%) found to be at similar levels (DECC 2015f). However the question which could be regarded as most pertinent to landscape/seascape, “*I would be happy to have a large scale renewable energy development in my area*”, attracted less positive support (55% agreed, 19% disagreed, and remainder did not know or showed indifference). Work undertaken for the Isle of Man in 2013 returned mixed results for marine renewables, with support being strongest for tidal devices rather than offshore wind (Willow Research & The Durham Energy Institute 2013).

Opinions on landscape issues related to wind farms, and therefore other marine developments, 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. Ladenburg (2009) notes a U-shaped change in attitude to offshore wind development, with attitudes being generally positive towards developments in the planning stage, with a general reduction in positive attitudes during construction, and a recovery following completion and operation.

5.8.3 Spatial consideration: outline assessment

Section 2.5 provides an indication of the prospectivity for each element of the draft plan/programme which gives an outline view of where activities could potentially take place on adoption of the plan/programme – see Table 2.2. An overall spatial consideration for each of the major plan elements where the technical resource can be defined is provided in Section 5.15. The following section makes use of the prospectivity of draft plan/programme activities to help frame the discussion (also refer to Figures 5.39-5.43), and is also informed by a range of information including landscape designations and the content of various national character area descriptions as referenced in Appendix 1c.

Figure 5.39: Designated landscapes in the UK, present wind leasing areas, and areas of technical and theoretical resource in relevant UK waters

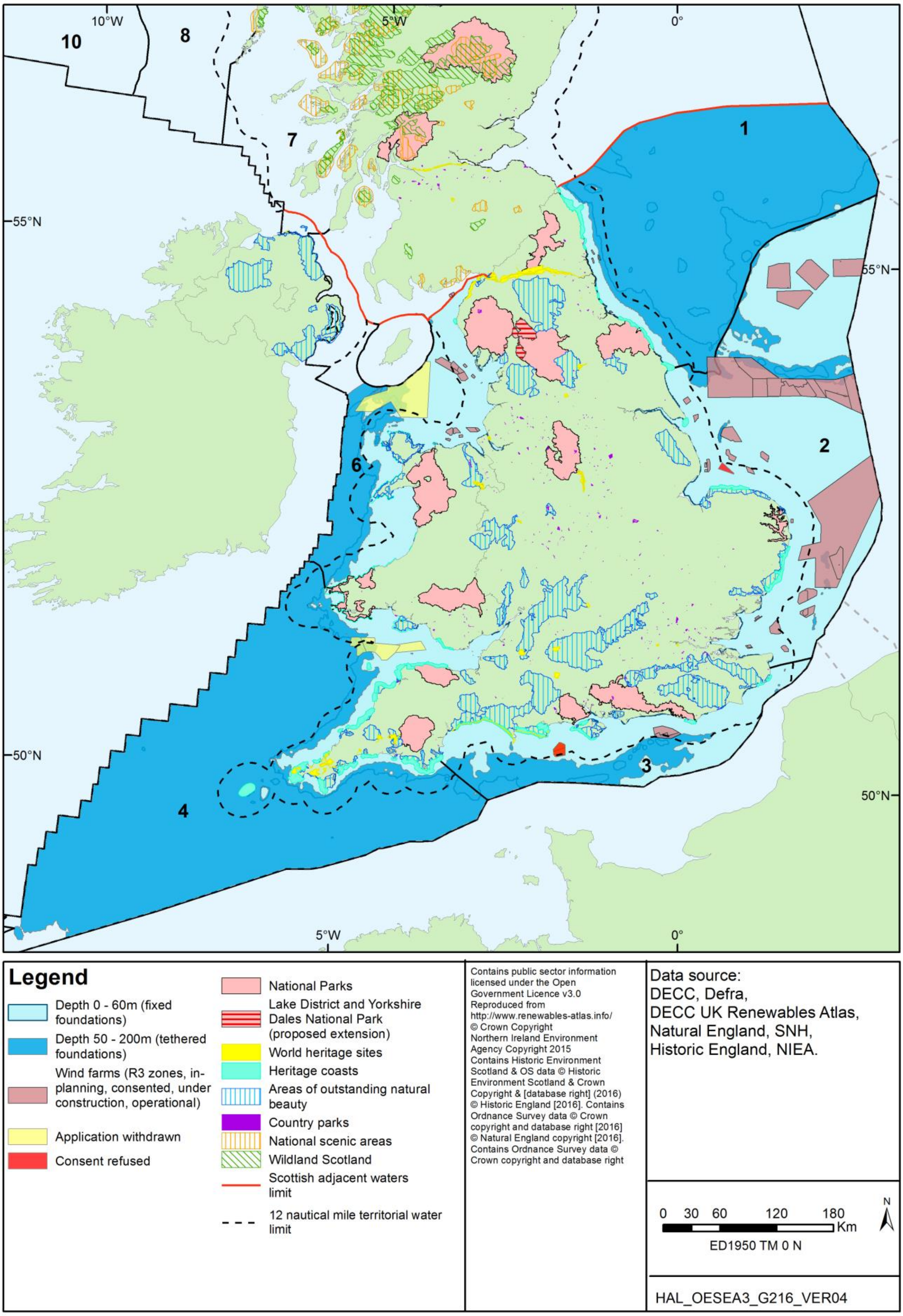


Figure 5.40: Designated landscapes in the UK in relation areas of technical and theoretical tidal stream resource in relevant UK waters

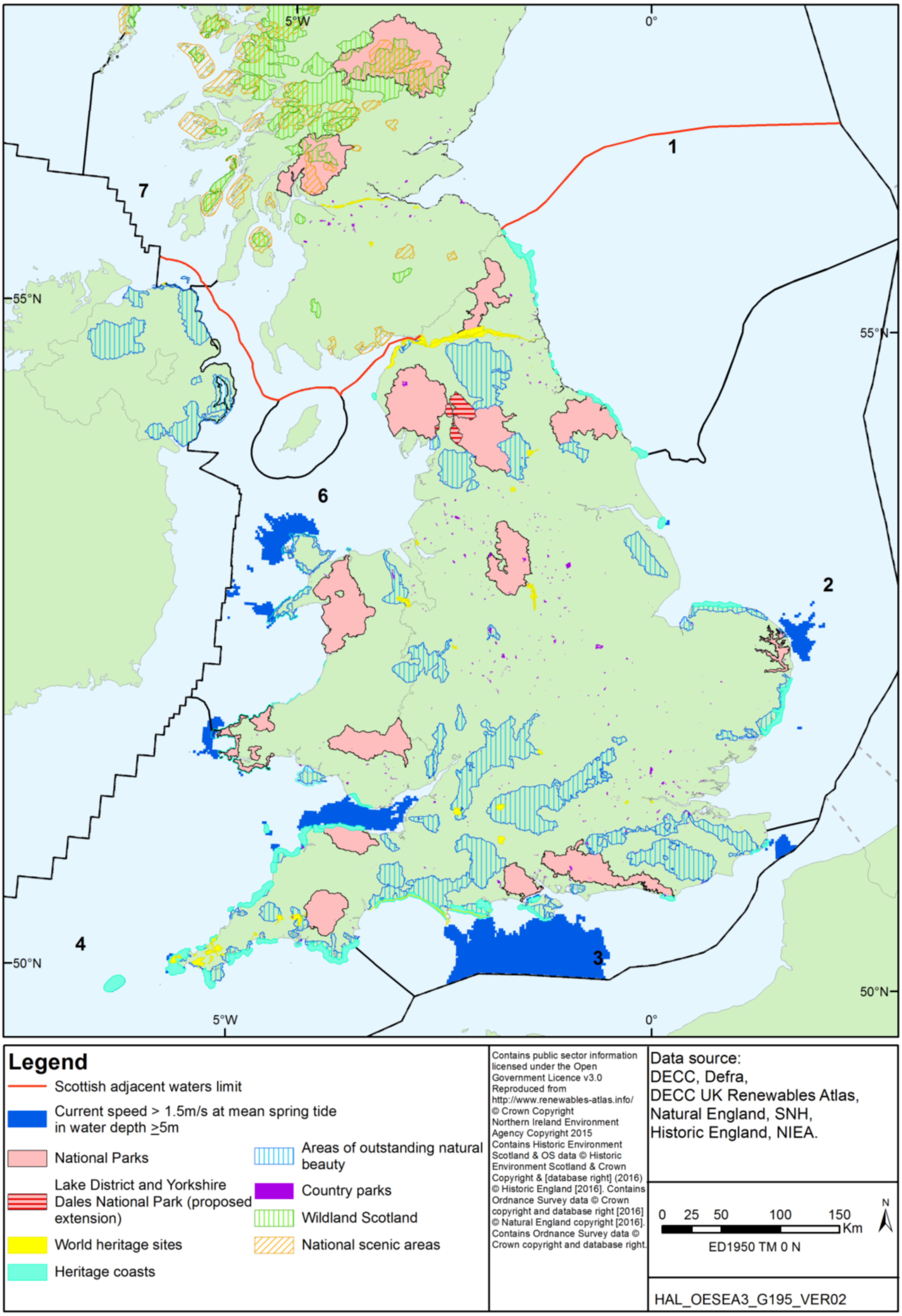


Figure 5.41: Designated landscapes in the UK in relation areas of technical and theoretical wave resource in relevant UK waters

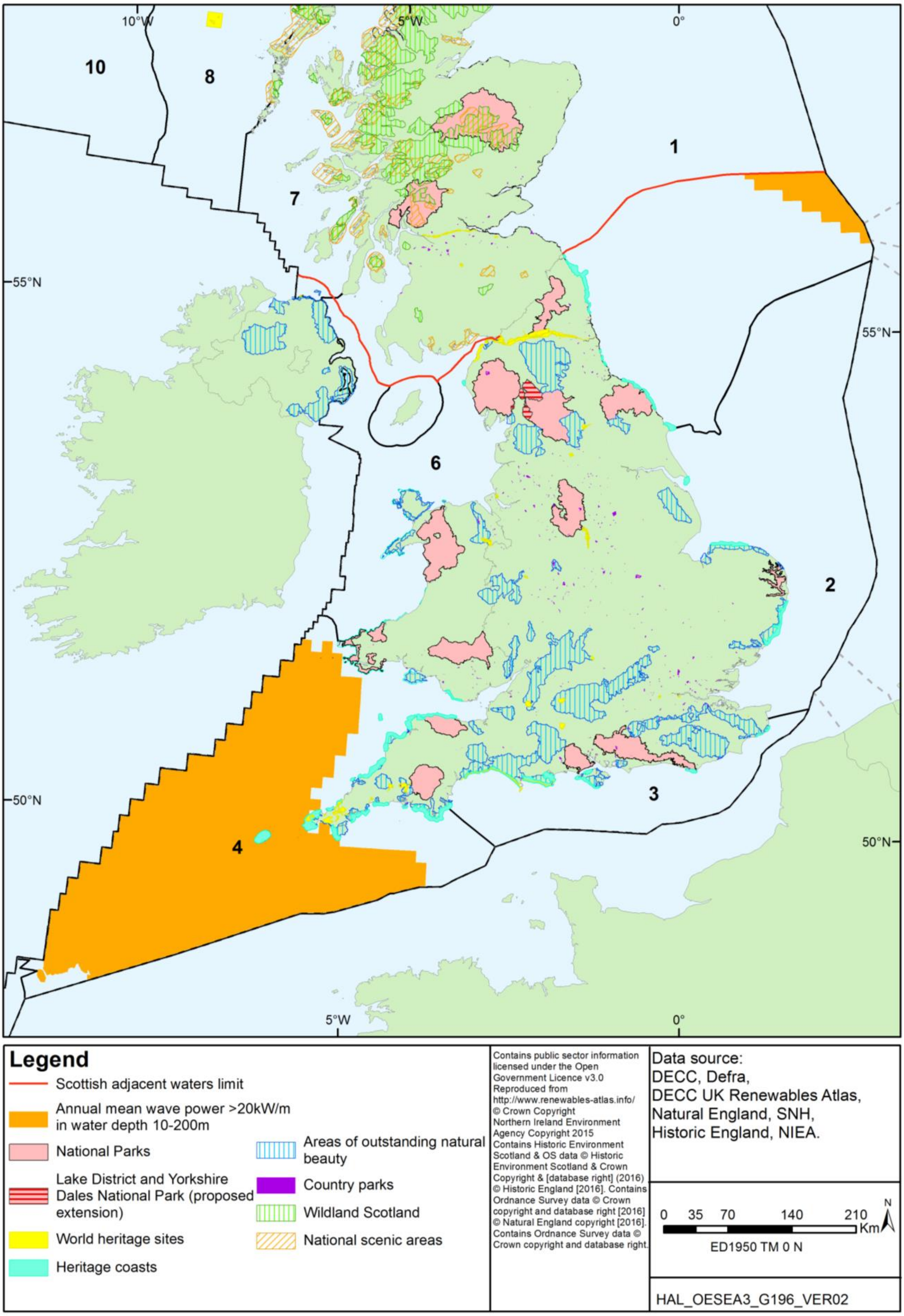


Figure 5.42: Designated landscapes in the UK and areas of technical and theoretical resource for tidal range in relevant UK waters

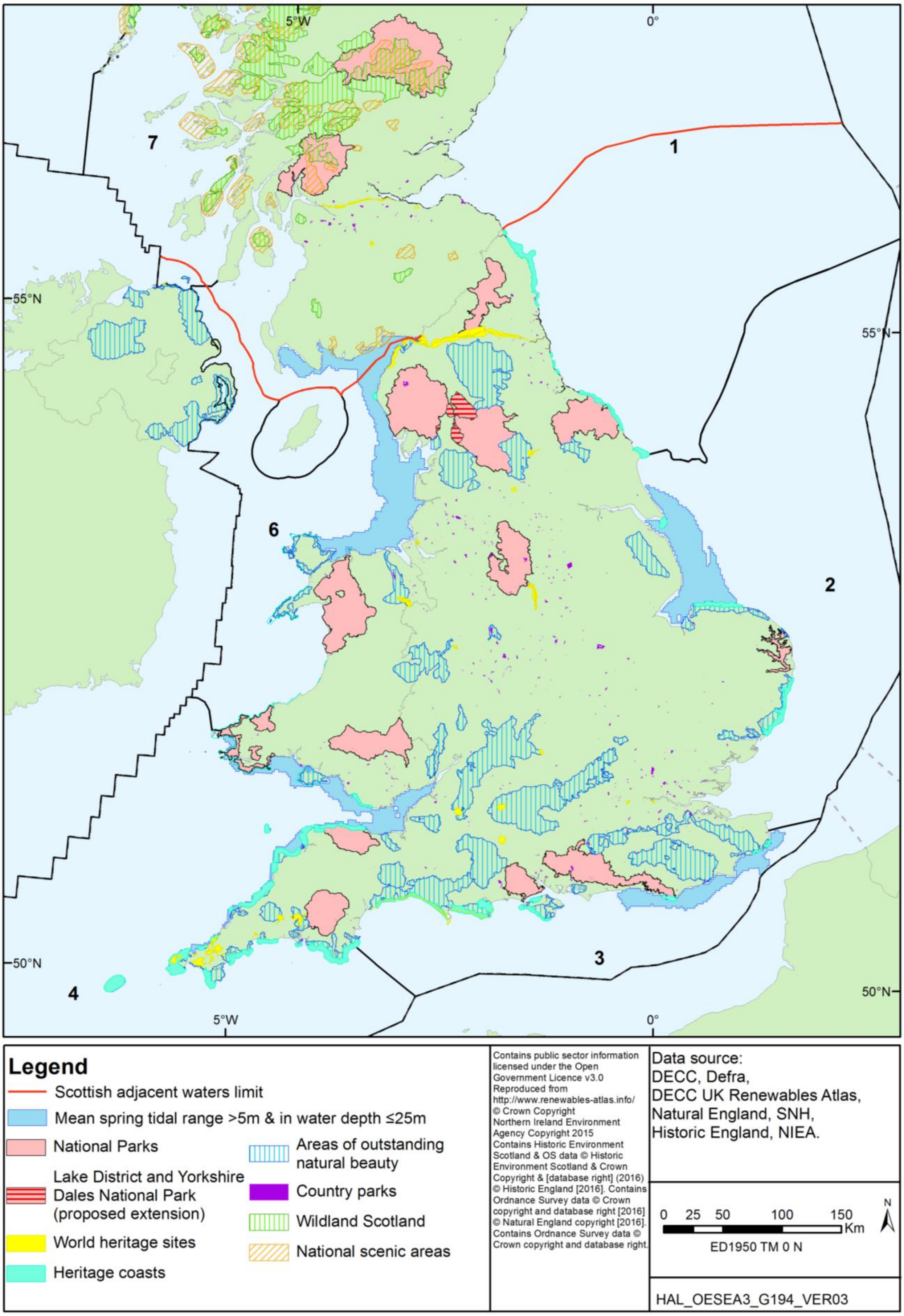
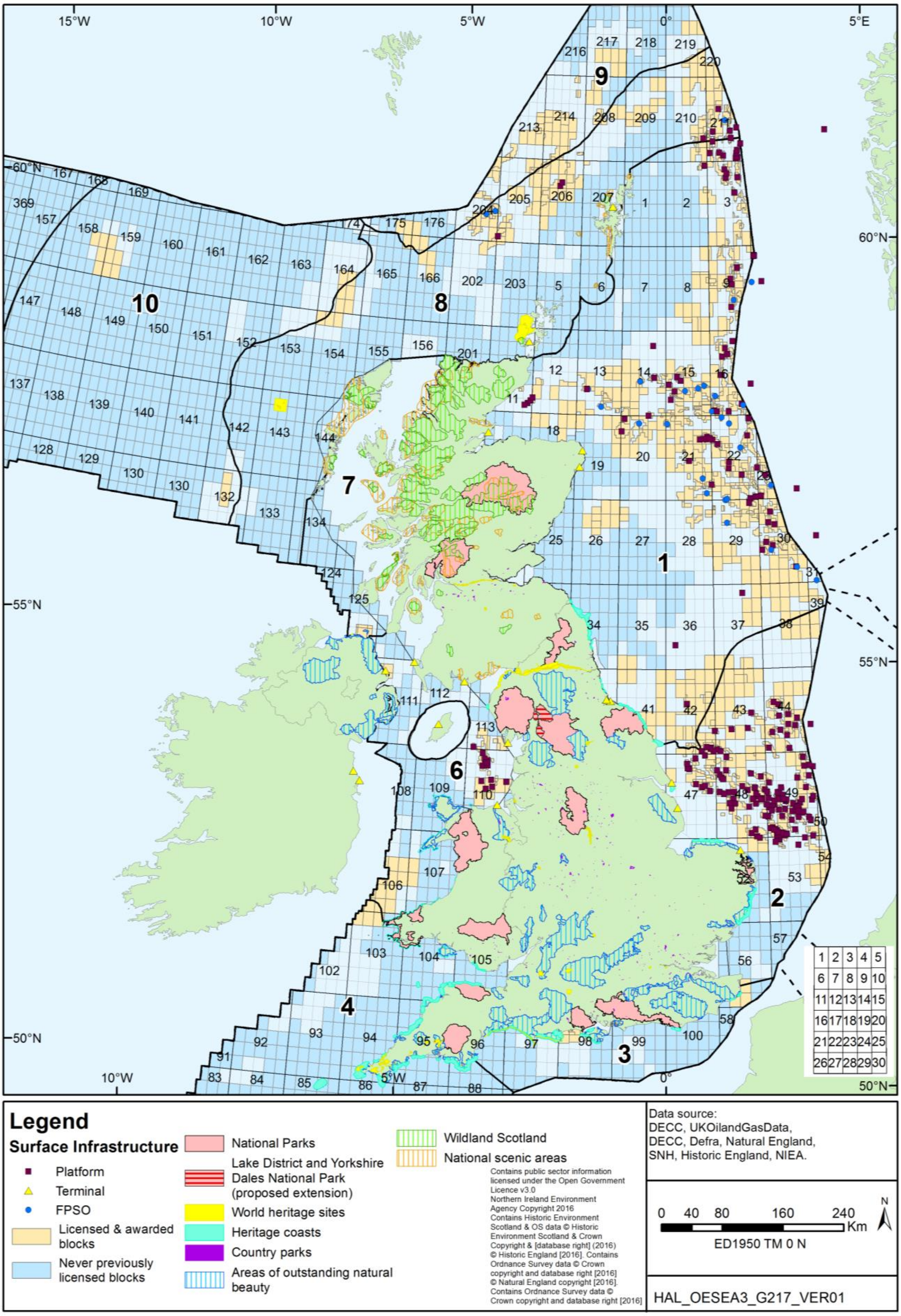


Figure 5.43: Designated landscapes in the UK in relation to existing licensed/awarded blocks for oil and gas exploration and production, and blocks never previously licensed



In the absence of any further assessment of landscape sensitivity to offshore development, it can be seen from Figure 5.39 that those areas least likely to generate significant visual intrusion are those to fall outside of the visible range of designated landscapes which may be surmised to have a high landscape/seascape "value", and more widely for OWFs, areas greater than 30km from the coast (i.e. a distance where the largest possible devices which could be used during the currency of this SEA (15MW wind turbines) are at the limit of visual acuity). The distance of 30km represents an indicative maximum visibility threshold for most of the country based on the studies discussed above (notwithstanding those views from ferry and other sailing routes), though this is not necessarily as far as an individual may be able to see. In relation to wind, the Dogger Bank, parts of Hornsea and East Anglia Round 3 zones are well beyond the area of visual significance (Figure 5.39), and it is expected that any further developments which could be proposed in lease areas not relinquished to The Crown Estate would similarly be beyond visual limits of the coast. As indicated above, those Round 3 zones partly or entirely in territorial waters have to date been the source of potentially significant effects on landscape/seascape. In view of this, any potential extensions to existing Round 2 areas in the future would need to consider the potential for significant effects to arise, particularly given the larger turbines proposed for some recent extensions (e.g. 8MW devices proposed for Burbo Bank).

Regional Sea 1

Wind turbines are the most likely renewables devices to be deployed in the area of Regional Sea 1 covered by this draft plan/programme. Deeper waters to the east of the UK in this Regional Sea enhances the prospectivity for tethered turbines, particularly given the relative quiescent wave climate compared to other major prospective areas in English and Welsh waters, namely the South West Approaches. A relatively small coastal strip therefore provides potential for fixed foundation offshore wind, and any such wind farm would be visible from the coast. There is limited prospectivity for wave devices to the north west of Regional Sea 1, however this area is a minimum of 210km from the coast, and therefore infrastructure at this location would be too far from the coast to see.

Oil & gas structures are typically located too far from shore to be perceptible, though a number of blocks have been awarded in recent offshore oil and gas licensing rounds which abut or are in close proximity to the coast (e.g. North Yorkshire – Block 14/18, Buchan coast – Block 18/9 and Caithness Coast – Block 11/24, see Figure 5.43), and so activities associated with exploration (and possibly development) may reasonably be expected to take place in this area in years to come should economically viable reserves be identified. Exploration activities tend to involve the use of vessels for seismic survey and for mobile drilling rigs (in this case a jack-up rig due to the shallow water depths), support vessels and helicopters for supply and crew changes during any drilling. Exploratory and appraisal work is temporary, perhaps as little as 30-90 days. Installations can be more permanent, but are increasingly subsea in nature.

Landfall associated with any gas storage, unloading or carbon dioxide transport and storage projects may locally affect certain areas. Pipeline and cable landfalls can both create effects on the landscape and visual resource, however tend to be temporary in nature (perhaps 6 months), however may have ancillary development which is more permanent, such as transformer stations. Teesside and Tyneside are centres of high CO_2 emissions, and may therefore be prime locations for CCS demonstration. The proximity of these regions to the North Sea is also advantageous, as extensive existing oil and gas infrastructure exists which could be used for CO_2 transport and storage on depletion of hydrocarbon reserves.

The open and expansive seascapes viewable from Shetland's coast may be compatible with the scale of any 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. To date, no oil and gas licensing blocks have been awarded in close proximity to Shetland, however the terminal located at Sullom Voe provides for an association with the oil and gas sector in this area. Increased use of the seas around Shetland for aquaculture may visually conflict or generate in-combination effects with offshore energy developments.

In the Moray Firth, the Beatrice and Jacky platforms can be seen from land by day and night, though are at some distance from any viewable location. Any further development of oil and gas infrastructure in this area is likely to be in a similar location, or else associated with a small area off the Caithness coast, however operations for the latter could be based onshore. The Beatrice field is at a mature stage of production and therefore is likely to be decommissioned in the coming years. 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, which provides an indication of the high degree of visibility in this area. Any further development would perpetuate the visual effect of offshore oil and gas infrastructure in the Moray Firth, and may act cumulatively with further offshore wind plans associated with Round 3 and Scottish Territorial Waters wind leasing. This may further affect the perception of this area as being remote and “undeveloped” (e.g. see areas of wildland identified for Caithness in Figure 5.38), however it should be noted that there continues to be some association with the oil and gas industry in this area, for example the rig servicing yard at Nigg provides for regular views of transiting mobile drilling rigs in the Moray Firth and Cromarty Firth.

With regard to carbon dioxide transport and storage, the Captain Sandstone in the Moray Firth has the potential for CO_2 storage. Any infrastructure that could be developed here (note that only offshore waters are of relevance to this draft plan/programme for CCS), would not be appreciably different than surface infrastructure associated with oil and gas exploration and development.

The east coast of Scotland has a paucity of statutory designations which amount to just two – the Dornoch Firth and Fair Isle NSAs. There are Local Landscape Designations which stretch around 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 NSAs, and the area does not contain the same “wild” perception as Scottish landscapes to the north and west. Within the context of the draft plan/programme, significant effects are not considered likely. To date no blocks off the east coast of Scotland have been licensed within ~40km of the coast, and no surface infrastructure has been installed in those areas which are licensed (see Figure 5.43). The terminals at St Fergus and Cruden Bay have an association with the industry which will continue for the foreseeable future, and major ports in the area including Peterhead, Aberdeen and Dundee are characterised by offshore oil and gas activity, with Dundee also servicing mobile drilling rigs.

For some areas such as the Firth of Forth and Firth of Tay, urban expansion is unlikely to significantly alter the sensitivity of the landscape, which contains landmark road and rail bridges, and great coastal variety, from sandy beaches and golf courses. The firths have some industrial elements including power stations and petrochemical plants which may reduce their sensitivity to development. Onshore and offshore wind developments in the Grampian and Highland areas have the potential to generate cumulative effects with offshore developments covered by the draft plan/programme, however these are not considered to be significant given the likely scale of oil and gas activity.

The coast from the Firth of Forth to the English border affords wide open views to the sea from a generally linear coastline. Existing development and transport infrastructure already give a developed character in places and busy shipping lanes are present in the sea. The coastal is dramatic in places, and includes views to Bass Rock and the Isle of May.

The stretch of coast from the Scottish border to Flamborough Head has a high number of designated landforms including 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. These paths are now being augmented with access (paths and recreation areas) created under the *Marine and Coastal Access Act 2009*, with the North Gare to South Bents section open, and the section between South Bents to Amble, and south of North Gare to Flamborough Head presently in progress[89] (see Appendix 1h).

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. Highly visible offshore structures may detract from the complexity and the unique, incised gorge-like coastal denes, 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.

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 from these elevated locations, sunrises would silhouette turbine or other structures against the sky and make them more visible. On clear nights, navigation or aviation lights located on any development 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 wind turbines or rig structures. In contrast, offshore infrastructure 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.

Regional Sea 2

The most likely renewables devices to be deployed in the area of Regional Sea 2 are wind turbines. A small area off Spurn Head and a larger area off the east Norfolk coast also fall within the technical range for tidal stream devices. No proposals have been made for such devices in these areas to date, and within the currency of OESEA3, demonstration or possibly small commercial deployments projects are considered likely. The design of tidal stream devices also mean they tend not to be surface piercing, or have a substantial surface component and are arguably less likely to generate significant effects. Large commercial deployments with surface elements (as exemplified at Strangford Lough) could introduce visual components in the form of low structures and lighting. Even if these devices do not meet the surface, they may require illumination in the form of buoys where water depths are limited and devices reduce the under-keel clearance of vessels. Like other areas of the English coast, coastal paths and related amenity land are being developed in Regional Sea 2. The stretch of path between Sea Palling and Weybourne has been complete and a number of other sections are in progress or due to start 2016-2017.

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[89] https://www.gov.uk/government/publications/england-coast-path-overview-of-progress

The area between Holderness and the North Norfolk coast has the largest potential tidal range resource outside on the east coast of the UK. A number of proposals have historically been made for schemes at the Humber and Wash (see Section 2.7.5), however these have not been realised, and focus to demonstrate the technology has tended to be on the Severn.

Oil & gas structures are typically located too far from shore to be perceptible, though a number of blocks have been awarded in recent offshore oil and gas licensing rounds which abut or are in close proximity to the coast (e.g. East Riding of Yorkshire – Block 47/6, see Figure 5.43), and so activities associated with exploration (and possibly development) may reasonably be expected to take place in this area in years to come. As indicated above, such activities are temporary in nature and development stage proposals are increasingly subsea in nature. The southern North Sea has a long history of hydrocarbon (principally gas) exploration and production, with gas terminals constructed at Easington, Theddlethorpe and Bacton, and a high concentration of surface infrastructure offshore (e.g. as recognised in the East Marine Plans seascape character area 3, the East Midlands Offshore Gas Fields).

The Yorkshire and Humber area has significant CO_2 point sources, and several power stations have been proposed to demonstrate carbon capture (Drax, the Don Valley Power Project), and one project is presently in planning which proposes to demonstrate full chain CCS. The proximity of this region to the southern North Sea is also advantageous, as extensive existing oil and gas infrastructure exists which could be used for CO_2 transport and storage on depletion of hydrocarbon reserves, proven storage and sealing structures in the form of former gas fields, and the largest and most prospective saline aquifer on the UKCS (see Appendix 1b, and also refer to East Marine Plans Policies CCS1 and 2).

This section of the coast contains a number of Heritage Coasts 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, signifying the importance that is attached to the landscapes, and associated seascapes, of these areas.

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 infrastructure is sited sufficiently offshore this should not significantly influence the impact of a development, though at night navigation and aviation lights may be more visible from higher ground. Where there are a number of offshore wind farms, the movement of blades passing aviation lighting on the nacelle could result in the appearance of irregular flashing of lights. 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 creation of large wind farms offshore, such as at Dogger Bank, has the potential to change the character of how these seascapes are experienced, or perceived. The East Marine Plans character area 1, Dogger Bank, emphasises the extensive and remote nature of the area, and the expansive open water character of the seascape which has few surface features. Both the existing proposals for this area, and any future proposals given the large technical area of opportunity for fixed offshore wind, or tethered turbines just to the north, would introduce surface components and likely affect the remote nature of Dogger Bank. Elsewhere, such as in proximity to the Hornsea Zone or the northern section of the East Anglia Zone, gas installations have been a feature of seascapes for some time though in low densities, or else high shipping densities result in a seascape for which industrial activity is better established.

In the last (28th) seaward licensing round for oil and gas, blocks was awarded which abuts the Holderness coast (Block 47/6) and so activities associated with oil and gas exploration and development may be reasonably expected within viewable distance of the coast in the coming years (however note that generally less than half of exploration wells drilled reveal commercially viable reserves). 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 offshore structures. Open, eastern facing views may mean that there is a strong contrast between structures and the sky during sunrise.

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. Any tidal range schemes which incorporate a barrage will alter such focussed views by generating a visual barrier to the open sea, having associated access roads, surface infrastructure, lighting, and the light and movement of vehicles. This may amount to a substantial change in the character of such areas. Loss of intertidal area and related changes to habitat and species in the estuary, for which climate change and any tidal scheme could act cumulatively, would also introduce a significant change to the landscape of the estuary.

Individual tidal stream devices would be less of a visual intrusion, though may still require navigational marking and lighting, and as indicated above, are highly restricted in terms of viable location. The low lying nature of the Broads and also North East Norfolk and Flegg, and screening of the sea by sea walls and dunes may restrict views of any tidal devices in this area (see Figure 5.40), however at the coastal views are expansive and so devices or their markers could be visible. The low-lying Broads back onto the coast near Great Yarmouth and are also a visually intricate landform which will increase the sensitivity of this section of coast to vertical offshore structures, including nearshore wind turbines.

The vast open views of the North Sea afforded from Norfolk, Suffolk, Essex and Kent coasts has the potential to reduce the perceived visual intrusion of any wind farm or other offshore development as it would only change visual aspects of a part of the seascape, however in view of the multiple activities taking place in the southern North Sea, and those extant and planned wind farms, any impact would need to be considered with regard to the potential for cumulative effects to be generated. 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 certain offshore structures. Cliffs also tend not to be high, and their scale may be further diminished by large turbines in proximity to the coast. 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 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 largest and most developed areas are Hull and Greater London 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 offshore structures than these more industrial areas. The Thames has area has high CO_2 emissions, and as a result may be an area supporting the demonstration of CCS, or its later commercial scale deployment assuming that it is proved to be economically and technically viable. Onshore developments may include those used for gas compression, or increased port activity and gas offloading – uses which are broadly comparable and compatible with activities already taking place in Regional Sea 2. Any offshore infrastructure associated with CCS has the potential to generate cumulative or incremental effects in a region which is already extensively used for other marine activities (see Appendix 1h and also Section 5.15).

Pressures on existing use of the landscape 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 historical coastal defence, its maintenance and other engineering is altering the physical form at a number of locations along the coast which may continue in the future (e.g. in relation to the implementation of shoreline management plan policies). Coastal squeeze leading to beach steepening and 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 and is a distinctive characteristic of these areas with strong historical associations (e.g. relating to lost villages). Onshore wind is also a feature of the coast, and these, and any subsequent developments within viewable distance of the coast, could generate cumulative impacts if there is sufficient intervisibility of onshore and offshore structures within seascapes.

Regional Sea 3

Prospectivity for plan activities in Regional Sea 3 is primarily for offshore wind and tidal stream, with an area in the eastern Channel between Sandwich Bay and Worthing having prospectivity for tidal range development. Note that the lack of large natural embayments makes this area more likely to be targeted for lagoon-type developments rather than barrages. Issues raised on visibility for previous wind farm proposals in this area, and the occurrence of multiple uses (particularly major shipping lanes) in a relatively confined area of sea, suggests a constrained and largely coastal resource for offshore wind (see Figure 5.39 and also refer to Section 5.15). Tidal stream resources are located off the Kent coast and in the central English Channel, south of Portland, St Alban's Head, Durlston Head and the Isle of Wight. In view of multiple users of this area, a more restricted potential resource for such devices may be available.

Limited offshore oil and gas potential exists in the area, however seaward blocks have been awarded in the most recent (28th) licensing round for blocks which abut or are in close proximity to the coast, such as 56/23 and 56/27 on the Kent coast, and 98/7b and 98/12a in Poole Bay and Christchurch Bay. The proximity of these blocks to the coast may provide for the ability to produce any commercial hydrocarbons from the shore via extended reach drilling (e.g. as at Wytch Farm, Dorset, where the above Blocks also relate), and therefore offshore activity may be limited, and onshore activity incremental. The hydrocarbon basins which have been exploited in this area have the potential to act as CO_2 storage in the future, however potential connectivity to large emitters is more restricted (i.e. Fawley refinery) than in other areas of the UK.

The coast of Regional Sea 3 has progressively more designated landscapes or features of natural and cultural importance to the west, however large, linear designations track the coast such as the Dorset and East Devon AONB, Dorset and East Devon Coast World Heritage Site, East Devon Heritage Coast, and Isle of Wight AONB and Tenyson Heritage Coast. The South Downs National Park extends in a general east-west trend and includes a number of notable seascapes with elevated views, for example from Beachy Head and the Seven Sisters (see LUC 2015 for an overview of views within this National Park). Between Dover and Beachy Head, the coast includes elements of the Kent Downs and High Weald 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 Folkestone, frequented by people seeking the views of the accompanying AONBs. Rufus Castle to Lulworth Cove is the only section of the English coastal path to be completed to date, with other stages due to commence 2016-2017 (see

Appendix 1h). Maritime use is a strong characteristic of most of the seascape character areas identified for the South Marine Plan areas, including the large commercial traffic associated with the Dover Strait and shipping lanes of the central Channel, and smaller fishing and recreational craft which more strongly characterise the inshore areas of Selsey Bill, south Wight and the Solent. The area has a long and established maritime history attested to by the number of historic shipwrecks and other losses in this Regional Sea (see Appendix 1i). In addition to views from the various coastal designated and other locations in Regional Sea 3, these areas also define aspects of these seascape character areas as they are experienced, for example, from recreational sailing.

Dover and Folkestone 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 wind 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 ~13km from the coast, and have the highest shipping density in UK waters.

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 structures.

The area off Hastings is likely to interact with two contrasting landscapes. There are a number of designated areas including the South Downs National Park and the Sussex Heritage Coast. 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 large 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.

Further west, 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 offshore developments. Some of the coast along the same route reaches elevations of up to 150m, increasing the viewable distance. 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 offshore infrastructure due to the level of development in these areas. As indicated above, landscape/seascape effects have proved to be a source of potentially significant effect for offshore wind farm developments in this area. Whilst future proposals may differ in scale or turbine design than those previous proposals, there is limited scope to mitigate the visibility of larger wind turbines within this enclosed area, and therefore significant effects may be expected for OWFs.

Submerged or partly submerged tidal stream devices could be viable should any deployment occur, with visibility determined by their design and requirements for navigational markings. Should such devices have a surface component, it will be relatively small (e.g. at the most 10m as suggested in Faber Maunsell & Metoc 2007) compared to offshore wind, though it is likely that these devices will be in close proximity to the shore. Should wind, tidal and oil and gas developments take place in the west of Regional Sea 3, there is the potential for cumulative visual impacts to develop from plan related activities.

Technical resource for tidal range approximately extends between Sandwich Bay and Worthing on the south east coast. As indicated above, the potential for any device here would be limited to lagoon-type developments. Any imposition of large, shore connected structures would interact with the contrasting coastal forms in this area, including coastal exposures of chalk in the form of cliffs including the Seven Sisters and Beachy Head which includes a chalk foreshore and subtidal chalk ridges, and the shingle ridges to the east culminating in the Dungeness Foreland – these areas also have strongly contrasting elevations. The area contains numerous RYA cruising routes and clubs/marinas and therefore views from sea to some of these major landforms may be altered by the construction of any lagoon.

Regional Sea 4

The waters of Regional Sea 4 (see Figure 5.39) have generally proven to be too deep for fixed offshore wind foundations however the area is highly prospective for tethered foundation-type technology. Shallower areas, including the Bristol Channel, have formerly been considered for offshore wind but did not prove viable. This area has some of the most prospective waters for offshore wave energy in the UK and contains the only wave demonstration sites in English and Welsh waters. Tidal stream energy is prospective off western Cornwall, within the Severn Estuary and off Pembrokeshire (see Smith *et al.* 2011), with demonstration sites being located in the latter two areas. There has been historically very strong interest in the Severn as a potential source of tidal range energy. Several lagoon development proposals are presently being considered for the Severn, and there is a wider technical resource along the coasts of the Bristol Channel.

To date, the majority of seaward oil and gas blocks have not been licensed in Regional Sea 4, with existing licences being present in Blocks off Pembrokeshire in St George's Channel on the boundary with Regional Sea 6. A single significant gas discovery has been made in the area however this has not been commercially exploited to date. Less geological understanding makes Regional Sea 4 a less likely candidate for gas storage or CCS compared with North Sea and East Irish Sea prospects, and so developments are not considered likely.

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, Quantock Hills and Gower AONBs, Exmoor, Dartmoor and the Pembrokeshire Coast National Parks, 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, along with the wider Wales Coast Path (completed in 2012), make the coast easily accessible to the public as regular visitors or tourists (see Appendix 1h). The combination of these elements provides an indication that the seascapes of this Regional Sea are likely to have a high landscape/seascape value.

Low and high cliffs 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 away from the main towns and transport links, though is much reduced since the 1960s (Countryside Agency 2006). The high coastline affords wide and expansive views out to sea from the coast including between Falmouth and Bigbury bays, and out from Mount's Bay, but the area has had a number of recent additions in the form of onshore renewable energy structures including wind and solar farms. 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, and their strong historical associations (see Appendix 1i).

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, with the underlying geology ("killas") being a key influence in the character of the area. Tourist centres such as Torbay, 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, however wave devices may be less visible by day due to their low profile, but would require navigational lighting which could influence how views are experienced by night.

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 (see Figure 5.39, Appendix 1c). Unlike most other areas, the Bristol Channel is viewable from almost all sides from high cliffed coasts, and there are also considerable stretches of flat low lying ground abutting the Severn such as the Gwent and Somerset Levels. Large developments may interfere with views across the Bristol Channel and down the Severn, where offshore wind 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 be incompatible with the industrial character of offshore structures.

The Severn has previously been subject to SEA for a feasibility of tidal range options including two possible barrage structures and a number of tidal lagoons, and the visual impacts of these may be found in DECC (2010c). Any changes imposed by the technologies covered by the draft plan/programme are further complicated by the longer term evolution of the baseline in this area, namely sea-level rise which unmitigated will lead to a reduction in intertidal area and related habitats and species which are characteristic to certain areas of the estuary. Mitigation in the form of compensatory measures[90] is already being undertaken (e.g. at Steart, EA 2011) with additional areas having been identified as part of an earlier GIS exercise (EA 2005). Such measures would require coastal change in the form of managed or unmanaged retreat which will itself be a force for change in certain areas. Additionally, beach steepening and loss and flood defence maintenance may also begin to alter the character locally, but this is likely to be in areas of existing sea defence.

[90] Defra policy guidance (2005): Coastal Squeeze. Implications for Flood Management. The Requirements of The European Birds and Habitats Directives.

The imposition of any tidal range device must therefore be considered in this context, particularly large estuary scale barrages which have the potential to exacerbate intertidal loss, in addition to changing the aspect of certain views, for example changes in water clarity and the form and type of shipping. Any such large device could affect the character of the area, including changes to strong regional associations such as the Severn Bore, and maritime associations with trade and now recreational sailing and cruising. Whilst crossings in the Severn include two bridges, these are in the inner part of the estuary and so have less of an effect on diminishing the range and type of view that a large barrage might impose at day and night due to the requirement for navigational lighting and any associated road network. Barrages may not affect views down the estuary, but depending on their location could generate locally significant effects. Using Figure 5.42, it can be concluded that devices in the inner Severn (i.e. around Cardiff and Newport, or on the English side of the Severn) will be highly visible, and there is strong intervisibility with the Welsh and Somerset coast here leading to the potential for a large number of affected receptors. The area has centres of urban development, including major ports at Cardiff, Barry and Newport, and associated industrial infrastructure (e.g. the Llanwern Steelworks, Usk Mouth Power Station), however this is juxtaposed with the low lying Gwent Levels which supports important plant, bird, invertebrate and mammal populations, and is recognised as one of the best historic landscapes in Wales (see Cadw 2007). Individual project level analysis would be required to understand which specific views from coastal aspects would be affected, and the magnitude of such change, in a landscape which is already under pressure from large industrial, commercial and urban expansion. For Swansea Bay tidal lagoon (TLP 2014), significant changes during construction were not identified in part due to the existing industrial and maritime nature of the area, however operational effects were considered to be significant immediately within or adjacent to the development. Foreshortening of views and reduction in the open character of certain views were highlighted, however the increase in amenity and contribution to overall regeneration of the area were also provided as advantages. For any tidal range device, the imposition of the lagoon or barrage walls represents a long-term change. The lifetime for most tidal range proposals exceeds 100 years, and after this period repowering may be possible, or else the bulk of the structure may be left *in situ*, as proposed for Swansea Bay.

The wave resource in the South West Approaches may lend itself to the deployment of wave based marine renewables. WaveHub was installed in 2010 off the north Cornish coast, which consists on a seafloor interconnector for the demonstration of wave devices. These are likely to generate a short term and small scale visual intrusion as devices of various designs are tested (similarly there is a wave test site off the Pembrokeshire coast and a tidal stream test sites off Lynmouth). In the longer term, wider installation of devices which are deemed to be technically feasible may be a potential source of visual effect, though Welsh, Scottish and Irish studies found that such devices tended to have less of a visual impact than wind or tidal devices with sea surface components. The scale of deployment in the currency of this SEA is likely to be demonstration, and large commercial deployments are not considered likely. Any impact would depend on the local characteristics of the coast and the distance from shore that any devices are placed. Floating devices are not so contingent on water depth as those requiring fixed foundations, and so may be placed further offshore where the wave resource is better, negating coastal landscape and visual impacts.

A previous strategic level consideration of the potential sensitivity of seascape units (see Appendix 1c) has been undertaken for wind, wave and tidal stream technologies by CCW (2008a, b also see Smith *et al.* 2011). The high level character type and sensitivity to these types of developments is provided in Table 5.27. It should be noted that this work used development scenarios and therefore can only be interpreted in a generic way for this SEA and that there will also have also been certain changes in landscape and seascape since its completion.

Table 5.27: Summary of landscape/seascape assessment for the Welsh coast relevant to Regional Sea 4

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

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: **Wind**: wind farm development scenario of many parallel turbines (160m to blade tip) at 550m intervals, 13km from the shore. **Wave:** 2 rows of linear objects 500x3m at 500m intervals 5km from the shore. **Tidal Stream**: 1 row of surface point structures 10x3m, at 60m intervals 0.75km from the shore.*

Visibility is based on a landward and seaward buffer of 24km.

Source: CCW (2008a, b)

Tourist pressure continues to increase in the South West with more 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, and changes in the location and nature of coastal defence and compensatory habitat, particularly in the Severn, may alter the character and certainly views of certain areas (for example, see the recent project at Steart). 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.

Regional Sea 6

Technical resources for offshore wind (mostly for fixed foundation in the east Irish Sea), tidal stream (primarily off the Lleyn Peninsula and Anglesey) and tidal range (extending east from Anglesey and north to the Solway) are located in Regional Sea 6. Many oil and gas blocks in the Irish Sea and Cardigan Bay have never been licensed, and to date this has been without commercial success for the latter. The east Irish Sea Basin has been exploited for hydrocarbons (primarily gas), and there is continued interest in exploration in the area. The wave power in this area is generally regarded to be too low for commercial exploitation.

Designations relating to landscape value (see Figure 5.39) 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) and the AONBs of Lleyn, Anglesey and coastal aspects of Clwydian Range and Dee Valley. In Wales a number of other non-statutory areas are recognised on the register of landscapes of historic interest, including (amongst others) Lleyn and Bardsey Island, Amlwch and Parys Mountain, Penmon and Creuddyn and Conwy.

Regional Sea 6 contains a number of estuarine or coastal areas which have been the subject of previous tidal range proposals (see Figure 2.12), which include Colwyn Bay, the Mersey, Wyre, Ribble and Solway Firth. Designs have included both barrage and tidal lagoon-type developments. There are two lagoon projects (Colwyn Bay and West Cumbria) at an early stage of proposal for Regional Sea 6, with other novel ideas at an early proposal stage for the Solway[91]. A number of landscape/seascape implications of such devices have already been discussed above, and these are likely to be applicable to these sites also, and will require site specific scoping, consultation and assessment both in terms of the siting of any tidal range project and also the potential for cumulative effects. Tidal range developments in Colwyn Bay and in any of the estuaries mentioned above are likely to be visible from a large number of viewpoints as they have a high degree of intervisibility with opposite and adjacent coasts. Similarly, any development within the Solway will be highly visible, could lead to the foreshortening of views along the estuary and out to sea, and interact with a range of landscape designations including the Solway Coast AONB, the Nith and East Stewartry Coast NSAs and Hadrian's Wall World Heritage Site (Figure 5.42). The Solway has a high degree of tranquillity and contains a range of nature conservation designations relating to, amongst other factors, intertidal mudflats which support internationally important numbers of wildfowl and waders. Analogous to the Severn, in view of the presence of estuaries and bays which have coincident SAC sites that include estuarine features and pressure from *inter alia* sea-level rise, any impact from barrage or tidal range structures alone or in combination with background changes to these could exacerbate the alteration of landscapes in these areas in the long-term. Unmitigated, this could include changes to intertidal area and a loss of related habitats and species which are a key component of the character in these areas, in addition to an alteration of the daily contrast in views afforded by the changing tides.

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 may reduce the sensitivity of the area to offshore developments, however this must be considered in the context of extant offshore energy development. The extensive intertidal sands and dunes of the Sefton coast are a distinctive landscape feature 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, but there is scope for cumulative effect with existing offshore structures. Barrow-in-Furness, Whitehaven and Workington provide an industrial element to the landscape which may reduce the sensitivity of the seascape to offshore wind or other industrial structures, as will the more developed areas of the Mersey and Dee Estuaries and other sources of industrial character including various nuclear and gas fired power stations located along the coast. Light pollution from these, other urban areas (e.g. Blackpool), and

[91] http://www.solwayenergygateway.co.uk/

extant offshore navigation and aviation lighting may make them less sensitive to further lighting, however there is scope for cumulative effects.

The technical resource for tidal stream is concentrated around Pembrokeshire, the Llŷn Peninsula and Anglesey. These areas coincide with some of the highest designations in Wales: Anglesey includes an AONB and Heritage Coast, is a designated geopark and in the east includes Beaumaris Castle, part of the wider Castles and Town Walls of King Edward in Gwynedd World Heritage designation; the Llŷn Peninsula incorporates an AONB and Heritage Coast, as well as the Llŷn and Bardsey Island historic landscape, and Pembrokeshire includes a National Park, Heritage Coast and a range registered historic landscapes. Several tidal stream proposals are in planning or pre-construction in Welsh waters off Pembrokeshire and Anglesey. These will introduce additional lighting in these areas at night and possibly also surface structures where waters are shallow (e.g. The Skerries off Anglesey), either in the form of surface lighting, boats for maintenance activities or occasional views of turbines being raised or lowered in the case of SeaGen S-type generators. No proposals have been made to date for tidal stream development off Llŷn Peninsula. The area has a strong sense of remoteness and the character is strongly influenced by natural influences, and has a sense of exposure and wildness, but is also rural and agricultural. Rural qualities and a lack of modern development in the area may not be compatible with industrial offshore developments, whether these are offshore wind farms or tidal stream devices, with night time lighting from each providing new points of focus.

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 (see Appendix 1c and 1h), 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 change may locally alter some areas through managed realignment or no active intervention (see Appendix 1b), however many estuarine areas such as the Mersey are already highly managed and it is likely defences will be maintained at the frontages of major towns and infrastructure.

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. Merseyside is also a site which would lend itself to CCS demonstration having high emissions of CO_2 in relatively close proximity to suitable storage formations, and existing oil and gas infrastructure which could possibly be reused, and similarly gas storage is prospective in this area. The Welsh Government has indicated the intention to diversify offshore energy production to include wave and tidal energies in addition to offshore wind[92]. The combination of these various technologies has the potential to generate cumulative impacts (though wind, wave and tidal resources tend not to coincide). Additionally, a number of sizeable onshore wind farms (e.g. Llŷn Alaw, Trysglwyn on Anglesey) are operational and pressure for such developments is likely to continue. Offshore wind farms characterise parts of the offshore seascape character (e.g. see Wales marine character areas 2 and 4, Appendix 1c), and are intervisible between some character areas (e.g. Rhyl Flats and Gwynt y Môr) and/or have altered views from the shore (e.g. off West Cumbria). Further offshore wind development within viewable distance of the coast in these and other areas should consider the potential for cumulative effects of further development.

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[92] See: http://gov.wales/topics/environmentcountryside/energy/renewable/marine/?lang=en and also the Marine Renewable Energy Strategic Framework and Marine Energy Pembrokeshire.

A previous strategic level consideration of the potential sensitivity of seascape units (see Appendix 1c) has been undertaken for wind, wave and tidal stream technologies by CCW (2008a, b also see Smith *et al.* 2011). The high level character type and sensitivity to these types of developments is provided in Table 5.28. It should be noted that this work used development scenarios and therefore can only be interpreted in a generic way for this SEA and that there have also been certain changes in landscape and seascape since its completion (e.g. offshore wind in the Irish Sea).

Table 5.28: Summary of landscape/seascape assessment for the Welsh coast relevant to Regional Sea 6

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

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

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: **Wind**: wind farm development scenario of many parallel turbines (160m to blade tip) at 550m intervals, 13km from the shore. **Wave:** 2 rows of linear objects 500x3m at 500m intervals 5km from the shore. **Tidal Stream**: 1 row of surface point structures 10x3m, at 60m intervals 0.75km from the shore.*

Visibility is based on a landward and seaward buffer of 24km.

Source: CCW (2008a, b)

Regional Sea 7

The majority of Regional Sea 7 falls within the bay closing lines subject to landward oil and gas Regulations. The remaining area has not been commercially exploited to date, however blocks in Northern Irish waters around Rathlin Island were licensed in the 26th seaward round, and a number of blocks have previously been awarded in seaward oil and gas licensing rounds between Islay and the northern coast of Northern Ireland in the North Channel. It is possible that further Blocks will be applied for during the currency of this SEA and therefore activities relating to exploration and production of offshore hydrocarbon could take place in Regional Sea 7 in the future.

The coast in Regional Sea 7 from Cape Wrath to the Mull of Kintyre has a high density of NSAs and also the highest number of wild land areas (see Appendix 1c). The area to the west of Scotland is generally not considered prospective for oil and gas, and is also within internal waters which are not considered for oil and gas licensing. The area therefore primarily prospective for renewable types of offshore energy however these are not a consideration of this draft plan/programme for Scottish waters. Should seaward blocks be applied for in Regional Sea 8, activities may be visible from some coasts in Regional Sea 7 (for example the west of the Outer Hebrides, Islay and Mull of Kintyre), and also Northern Ireland (see Figure 5.38). In the most part however, blocks immediately to the west of these areas have never been licensed.

The area to the south and west of Islay and around Rathlin Island has a potentially viable tidal stream resource, and projects are in-planning or development at these locations. It may be reasonably expected that activities associated with such developments and oil and gas activity may take place in the coming years, and that these have the potential to visually interact. The Antrim Coast and Rathlin Island have some of the most varied scenery in Northern Ireland and is recognised by an AONB. To the south west of this, the Giant's Causeway and Causeway Coast WHS is of global geological importance and has strong artistic, cultural and historic associations. Should any exploration activity take place within this area, the potential long-term effects of development scale activity would need to be considered in relation to seascape, particularly should this coincide with any other offshore energy development.

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, and any development that takes place which influences views in Regional Sea 7 will alter the landscape and may change the perception of some areas as "wild". Any cumulative effects with marine energy development undertaken in Scottish waters may also generate cumulative impacts as an increasing number of built, industrial structures are imposed on this largely rural coast. The interaction between these and any expansion in aquaculture should also form part of any cumulative consideration.

Regional Sea 8

The western extent of Regional Sea 8 which is covered by the Rockall Basin is generally under explored, and a single gas discovery has been made in the area. It is possible that further Blocks will be applied for during the currency of this SEA, but large scale and expansive changes to landscape character are not considered likely in viewable distance from the coast. Should any development take place which is more than short-term (i.e. outside of exploratory activity) and interact with views from the coast, or where effects on landscape or seascape character are predicted, then the impact of development would need to be considered, particularly given the relative rural and wild nature of the islands and coasts of Regional Sea 8, as recognised in the high concentration of NSAs, in addition to the World Heritage Sites of St Kilda and the Heart of Neolithic Orkney (Figure 5.38).

Regional Sea 8 includes the high cliffs of Scotland's northern coast, affording wide open views which could accommodate offshore structures, though depending on their scale and location, they could 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. 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 offshore energy developments. 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. The seas to the west of the Western Isles contain some of the best wave resource on the UKCS and may therefore be subject to the installation of such devices once they are technically proven (not considered by this draft plan/programme).

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, which could introduce incremental industrial elements to the landscape.

5.8.4 Controls and mitigation

The form of offshore structures is largely functional, and therefore mitigation opportunities are limited to siting and certain elements of development aesthetics, though the former will be restricted by spatial and technical constraints, or due to the location of particular energy resources. DTI (2005) highlights a number of considerations which may help to reduce the impact of a given development, in this case offshore wind, though these may be reasonably extrapolated to any offshore structure. These mitigations have been modified for the purposes of this assessment below.

Siting:

- Try to locate in low sensitivity or high capacity seascapes
- Place development as far offshore as possible
- Try to locate developments away from coastal landscape designations
- Try to use development siting to minimise visibility (e.g. behind headlands)
- Consider siting relationships with other offshore infrastructure (cumulative effects)

Layout and design:

- Consider different viewpoints, try to attain the best possible arrangement of structures
- Through the SVIA process, try to design out aspects of the development that are the source of most significant impacts
- Make the SVIA process iterative in order to try a variety of locations, patterns and number of structures
- Where possible, while taking account of all navigational standards and recommendations, the use of colour most appropriate for prevailing/average meteorological conditions may reduce the actual visibility of structures, particularly at increasing distances
- Where possible minimise the height of structures above sea-level, with fully submerged structures being preferable, particularly those at sufficient depth in the water column to avoid the use of surface lighting

5.8.5 Summary of findings and recommendations

The following summarises the consideration of the evidence and spatial consideration above:

- Viewable distance is restricted by the curvature of the earth, atmospheric haze and prevailing meteorological conditions. The height, form, lighting, motion and aspect of an offshore object affects how well it can be seen and its relative impact on the coast.
- A range of physical attributes which are locally variable, in combination with the design of a development, and the attitudes of individual receptors define the sensitivity and capacity of a particular location to change in landscape and visual resource.
- Landscape designations provide a relatively objective general assessment of the 'value' attached to certain areas of the coast, though in keeping with the European Landscape Convention, all landscapes should be considered in seascape assessment. The occurrence of multiple overlapping designations (Heritage Coast, National Park, World Heritage Site, AONB) may be taken to indicate areas of particularly high value. In deciding new lease areas, and in early zone appraisal, the potential for a development to be refused on the basis of landscape/seascape issues, and indirectly generate economic effects on tourism, should be considered. Siting wind farms further from shore is likely to generate fewer effects at the coast and experience to date suggests less public opposition to such projects.
- Wind farm proposals in the UK, and other European countries, have progressively moved further offshore in recent years, reducing shore based visual disamenity. There remains potential for future leasing to take place closer to the shore, and within the broad ranges of visibility defined in Section 5.8.2.1 above. Project specific assessment will be necessary to gauge whether any such development is appropriate, which should be undertaken early in the leasing/zone appraisal stage (see above).
- The scope for cumulative impacts between different renewables aspects of the draft plan/programme is minimised by little overlap in the geographical range of energy resources. The exception is the wave energy and tethered wind turbine resource in the South West Approaches, however the high energy nature of this area may make central North Sea locations more likely for early deployment of this technology (see Section 5.15).
- Cumulative impacts are most likely to occur in the future between multiple wind farm developments, particularly if these are sited close to shore. Further effects could be possible from a variety of offshore oil and gas, CO_2 storage, gas storage and wind farm development in the East Irish Sea, Moray Firth, English Channel and areas of the southern North Sea off Holderness and Thames Estuary.
- A development specific seascape assessment incorporating cumulative impact assessment is necessary in order to minimise visual impacts from the variety of activities covered in the draft plan/programme, and existing and likely future uses of the sea.
- England's seascape presently lacks a comprehensive characterisation or high level analysis with regards to the sensitivity or capacity of particular seascapes to offshore development. The seascape characterisation work being undertaken by the MMO and

other marine planning authorities is informative and in time could be useful in monitoring the influence of marine energy installation offshore, particularly where they have started to form a key component of views and landscapes. In offshore locations in the southern North Sea and East Irish Sea, the components of the seascape which have associations with offshore energy may transpose from oil and gas activity to offshore wind energy in the coming years.

The likelihood of cumulative effects to be generated by more than one aspect of the plan together is limited by the lack of significant overlap in resource areas for most activities. Offshore wind developments are already starting to characterise certain seascapes, and any additional siting of this technology in combination with that already in place has the potential to generate significant cumulative effects at day and night (e.g. through navigational and aviation lighting). Continuing urbanisation in some areas, onshore energy infrastructure such as wind turbines, and grid reinforcement (e.g. new overhead power cables) have the potential to act cumulatively in certain areas. The general trend in European waters, including the UK, of offshore wind farms being progressively sited further from shore helps to mitigate such cumulative effects at the coast, if this trend continues. Tethered turbine technology is at demonstrator scale, however cost reduction for this foundation-type is considered likely in the coming years which could enhance the ability to deploy wind farms further from shore. Tidal stream and tidal range devices are limited by technology and resource to coastal and estuarine areas where visual effects could act cumulatively, and secondarily for the latter should it contribute to seascape changes from coastal squeeze. Transboundary effects are limited by intervisibility with continental Europe – primarily the Channel, and the Isle of Man.

5.9 Marine discharges

Assessment Topic	Potentially Significant Effect	Oil & Gas	Gas Storage	Carbon Dioxide Storage	Offshore Wind	Tidal Stream	Tidal Range	Wave	Assessment Section
	The introduction and spread of non-native species	X	X	X	X	X	X	X	5.9.3.4
	Potential for effects on flora and fauna of produced or treated water and drilling discharges	X	X	X	X	X	?	X	5.9.3.1 5.9.3.2 5.9.3.3
	The nature and use of antifouling materials				?	X	?	X	5.9.3.2
	Sediment modification and contamination by particulate discharges from drilling etc or resuspension of contaminated sediment	X	X	X	X	X	X	X	5.9.3.2
	Effects of reinjection of produced water and/or cuttings and carbon dioxide	X	X	X					5.9.3.1 5.9.3.2
	Changes in seawater or estuarine salinity, turbidity and temperature from discharges (such as aquifer water and halite dissolution) and impoundment		X	X			X		5.9.3.3
	Potential for effects on human health associated with discharges of naturally occurring radioactive material in produced water	X	X	?					5.9.3.1 5.9.3.3

5.9.1 Sources of potentially significant effect

As described in previous SEAs, marine discharges from exploration and production activities include produced water, sewage, cooling water, drainage, drilling wastes and residual WBM, which in turn may contain a range of hydrocarbons in dissolved and suspended droplet form, various production and utility chemicals, metal ions or salts (including Low Specific Activity (LSA) radionuclides). In addition to these mainly platform-derived discharges, a range of discharges are associated with operation of subsea 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 activity specific permitting procedures). The list above equally applies to gas storage or CCS activities in depleted reservoirs, although scale and typically, produced water volumes will be minor. An exception could be during CCS injection into a saline aquifer when aquifer water may need to discharged to control pressure build-up in the storage formation; concentrations of sodium chloride in saline aquifer water can be near saturation.

In addition to discharges associated with drilling and support activities, construction of salt caverns involves the discharge of relatively large volumes of high salinity brine, which in addition to dissolved halites may potentially contain trace quantities of other components.

OWF and other renewable energy developments were thought to have essentially no planned discharges. The Danish Hydraulic Institute (2000) indicates there is a potential incidental release of copper and carbon dust from abrasion of the slip-rings of wind turbines but this is considered to have negligible environmental effect. However, it is now evident that the protection and maintenance of monopiles can involve use and release to sea of a range of chemicals such as biocides and corrosion inhibitors. These chemicals are typically drawn from the list of those approved for use in the oil industry, which are registered through the Offshore Chemical Notification Scheme set up by DECC for oil industry chemicals. Some wave energy devices have significant inventories of hydraulic fluids, although there is no planned discharge of these (see also Section 5.9.3.2). Some renewable energy technologies and in particular wave devices may use antifouling coatings, paints or surfaces to prevent the accumulations of excessive loads of algae and encrusting fauna; chemicals used in antifouling in UK and European waters are strictly controlled and significant effects would not be anticipated.

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. Mainly due 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 had been increasing, but it is now falling year on year as production levels and produced water volumes decline. 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 for 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 the 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.

The contamination background of the UK marine environment was reviewed in Appendix A1b.14. 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, Eastwood *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 923.6km^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.

5.9.2 Consideration of the evidence

5.9.2.1 Produced water

Potential effects of produced water discharges are described in previous SEAs. It should be noted that a general presumption is in place that produced water from future developments on the UKCS will be reinjected and not discharged. 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.

The QSR 2010 noted that water column monitoring to determine possible effects from polycyclic aromatic hydrocarbons (PAHs) and other chemicals such as alkyl phenols discharged with produced water has been carried out to a limited extent in the OSPAR area. Monitoring with caged mussels in the Netherlands and Norwegian sectors of the North Sea has shown that mussels exposed to produced water discharges may accumulate PAH and show biological responses up to 1000m from the discharge. Concentrations of PAHs and alkyl phenols and measured biological responses in wild fish such as cod and haddock caught in the vicinity of offshore installations from Norwegian waters in 2002 and 2005 showed a mixed pattern mostly with no increased concentrations, but some elevated biological responses suggesting past exposure. Exposure of cod sperm cells to environmentally relevant concentrations (100, 200, 500 ppm) of produced water from the Hibernia platform, Newfoundland, did not result in a strong toxicity to the cells (only subtle changes were observed) or a significant change in fertilisation rate (Hamoutene *et al.* 2010).

The QSR further noted that results from water column monitoring are complex to interpret, particularly for wild fish for which it is not possible to link observed biological responses to a specific exposure source. Monitoring data are limited and do not yet allow conclusions to be drawn on the significance of observed responses for marine life and ecosystems. The concentrations of radionuclides in water and sediments surrounding platforms are low and there is no evidence of a pathway that could lead to significant accumulation in fish, and consequently effects on human health are not predicted.

Bakke *et al*. (2013) reviewed recent research on the biological effects of offshore produced water (and drill cuttings) discharges, with focus on the Norwegian waters. Produced water discharges are a continuous source of contaminants to continental shelf ecosystems, and alkylphenols and polyaromatic hydrocarbons (PAHs) were found to accumulate in cod and mussels caged near the discharge points, but these compounds are rapidly metabolized in cod. Such compounds may affect reproductive functions, and various chemical, biochemical and genetic biomarkers but Bakke *et al*. (2013) concluded that the risk of widespread impact from such operational discharges is low.

5.9.2.2 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 (barium sulphate used as a weighting agent to aid well control although other dense materials such as ilmenite or haematite may also be used), 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, residual 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. 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 reported 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. 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 2008a).

In response to the progressive tightening of OSPAR and UK discharge and other standards for cuttings drilled with OBM and organic phase fluids, and for the oil content of produced water and production, drilling and cementing chemicals, the UK Government/Industry Environmental Monitoring Committee has reviewed UK offshore oil and gas monitoring requirements. The committee has developed a monitoring strategy which aims to ensure that adequate data is available on the environmental quality status in areas of operations for permitting assurance and to meet the UK's international commitments to report on UK oil industry effects. This strategy has been implemented since 2004 and has included regional studies in various parts of the North Sea, and surveys around specific single and multiwell sites; the most recent surveys has been undertaken as part of DECC SEA monitoring with surveys in the Fladen Ground in late 2015 and the Mid North Sea High in early 2016 (see Appendix 1b, Figure A1b.15).

Overall indications are of recovery of sediments and communities in both the Fladen Ground and East Shetland Basin from the historic effects of oil-based mud discharges; Forties crude oil equivalent, diesel oil equivalent, total PAH and total n-alkane concentrations in Fladen Ground sediments were all lower in 2001 than in 1989 and are now at levels which are considered below 'background'. The results of the analyses of samples from the recent Fladen Ground regional survey are due to be published in 2016. In the East Shetland Basin, comparison of 2002 and 2007 survey data with historic surveys showed that there has been a significant decrease in Forties crude and diesel oil equivalent concentrations. There was also a significant decrease in the concentrations of PAHs. Time series studies of hydrocarbon contamination at selected field developments throughout the North Sea suggest that long-term changes in nearfield concentrations are limited, with recovery periods likely to be multi-decadal.

The timescale of recovery at exploration well sites has also been investigated by UK Government/Industry Environmental Monitoring Committee surveys. THC and metals concentrations in surface sediments at the single exploration wellsite (21/12-2B) drilled with diesel based OBM had declined substantially between 1987 and 2004 although the process of biodegradation and recovery was not yet complete. A similar situation was evident at another single exploration wellsite (16/27-4z drilled with low toxicity OBM) where only low concentrations of OBM derived hydrocarbons were present in surface sediments and concentrations in depth sectioned cores from the 50mS station were substantially less than those found in 1987.

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, Currie & Isaacs 2005, OSPAR 2009b, Bakke *et al*. 2013). 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. Modelling of WBM cutting discharges has indicated that deposition of material is generally thin and quickly reduces away from the well. Jones *et al*. (2006, 2012) compared pre- and post-drilling ROV surveys of a West of Shetland exploration well in Block 206/1a in ca. 600m water depth and documented physical smothering effects within 100m of the well. Outside the area of smothering, fine sediment was visible on the seafloor up to at least 250m from the well. After 3 years, there was significant removal of cuttings particularly in the areas with relatively low initial deposition (Jones *et al*. 2012). The area impacted by complete cuttings cover had reduced from 90m to 40m from the drilling location, and faunal density within 100m of the well had increased considerably and was no longer significantly different from conditions further away.

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 magellanicus* 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 an 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.

The effect of water-based drill cuttings on the benthic ecosystems and geochemical fluxes has been examined in a series of mesocosm (Schaanning *et al*. 2008, Trannum *et al*. 2010) and field experiments (Trannum *et al*. 2011). The mesocosm experiments highlighted a potential reduction in number of taxa, abundance, biomass and diversity of macrofauna with increasing thickness of drill cuttings, possibly as a result of oxygen depletion, which Trannum *et al*. (2011) in comparing difference between the mesocosm and field-based experiments results, suggested that it was probably due to the lack of continuous water flow over the sediment surface in the mesocosm experiments. In addition, the mesocosm results cannot be readily extrapolated to field effects since operational discharge of WBM drilling waste is intermittent and near surface, allowing differential settlement of particulates and dispersion of water soluble components as the material passes through the water column. The field experiments found that the difference in faunal composition between the controls and those treated with drill cuttings was of small magnitude 6 months after drill cuttings deposition indicating a relatively rapid recovery process following discharge of water-based drill cuttings.

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.

A PhD study (Strachan 2010, Strachan & Kingston 2012) was carried out to observe effects of standard grade and fine grade barite on the filtration rates of four suspension feeding bivalves, *Modiolus modiolus*, *Dosinia exoleta*, *Venerupis senegalensis* and *Chlamys varia*. The species were exposed to 0.5mm, 1.0mm and 2.0mm daily depth equivalent doses of standard grade barite, which were maintained in permanent suspension. Standard grade barite, the most commonly used weighting agent in water-based drilling mud, was found to alter the filtration rates of the four bivalve species and to damage the gill structure. All three barite treatments altered the filtration rates leading to 100% mortality. The horse mussel, *Modiolus modiolus* was the most tolerant to standard barite with the scallop, *Chlamys varia* the least tolerant. Fine barite, at a 2mm daily depth equivalent, also altered the filtration rates of all species, but only affected the mortality of *Venerupis senegalensis*, with 60% survival at 28 days. *In vivo* studies showed damage to the gills, ranging from displaced inter-lamellar junctions to the deletion of large parts of the demibranch. Post-mortem microscopy studies showed damage to individual filaments with a marked reduction in the active surface area of the gill. Field studies undertaken by Strachan (2010) showed that the presence of standard grade barite was not acutely toxic to seabed fauna but did alter benthic community structure when persistent.

Strachan (2010) and Strachan & Kingston (2012) concluded that it may be less detrimental to the marine environment if fine barite was used in preference to the coarser standard barite.

Although suspensions of finer particles may be dispersed over greater distances than those of coarser particles, they will also be more dilute and therefore can be expected to have less impact on the marine environment. Although chemically inert, suspended barite has been shown under laboratory conditions to potentially have a detrimental effect on suspension feeding bivalves causing demonstrable damage to the gill filtration system and, after prolonged exposure, mortality.

When the suspended barite levels used in laboratory studies are translated to field conditions (i.e. distances from the point of discharge) it is clear that any effects will be very local to a particular installation (in the case of oil and gas facilities, well within the 500m statutory exclusion zone).

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 water depth 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 impacts from WBM discharges may be of more concern in areas with sensitive benthic fauna, for example corals and sponges. Laboratory experiments by Allers *et al*. (2013) indicated that cold water coral (*Lophelia pertusa*) fragments were resilient to sedimentation-induced oxygen stress, but if coverage by sediment was complete and lasted long enough, the coral could not recover and died. Such effects can be mitigated in areas of sensitive species presence through site specific controls on whether, and where, drilling discharges are made.

5.9.2.3 Saline aquifer and halite cavern construction discharges

Displacement of saline formation fluids from aquifers and construction of caverns in salt formations will potentially result in discharge of significant quantities of brine. For example, proposed construction of the Gateway gas storage facility in the eastern Irish Sea will involve solution mining of 20 salt caverns (total gas capacity 1.136 billion cubic metres) over a four year period. The leaching process at each cavern will involve cycling large amounts of seawater through the well; thereby dissolving some of the salt in the deposit and discharging the resultant brine mixture into the sea at a maximum discharged rate of 386 m^3/hour. The maximum anticipated discharge salinity, which will occur during the cavern commissioning will be in the order of 7 times that of seawater (ca. 250 parts per thousand (ppt)), although it is anticipated to be much less than this during most of the leaching process. The maximum temperature of the discharge will also occur during the cavern commissioning period and is estimated to be 8.68ºC.

Modelling studies of dispersion of the brine plume around each of the discharges indicated that the brine effluent would be best discharged through two 0.15m diameter horizontal ports located at right angles to the main current direction at about 10m above the seabed. This configuration would be expected to give at least a 33 times dilution at the point of seabed impact and a maximum salinity rise at the seabed of less than 7ppt. Further 3D hydrodynamic modelling of the saline discharges showed that the dilution and dispersion of the discharge by the tidal currents would result in a number of separate plumes from each monopod. It was predicted that there would be some merging of the plumes, but only at low salinities (less than about 1ppt above ambient). The saline plumes are expected to be confined to the bottom 0.5 to 1.0m of the water column. Central concentrations are about 7ppt, consistent with the initial dilution (i.e. there is no significant build-up that would reduce the dilution efficiency). The average impact at more than 1ppt above ambient is expected to be confined to an area within some 100m of each monopod during spring tides and within about 300m of each offshore structure during neap tides.

With respect to discharge temperature, it is anticipated that the temperature will reduce to about 2ºC above ambient or less within 1m of the point of discharge. There will also be an insoluble fraction to the discharge, mainly comprising fine mudstone particles. Modelling of this fraction found that in all cases the suspended sediment concentration that results from the discharge was very low, less than 0.5ppm. This is negligible compared with natural levels of suspended sediment and would not be expected to result in visible discolouration of the water.

Very little data is available on the composition of trace minerals in aquifer formation water, which may potentially include toxic species; however, the limited available information suggests a high proportion of sodium chloride (and much smaller proportions of calcium, magnesium, sulphate, carbonate and bicarbonate, all of which are present in seawater).

Halite deposits, being generally formed by evaporation of seawater over geological timescales, have a composition which is comparable to dissolved salt in sea water (i.e. predominantly sodium chloride). There is little data on the composition of brines from solution mining of halite caverns on the UKCS. Geochemical analyses of the Preesall halite formation which will be solution mined to form the Gateway Gas Storage Project caverns was provided in Supplementary Information to the Offshore ES. Core samples from onshore and offshore locations of the formation were very similar, and showed only trace quantities of the metals mercury, cadmium arsenic, chromium, copper, lead, nickel, vanadium and zinc. The halite formation will also contain insoluble components, and the Gateway Project ES considered it a reasonable assumption that the insoluble:soluble ratio identified from the onshore cores will be very similar to the offshore cores. A possible reason for any difference might be a result of later mineralisation associated with hydrothermal activity along faults. However, there are no faults identified in the area of the Gateway 1-e borehole, and the lower zinc content recorded is a good indication that post depositional mineralisation has not occurred. Also Gateway 1-e core descriptions show little evidence of diagenetic alteration within the salt. The Gateway Project ES concluded that available data provided sufficient confidence that the discharges would meet the requirements of EC Directive 76/464/EEC on Water pollution by discharges of certain dangerous substances (List 1 and 2).

The Aldbrough Gas Storage Facility is located approximately 12.5km south of Hornsea on the Holderness coast, Yorkshire. Phase 1 involved the creation of salt caverns in the Zechstein salt deposits under the coast by drilling wells into the salt strata and dissolving the halites with seawater pumped down the well (SSE & Statoil 2006).

Phase 1 salt cavern leaching began in March 2005 with brines being discharged to sea and was estimated to take some 52 months. Brine discharge modelling was undertaken based on a discharge rate of 2,050m^3/hr with a Practical Salinity of 284. The Environment Agency consent conditions for the brine discharge included a regulatory mixing zone 250m from the diffuser within which a salinity of 40 was acceptable. During the first year of monitoring discharge flow rates reached a peak of 1,942m^3/hr with a salinity of 235, averaging at 721m^3/hr with a salinity of 171. Surveys following commencement of discharge indicated that stratification or pooling did not occur. The regulatory mixing zone limit was not approached; maximum ambient salinity monitored was 37 at 250m from the diffuser (SSE & Statoil 2006). Consent was granted for a second phase of development at Aldbrough although this phase of the development has been delayed.

The Whitehills gas storage project to the north of Aldbrough also involves the creation of salt caverns in the Upper Permian (Zechstein) salt deposits underlying the Holderness coast (E.On 2011).

The proposed discharge outfall was approximately 3km from the Aldbrough outfall. The expected salinity of the Whitehills brine discharge was 241ppt. The ES for the development describes disposal of the brine solution to sea via a diffuser located 800m from the shore at a water depth of 7m MLWS (13m MHWS). The diffuser is some 40m long, buried 1.5m under the seabed with a series of riser-heads spaced along it (5.4m apart). The riser heads terminate 1m above the seabed, each with 4 nozzles through which brine would be discharged. The design maximum leaching flow rate is 1,320 m^3/hr. Dilution was expected to be 10 fold within ca. 2m of the riser head discharge points, and modelling of the Whitehills and Aldbrough discharges indicated that the plumes would not overlap (E.On. 2011).

Potential ecological effects from both saline aquifer and halite solution mining discharges are therefore likely to be associated with osmotic effects of hypersalinity rather than toxicity, and will be mitigated by effective dispersion of brine plumes. Although there have been no previous developments of offshore salt caverns in the UK, the environmental effects of brine discharges have been well studied in other countries, notably in relation to discharges from desalination plants but also in relation to solution mining. Construction of salt caverns on the coast of the Gulf of Mexico as part of the US Strategic Petroleum Reserve Program in the 1970s was accompanied by a major environmental monitoring study of the discharge from the Bryan Mound (Texas) site, coordinated by Texas A&M University (Randall & Hann 1981). This included extensive measurement of the brine plume and baseline and postdisposal evaluation of water and sediment quality, nekton (free swimming fauna), benthos, phytoplankton and zooplankton. Biological and water and sediment quality data indicated no substantial effects of the brine plume, which extended over a maximum recorded area of 7.4km^2 and vertical height above the seabed of 7.6m. A complementary study of the West Hackberry (Louisiana) site found no demonstrable effects on sediments or phytoplankton, and limited long-term effects on zooplankton, benthos and nekton (Giammona & Darnell 1990). Seasonal variability in species abundances was a predominate feature as dramatic population fluctuations occurred in all groups studied.

Differences among stations of relatively small magnitude were observed for many species and biomass estimates studied. Some of these differences were consistent when specific comparisons were made between control and diffuser area stations. They include: statistically significant differences in population densities of certain numerically dominant macrobenthic species, and significantly lower values for coefficient of condition (weight at length) of certain nekton target species collected in the vicinity of the brine diffuser. None of the observed changes in biotic communities were catastrophic in nature and all other measured parameters were either within expected ranges of or could not be attributed to diffuser activities (DeRouen *et al.* 1983).

5.9.2.4 Ballast water discharges

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.

5.9.3 Controls and mitigation

5.9.3.1 Hydrocarbon related activities

OSPAR Recommendation 2001/1 for the Management of Produced Water from Offshore Installations provided 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 is now in place which replaces the POPA exemptions, and more wide-ranging powers have been given to DECC Environmental inspectors. Operators are required to make regular reports of actual oil discharge. The regulations are a mechanism to continue implementation on the UKCS of OSPAR Recommendation 2001/1.

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*).

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*.

OSPAR Recommendation 2001/1 focuses on oil in produced water and the application of Best Available Technique (BAT) and Best Environmental Practice (BEP). Since discharges of produced water contain other substances, e.g. heavy metals, aromatic hydrocarbons, and alkyl phenols which are naturally present in a hydrocarbon reservoir, a need was identified to move towards a more holistic, risk-based approach (RBA). In 2012 OSPAR adopted a Recommendation for a Risk-based Approach to the Management of Produced Water Discharges from Offshore Installations and produced associated guidance; DECC published The United Kingdom Risk Based Approach Implementation Programme in 2014: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/361475/United_Kingdom_Risk_Based_Approach_Implementation_Programme_.pdf

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).

5.9.3.2 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 controlled in England and Wales under the MMO's Marine Licence permitting system. All chemicals used in oil industry drilling operations 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). The OCNS does not apply to chemicals used by other industries, however, most of the chemicals used by the renewables industry are similar to those used in the oil industry there seems a logic to standardise their control and reporting (including those chemicals listed by OSPAR for priority action or candidates for substitution) in a similar manner.

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.

5.9.4 Summary of findings and recommendations

5.9.4.1 Marine renewables leasing

With the potential exception in some instances of drill muds and cuttings, and a range of maintenance and operational chemicals, no significant discharges to the marine environment are predicted to result from the proposed leasing for future OWF and other marine renewable energy developments.

5.9.4.2 Oil & gas including gas storage and CO_2 storage in depleted reservoirs

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.

5.9.4.3 Gas storage in saline aquifers and halite cavern construction

Carbon dioxide storage in saline aquifers may result in the production and discharge of aquifer water. The *Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005* apply to discharges containing reservoir hydrocarbons. The quality of aquifer water is variable and the concentrations of elements and compounds of potential environmental concern are poorly characterised: a permitting mechanism is needed to ensure that such discharges can be controlled. On the basis of dispersion modelling and experience from the Gulf of Mexico and elsewhere, effects of saline brine discharges resulting from solution mining of halite caverns or pressure relief in saline aquifer CCS, are predicted to be localised, and not to result in significant ecological effects.

5.10 Waste

Assessment Topic	Potentially Significant Effect	Oil & Gas	Gas Storage	Carbon Dioxide Storage	Offshore Wind	Tidal Stream	Tidal Range	Wave	Assessment Section
	Onshore disposal of returned wastes – requirement for landfill	X	X	X					5.10

5.10.1 Introduction

The European Union (EU) Waste Framework Directive (2008/98/EC)[93], includes a common definition of waste and defines waste as "any substance or object which the holder discards or intends to discard". This section considers wastes from relevant offshore operations transported and disposed of onshore.

Large-scale offshore oil and gas production facilities can generate significant quantities of waste (comparable to an equivalent onshore industrial/residential development) throughout its life cycle from initial exploration and appraisal, through production to decommissioning. Offshore renewables developments are generally not manned and produce minimal waste during operations.

As for onshore industrial waste streams, waste from offshore can be characterised (for management and regulatory purposes) as: hazardous[94] (called special waste in Scotland) (e.g. chemicals, paints, solvents, oils and sludges, hazardous waste containers); general non-hazardous waste (e.g. scrap metal and segregated recyclables) and other (e.g. radioactive materials).

5.10.2 Sources of potentially significant effect

The transfer of offshore wastes to shore for treatment and disposal generally involves the waste being landed at a port and then transferred to a licensed contractor, and can result in a variety of effects including visual intrusion, noise, 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 location and method.

5.10.3 Consideration of the evidence

The quantity of waste generated offshore and transported onshore will vary from year to year depending on the level and type of offshore industrial activity.

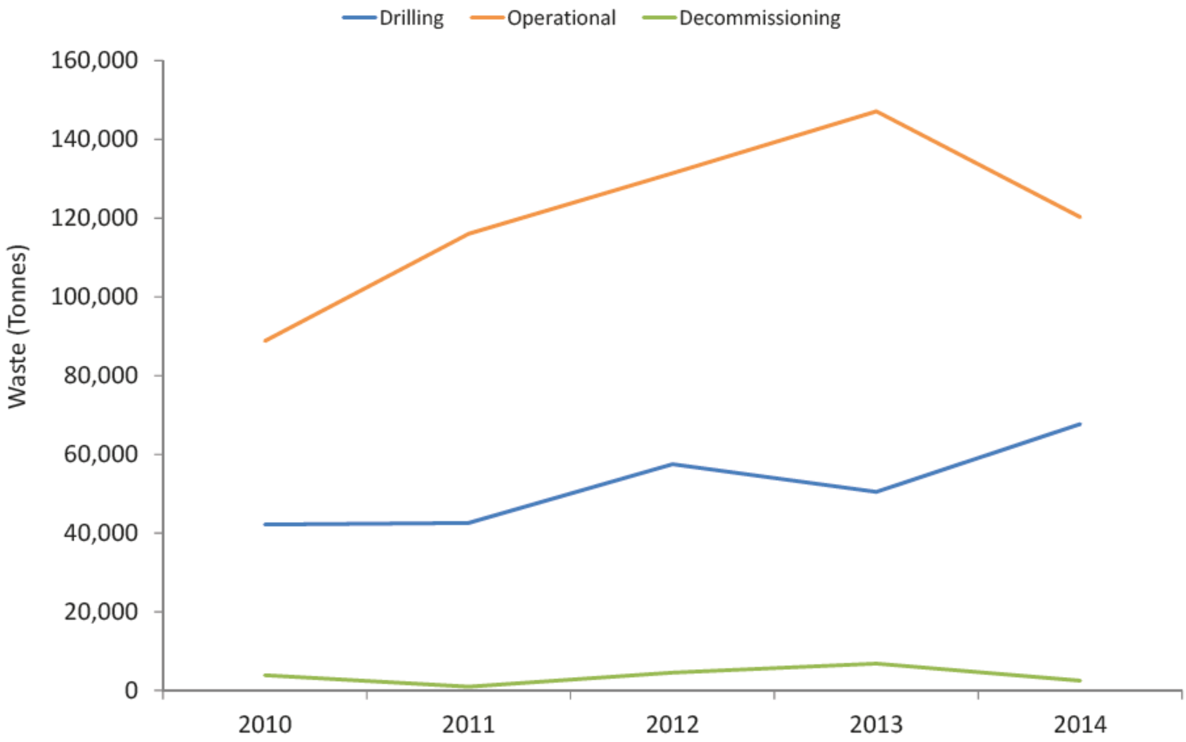
In 2014, the UKCS offshore oil and gas industry returned just over 190,000 tonnes of waste material to shore, representing a 7% reduction from 2013 (>204,000 tonnes). Of this, just over 120,000 tonnes was operational waste, a decrease from 2013, approximately 68,000 tonnes of drilling waste, a 34% increase from 2013, and just over 2,500 tonnes from decommissioning

[93] Directive 2008/98/EC of the European Parliament and of the Council of 19th November 2008 on waste and repealing certain Directives: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098&from=EN

[94] Note – solids and liquids that contain small amounts of oil are classified as hazardous waste

(see Figure 5.44). Waste from the latter is likely to increase in the future as decommissioning activity increases. The majority of this waste was landed in the UK, with a small amount (2%), transferred to the Netherlands for processing (Oil & Gas UK 2015).

Figure 5.44: Waste generated offshore by activity (2010-2014)



Source: Oil & Gas UK (2015), using EEMS data

The majority of offshore oil and gas industry waste (just under 160,000 tonnes, 84% of the total) was landed in Scottish ports in 2014, i.e. Aberdeen and Peterhead. Of this, 66,000 tonnes (41%) was sent to landfill, 49,000 tonnes (31%) was designated as "other" for disposal routes including treatment of aqueous wastes, composting and land spreading and >43,000 tonnes (27%) was reused or recycled (Oil & Gas UK 2015). Figure 5.45 shows the total waste generated offshore by waste disposal route, which includes that landed in England, at ports such as Heysham, Immingham and Great Yarmouth.

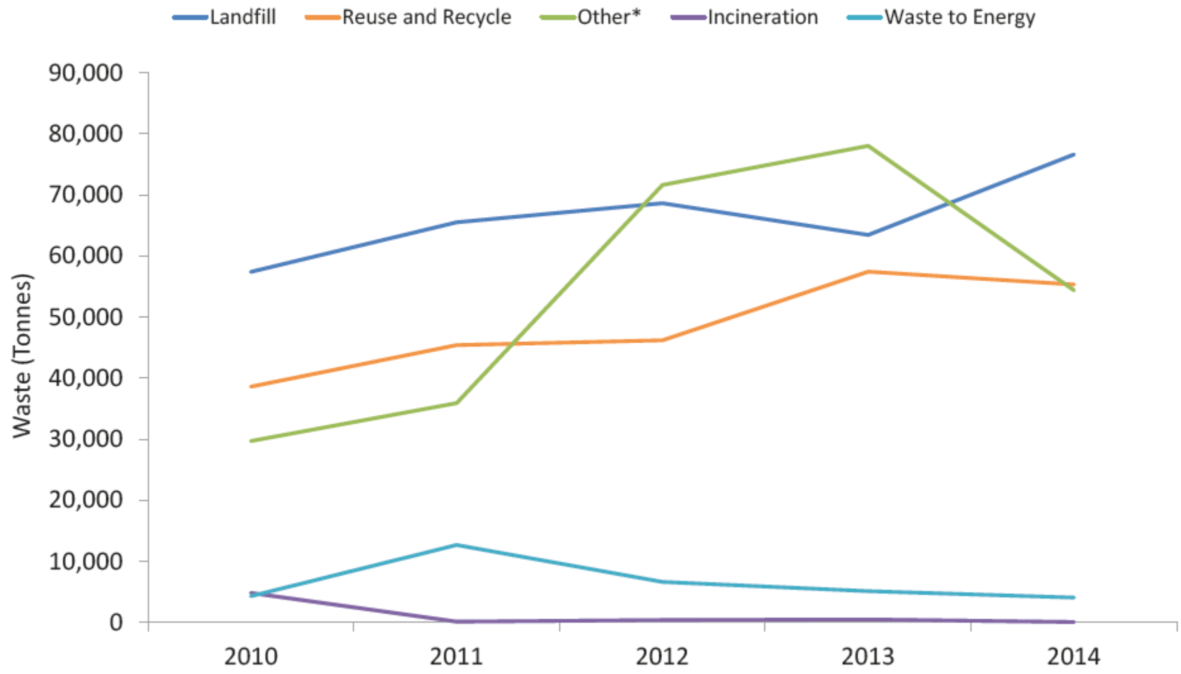
Since 2001[95], discharge into the sea of drill cuttings contaminated with oil based (non-aqueous) drill fluids at a concentration greater than 1% by weight on dry cuttings has been prohibited on the UKCS, (discharge of cuttings contaminated with synthetic organic phase drill fluids is effectively prohibited). Cuttings from wells drilled with water-based drill fluids may still be discharged. (Note, the use and discharge of offshore chemicals on the UKCS are regulated.)

Used drill muds and cuttings can also be ground and disposed of by reinjection into deep rock formations rather than discharged to sea or returned to land. An application must be made to DECC to obtain approval for reinjection at the site of origin. The reinjection of wastes to source is an alternative disposal route avoiding the requirement for onshore disposal and landfill space. However, the process of reinjection can be energy intensive and thus result in increased atmospheric emissions from the installation. The target formation(s) for reinjection of such

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

materials is not always available. Where it is, the target is selected on the basis of geological understanding from previous drilling in the area, with performance monitored over time. 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.

Figure 5.45: Total wastes generated offshore by waste disposal route (2010-2014)

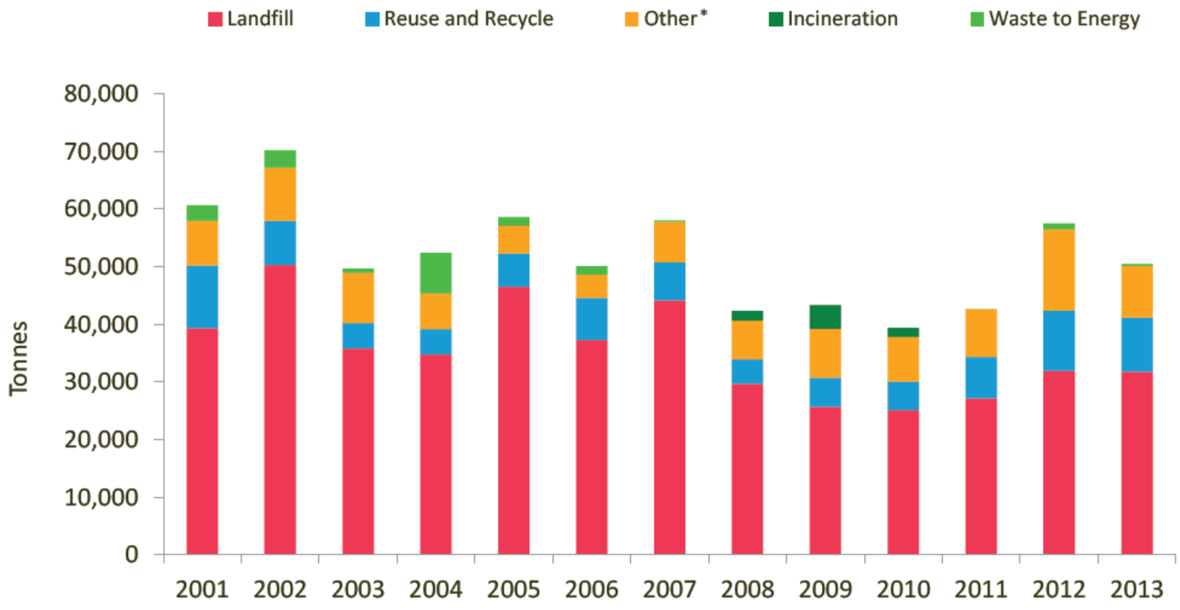


*Note: Total waste includes drilling, operational and decommissioning wastes, *Other includes any other disposal route such as treatment of aqueous wastes, composting and land spreading.*
Source: Oil & Gas UK (2015), using EEMS data

Drill cuttings returned to shore are processed at specialist treatment plants to separate oil (or synthetic fluids) and water from the cuttings (solids) prior to disposal. In 2013, solids accounted for 56% of the back-loaded cuttings total, with the majority, ~32,000 tonnes sent to landfill (following treatment) and ~9,400 tonnes (19%) recycled – see Figure 5.46 (Oil & Gas UK 2014). In the same period with ~11,000 tonnes were injected back into the rock strata; and ~5,000 tonnes of cuttings from oil based (non-aqueous) drill fluids discharged to sea following treatment to remove residual oil to <1% of the total volume (Oil & Gas UK 2014).

In 2014 ~ 68,000 tonnes of drilling waste was returned to shore (Oil & Gas UK 2015).

Figure 5.46: Disposal route of back-loaded cuttings from the UKCS (2001-2013)



*Note: *Other includes any other disposal route includes composting, land spreading and treatment of aqueous wastes.*
Source: Oil & Gas UK (2014), using EEMS data

Waste produced offshore and disposed of onshore contributes to overall waste generation and disposal. In 2012, some 200 million tonnes of total waste was generated by the UK as a whole. Half of this (50%) was generated by construction; ~24% was generated by commercial and industrial activities, with 14% generated by households (see Table 5.29).

Table 5.29: Waste generation split by NACE economic activity in UK, 2012[1]

Commercial & Industrial ('000 tonnes)	Construction[2] ('000 tonnes)	Household ('000 tonnes)	Other[3] ('000 tonnes)	Total ('000 tonnes)
47,567	100,230	27,506	24,716	200,020

Notes: [1] Excludes secondary waste and includes waste which may go on to be exported. NACE = Nomenclature of Economic Activities [2] Construction includes dredging spoils. [3] Other consists of agriculture, forestry and fishing and mining and quarrying.
Sources: Waste Statistics Regulation return, as cited in Defra (2015)

Waste generated offshore in 2012 (a total of 193,000 tonnes) represented 0.1% of the UK total for that year (Oil & Gas UK 2015).

In 2012, of the ~186 million tonnes of UK total waste that entered final treatment, ~50% was recovered, with ~26% landfilled (Defra 2015) (see Table 5.30 for final treatment quantities).

Table 5.30: UK waste entering final treatment, split by final treatment method, 2012[1]

Energy recovery ('000 tonnes)	Incineration ('000 tonnes)	Recovery other than energy recovery – except backfilling ('000 tonnes)	Recovery other than energy recover - backfilling ('000 tonnes)	Landfill ('000 tonnes)	Land treatment and release into water bodies ('000 tonnes)
1,585	6,102	77,467	14,114	48,512	38,383

Notes: [1] Includes waste that may have been imported.
Sources: Waste Statistics Regulation return, as cited in Defra (2015)

5.10.4 Controls and mitigation

The Merchant Shipping (Prevention of Pollution by Sewage and Garbage from Ships) Regulations 2008 (as amended) implement Annex V of MARPOL 73/78 (Regulations for the Prevention of Pollution by Garbage from Ships – revised Annex V entered into force in 2013). Annex V, which applies to fixed and floating offshore installations (including rigs) and their support vessels operating on the UKCS, prohibits the discharge of all garbage into the sea (except ground food wastes where the installation is more than 12 miles from the nearest land), requires facilities/ships to have a waste (garbage) management plan and display placards to notify all persons on board that the over-board disposal of waste is prohibited, and to maintain waste records. Because the offshore disposal of garbage is prohibited, then all such waste must be transferred to shore for disposal and must therefore be managed in accordance with the Duty of Care for waste and the requirements of all relevant UK waste legislation. There are strict controls on the trans-frontier shipment of waste.

Other controls and mitigation applied include annual waste reporting requirements (records quantities and disposal routes i.e. through the Environmental and Emissions Monitoring System, EEMS), waste segregation and the use of waste hierarchy whereby opportunities for waste prevention, re-use or recycling of equipment and materials is maximised, yard selection and regular contractor audit, use of licensed contractors and sites. The DECC Guidance Notes for Decommissioning of Offshore Oil and Gas Installations and Pipelines under the Petroleum Act 1998, states that decommissioning of facilities will be regarded as the last option, after reuse for energy or other projects has been ruled out, and decommissioning decisions are consistent with waste hierarchy principles.

5.10.5 Likelihood of significant effects

There are regulatory controls of waste management on- and offshore and significant effects from waste treatment and disposal are not expected.

At a national scale the waste produced from offshore energy activities is a minor cumulative contribution; significant transboundary effects are not envisaged.

5.10.6 Summary of findings and recommendations

At around 0.1% of total UK waste generation, the contribution from offshore energy industry is, and is expected to remain, minor. Effective regulatory controls are established which have minimised the generation of hazardous and other waste materials, and provided waste management procedures comparable with those onshore.

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.

Substantial waste generation would be expected at decommissioning of offshore infrastructure (both oil & gas and renewables), 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. Offshore decommissioning activity is expected to rise in the coming years, increasing the potential waste generated from this sector of the offshore industry. 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.

5.11 Air quality

Assessment Topic	Potentially Significant Effect	Oil & Gas	Gas Storage	Carbon Dioxide Storage	Offshore Wind	Tidal Stream	Tidal Range	Wave	Assessment Section
	Local air quality effects resulting from exhaust emissions, flaring and venting	X	X	X	X	X	X	X	5.11
	Air quality effects of a major gas release or volatile oil spill	X	X	X					5.11
	Potential for effects on human health associated with reduced local air quality resulting from atmospheric emissions associated with plan activities	X	X	X					5.11

5.11.1 Introduction

Poor air quality may result in effects on human health, the wider environment and infrastructure. Atmospheric acid gases include sulphur dioxide (SO_2) and oxides of nitrogen (NO_X). These gases can 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). Reduction in local air quality through inputs of contaminants such as oxides of nitrogen (NO_X), volatile organic compounds (VOCs) and particulates, may contribute to the formation of local tropospheric ozone and photochemical smogs, which in turn can result in human health effects (see COMEAP 2010 2015, WHO 2013). Ozone is known to impair lung function and NO_X causes irritation of the airways and can be particularly problematic for asthma sufferers (see EPAQS 1996, WHO 2014, Defra 2015a). An overview of recent UK pollutant emissions and trends is provided in Appendix 1e.

The potential sources of emissions from activities associated with each of the draft plan elements is discussed below.

5.11.1.1 Offshore wind farms

Offshore wind farm (OWF) development will result in emissions during the construction, commissioning and decommissioning phases of the project, principally through gaseous emissions from vessel power generation. The operational stage of OWF development has minimal energy requirements, principally associated with maintenance activities involving small wind farm service vessels, often involving high speed light craft.

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 foundation types (monopile, jacket and bucket) only require placement and pile drive/suction installation. The installation of tethered turbines will differ depending on the type of foundation and mooring system, however analogous to gravity base-type foundations; construction of floating devices can largely take place onshore. The Hywind project utilises a series of pre-installed steel suction caissons followed by cable installation and the towing of the pre-assembled ballasted wind turbine to site to be moored (Statoil 2015). Similarly, both the PelaStar floating wind turbine using a tension-leg platform (TLP)-type foundation, and WindFloat using a semi-submersible-type foundation, can be substantially constructed at an assembly yard and then towed to site (see DNV GL 2015 and Section 2.7 for explanation of different foundation types). Time in the field of installation/support vessels may therefore vary depending on foundation 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 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 and variable size depending on the nature of the maintenance.

Emissions to atmosphere from individual projects will vary depending on the number of vessels required and the time these vessels are in the field. These assessments will be undertaken at a project specific level, however those undertaken for representative Round 3 OWFs to date (e.g. Royal HaskoningDHV 2013, 2015) have concluded negligible to no effect, and have in some instances been scoped out entirely from EIA (Royal HaskoningDHV 2015).

5.11.1.2 Wave and tidal developments

The effects on air quality identified in the OWF section also apply to wave and tidal stream technologies and predominantly relate to atmospheric emissions from the vessels used for installation, decommissioning and maintenance of installations.

Atmospheric emissions and therefore air quality associated with tidal range schemes are skewed heavily by the long construction times (e.g. 7 years for La Rance, estimated to be 3 years for the Swansea Bay tidal lagoon), with high cumulative levels of emissions from construction and dredging vessels and vehicles on the landward side during this project phase. There are few Air Quality Management Areas (AQMAs) in the tidal range resource area (see Figure 2.13 and Figure A1e.1), with those in Cardiff being in closest proximity to the coast and being in a prospective area. In addition to potential human health effects, the proximity to habitats sensitive to acid deposition should also be considered, in addition to exceedance in thresholds for these[96]. Previous studies of barrage and lagoon options (DECC 2010d) noted that despite a significant rise in the air pollutant concentrations above background levels during construction, these would likely be localised (e.g. along main routes to the site and construction site itself). DECC (2010d) also noted the potential for changes to emissions from shipping should re-routeing be required, particularly for barrage options. Measures to reduce or prevent such re-routeing were identified (e.g. improved logistics to locks, coordination of transiting vessels, and dredging approaches and navigation channels), but an increase in transit times was generally expected but could not be quantified.

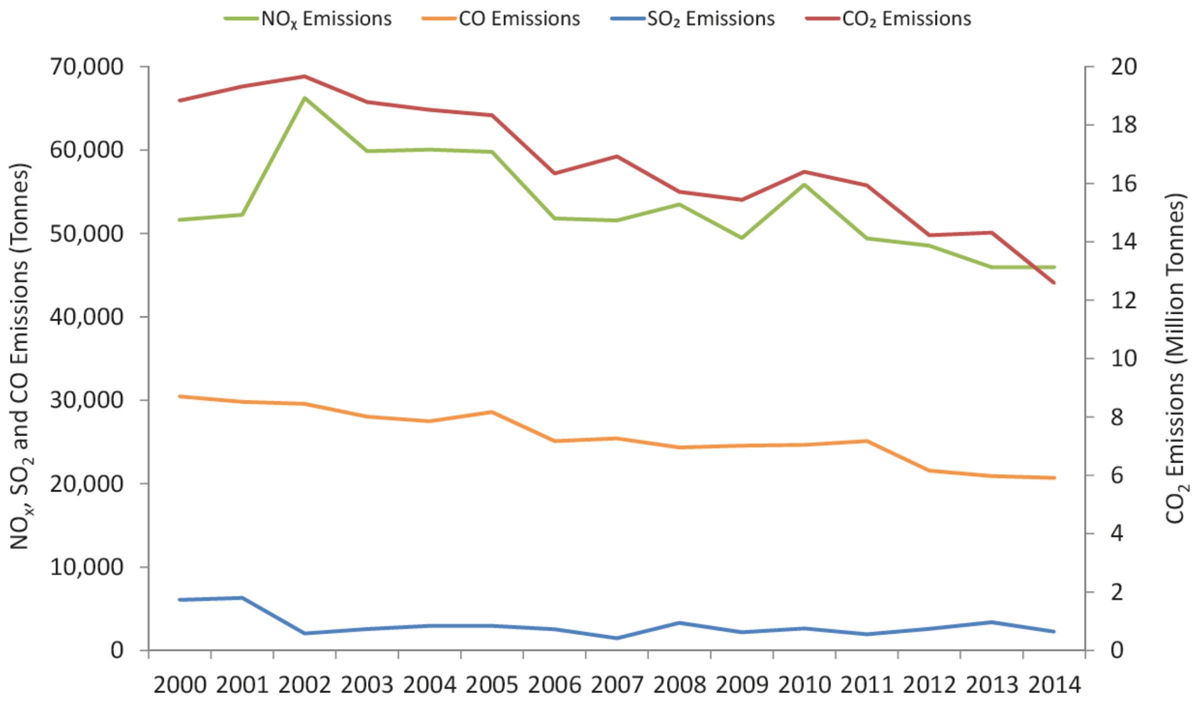
5.11.1.3 Oil and gas

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. 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. Incidental emissions

[96] See: http://www.cldm.ceh.ac.uk/exceedances/maps

may also be associated with refrigeration and fire fighting equipment. Additionally, any new installations will generate emissions through the transport of fixed or floating infrastructure to site and commissioning, with any effect being relative to the time spent in the field.

Figure 5.47: UK offshore atmospheric emissions, 2000-2014

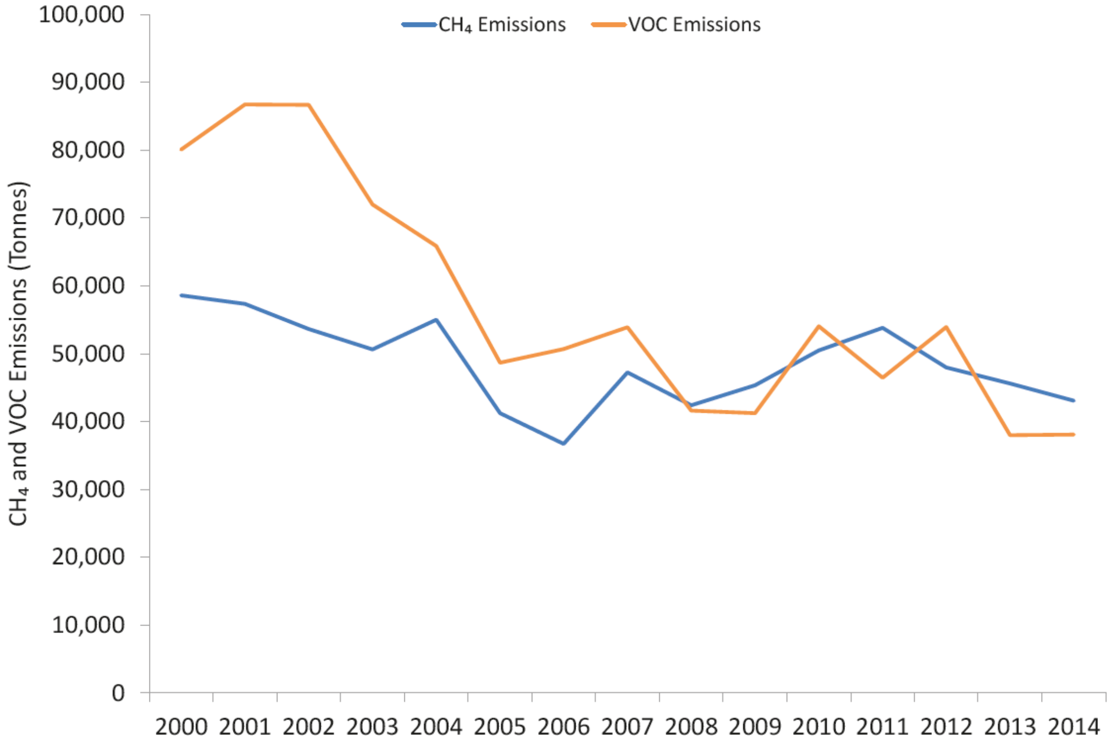


Source: Oil & Gas UK (2015), using EEMS data

The Environmental Emissions Monitoring System (EEMS) database was established by UKOOA in 1992. 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 emissions (e.g. Figures 5.47-5.48).

Emissions from oil and gas activities on the UKCS have generally declined between 2000 and 2014, notably for CO_2 and CO (Figure 5.47) and nmVOCs (Figure 5.48), with emissions of other gas species such as SO_2, NO_x and CH_4 being more variable. In 2014, offshore oil and gas activities accounted for 3% of total domestic CO_2 emissions (12.6Mt of 422Mt CO_2 – see Section 5.12), and emissions of most gases were dominated by use in combustion, with the exception of CH4 and nmVOCs which were largely the result of flaring, venting and loading activities (Oil & Gas UK 2015).

Figure 5.48: UK offshore atmospheric emissions, 2000-2014



Source: Oil & Gas UK (2015), using EEMS data

The general decline in atmospheric emissions may be attributed to a decline in exploration activity and falling production, as well as reductions being made through measures to reduce emissions (see Section 5.11.2). The general trend of declining production has been estimated to continue in the near term, however such projections are difficult to make due to uncertainties over new field start-up profiles and market conditions (OGA 2015a). Despite these declines, recent UKCS oil and gas licensing Rounds (27th and 28th Rounds) have maintained significant interest in exploration, including of mature hydrocarbon areas. It would also be expected that emissions associated with mature fields would increase due to greater power demands associated with the use of injection as a method of disposal of produced water and drill cuttings, and the possible use of diesel generation for such activities where there are native fuel gas supply deficits. The potential future use of reservoirs for gas storage also has the potential to increase sources of emissions for compression and injection (see below). These latter factors may partly obscure the effect of any EU or national measures taken to reduce air emissions from the offshore industry (OSPAR 2014b).

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. Generally, flaring has reduced by ~20% in the last 10 years (DECC 2016b), and total flaring (excluding terminals) on the UKCS was 2.63 million cubic metres (Mcm) per day in 2014 (DECC 2015b). New developments will generally flare substantial quantities only for well testing, for start-up and emergency pressure relief. Other than start-up flaring, subsea tie-back developments, which are predicted to account for the majority of production in mature areas, will generally have little effect on host platform flaring.

Previous SEAs have forecast the atmospheric emissions likely to result from exploration drilling following the last three licensing rounds, and as a proportion of total UKCS emissions from exploration drilling. It is clear that successive rounds have in the past each made a relatively small incremental contribution to total emissions from this sector (at most 3% for the 23rd Round (SEA 5)), and therefore negligible contribution to overall UK emissions. In general, the number of exploration wells drilled on the UKCS shows a decline over time (Figure 2.4). Trends in emissions from well testing, if taken as one of the most emissions intensive aspects of exploratory and appraisal drilling, have shown a similar reduction over time. For example emissions of NO_x and SO_2 in 2013 were both <1% of that emitted in 1990, with similar declines in CO and nmVOCs, but having remained largely constant since 2000 (NAEI data). If current trends continue, and in view of the contribution of emissions reductions measures (including of that for ships, see 5.11.2), then emissions from future licensing rounds are not expected to be appreciably greater than any past round.

As fields cease production, emissions associated with their removal will be analogous to that of their installation, possibly involving the use of rigs to abandon wells, shipping including the use of heavy lift vessels to remove installation components and to transport them to licensed disposal yards onshore.

5.11.1.4 Gas storage

Atmospheric emissions associated with gas storage can be split into similar phases to those for oil and gas exploration and production, including the use of survey vessels, rigs to drill exploration and appraisal wells, vessels used to install facilities and drill injection wells, as well as operational emissions resulting from power requirements for 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.

As outlined in Section 2.2, gas storage capacity in the UK is comparatively less compared to that in wider Europe, as supply has to date been dominated by domestic supply and an abundance of import infrastructure (DECC 2014e). Domestic gas supply has been in decline in recent years (see above) which is enhancing import dependency which could reach 90% by 2035 (National Grid 2015b). In the absence of projections for potential future UKCS or onshore gas supply, which is exploratory, the availability of future domestic production to meet UK demand in the future is uncertain, and therefore more gas storage may be required to enhance the security of supply should import dependence continue to grow. The number of any such facilities which could be proposed and/or constructed during the currency of this SEA is uncertain, but the present number of offshore facilities (Rough) and those which have been proposed in recent years and which remain in planning (Deborah), suggest that relatively few proposals may be made (see Appendix 1h for more details). Therefore, in view of the major sources of atmospheric emissions from gas storage facilities and as many of these will be made offshore, air quality effects from these activities are regarded to be negligible and small in a national context.

5.11.1.5 Carbon dioxide storage

Atmospheric emissions associated with carbon dioxide storage can be split into similar phases to those for oil and gas exploration and production and natural gas storage, including the use of survey vessels (including for operational monitoring), rigs to drill exploration and appraisal wells, vessels used to install facilities and drill injection wells, as well as operational emissions resulting from power requirements for compression. Transport of carbon dioxide to offshore facilities will most likely be delivered via new or existing pipelines (and possibly be used in enhanced oil recovery for partially depleted hydrocarbon fields), however the possibility of ship transfer cannot be entirely excluded. The use of existing facilities through storage in depleted hydrocarbon reservoirs (where practical) could reduce installation emissions, and is consistent with policies contained in the East Marine Plans and Scotland’s National Marine Plan (policy CCS2 in both documents). In general, minimal operational emissions and distance from shore is likely to mean that routine atmospheric emissions are not a source of likely significant effect for carbon dioxide transport and storage.

The *Energy Act 2008* (as amended) makes provisions for the carrying out of carbon dioxide storage with a view to its permanent disposal, in keeping with the terms of the CCS Directive 2009/31/EC (see Appendix 2 for more information and Section 5.13). Article 1(2) of the CCS Directive states that, "*The purpose of environmentally safe geological storage of CO_2 is permanent containment of CO_2 in such a way as to prevent and, where this is not possible, eliminate as far as possible negative effects and any risk to the environment and human health*." In view of this central purpose, and for this section the human health aspect, a short consideration of potential leak effects on human health and the mitigation measures available is given below. The CCS Directive, and therefore the transposing UK Regulations, require sufficient information on a proposed storage structure to understand, *inter alia*, the geology and flow properties of the reservoir overburden (caprock, seals, porous and permeable horizons) and surrounding formations, including fracture characterisation and any man-made pathways (e.g. wells). Any application for a storage permit must also include a monitoring plan to confirm that the carbon dioxide remains in storage and to validate any modelling, or whether unintended migration and leakage is occurring and that corrective measures must be taken using an approved "corrective measures plan".

The Health and Safety Executive (HSE) are responsible for regulating the full CCS chain under the *Health and Safety at Work etc. Act 1974*, under which employers are required to ensure the health and safety of workers and members of the public, so far as is reasonably practicable. At present, carbon dioxide is not defined as a dangerous substance under the *Control of Major Accident Hazards Regulations 1999*. It should be noted that HSE (2009, 2011) concluded that CCS developments have the potential to introduce a major accident hazard, as hazard ranges modelled for instantaneous releases (50-100m) are in line with other regulated hazardous substances, but that the risk posed by a pipeline rupture is likely to be similar to natural gas, but for toxicity rather than it being a flammable gas. Though behaviour of an instantaneous release of dense phase CO_2 is still not well understood, and can introduce other hazards such as cryogenic burns, HSE (2009) suggest that the hazard ranges may be substantially higher for CO_2 transported in this manner. With regards to offshore elements of the risk, good project design, including the use of existing guidelines on pipeline design (BS PD 8010: 2004 Part 2, DNV RP-J202: Design and Operation of CO_2 Pipelines) and any future modifications to these with regards to specific CO_2 requirements should provide for suitable mitigation at a project level.

Low release concentrations would have minimal effect beyond associated climate impacts and possibly small localised acidification of adjacent waters (see Phelps *et al.* 2015), but high concentrations could affect human life, ecology and other organisms, and potentially have transboundary implications depending on the storage site/release location (see Section 5.13). CO_2 is denser than air and therefore can displace it causing a suffocating effect; however it is also toxic to the cardiovascular system at concentrations exceeding 3%, with symptoms notable at exposure for 1 hour, or largely fatal at 15% for 1 minute (HSE 2011) – note that CO_2 is naturally present in the atmosphere at a concentration of ~0.037%. Catastrophic releases are not the only concern, for instance IPCC (2005) reports that chronic effects of CO_2 exposure at atmospheric concentrations of between 0.5 and 1% can result in metabolic acidosis (an increase in blood acidity) and increased calcium deposits in soft skin. Examples from real world exposure are few, but include a very large natural release of CO_2 from the Lake Nyos volcanic crater in Cameroon which caused 1,700 human deaths and loss of livestock at a distance of up to 25km. HSE (2011) note that this release was in the order of 1.6 million tonnes CO_2, and very large when compared with the potential scale of commercial CCS in the UK: a pipeline from source to injection facility might hold 10,000 tonnes or a large pipeline cluster 100,000 tonnes, distributed over a large area and segmented by valves to isolate and possible release quantity.

Significant survey work would need to be undertaken to avoid formations and storage areas with faults or other features that could cause loss of containment and long term monitoring would need to be carried out on any storage site to make sure that leakages do not occur during operation and once the site is full and in its post-closure phase. The requirement for the site operator to monitor and take any corrective actions following the closure of a site should be for at least 20 years unless the competent authority (presently DECC) are convinced that the CO_2 will be completely and permanently contained. Once this is proven, the responsibility for the site is transferred to the competent authority. A wider range of considerations with regard to carbon dioxide transport and storage and accidental release is provided in Section 5.13 Accidental events.

5.11.2 Controls and mitigation

The potential sources of effects identified above are largely from routine combustion emissions, much of which are associated with shipping (e.g. in development installation, operation (including maintenance) and decommissioning). For all the draft plan related activities, it should be noted that the *Merchant Shipping (Prevention of Air Pollution from Ships) and Motor Fuel (Composition and Content) (Amendment) Regulations 2014* which came into force in December 2014, partly implements EU Directive 2012/33/EU on the sulphur content of marine fuel. The Regulations include limits to the sulphur content of fuel oil used or intended to be used in sulphur oxide emission control areas (defined by Annex VI of the MARPOL Convention and including the North Sea and English Channel), to not more than 0.1% by mass from January 2015. Similarly, the emissions of NOx from shipping are being controlled through the requirements of MARPOL Annex VI, whereby different “tiers” of emissions are permitted depending on vessel construction date and whether it operates within an emissions control area (as defined for the UK above). The UK Government has supported this approach and intends to implement it through amendments to the Merchant Shipping legislation (Defra 2015j). Emissions and deposition is higher around major shipping routes such as the Southwest Approaches and English Channel (see Appendix 1e). Routine emissions are also made on offshore oil and gas installations (and also any for gas storage including carbon dioxide) for general power generation (e.g. lighting) and compression (e.g. for injection of water or gas).

For offshore oil and gas installations with gas combustion installations (power generation, turbines, fired heaters etc.) that have a combined total rated thermal input exceeding 50MW and a Pollution Prevention and Control (PPC) permit is required. Conditions on such permits include provisions based on best available techniques, emission limits, energy efficiency and monitoring requirements. There are a number of exclusions including mobile drilling rigs. Any flaring and venting at offshore installations is subject to flare and vent consents. Where flaring exceeds 40 tonnes per day consent will only be given for one year, and applications need supporting information on medium- and long-term plans for flare reduction. Specifically with regards to carbon dioxide equivalent emissions (see Section 5.12), combustion installations with a rated thermal input of more than 20MWth are required to have a permit under the *Greenhouse Gas Emissions Trading Scheme Regulations 2012* to discharge CO_2 as part of the implementation of the EU Emissions Trading Scheme (EUETS). It should be noted that under Phase III of the EU ETS, CO_2 from flaring must also be taking into account. CCS activities are also covered by these Regulations such that any leaked/fugitive carbon dioxide emissions would be subject to the surrender of emissions trading allowances, in the same way as combustion emissions.

At a wider UK level, the Government’s Air Quality Strategy for England, Scotland, Wales and Northern Ireland (2007) set national air quality standards with the objective of protecting human health, vegetation and ecosystems. There was recognition in an addendum to this in 2010, Air Pollution: Action in a Changing Climate, that it would be conducive to consider the linkages between air quality and climate change policy areas, since activities generating air pollution were often also associated with GHG emissions (see Section 5.12). AQMAs have been declared to deal with problem areas in the UK, mainly for NO_2 which is largely derived from transport sources, predominantly from road transport (see Appendix 1e and Bush *et al.* 2014). Where these are in coastal areas, they could be influenced by activities associated with the draft plan/programme where there is an increase in port related activity, or particularly in the case of tidal range developments, ancillary development and shore-based construction. Any development will need to consider how their estimated emissions could affect air quality limit values, particularly where these could affect AQMAs. A high degree of coordination between marine and terrestrial planning may there therefore be required, as indicated the Marine Policy Statement which requires marine plan authorities to take account of any relevant statutory air quality limits or how air quality may be improved, particularly within, or adjacent to, AQMAs. The National Policy Statement (NPS) for ports, though largely set within the thresholds set out in the *Planning Act 2008*, provides further guidance and potential mitigation, for instance the provision by ports of shore-side electrical connections to eliminate emissions from ship generators when in port where ships can utilise such supplies, and the use of systems to reduce acting cumulatively on existing air quality issues, for instance HGV booking systems to avoid peak times.

5.11.3 Summary of findings and recommendations

OWF, wave and tidal stream development will result in atmospheric emissions during the construction, commissioning and decommissioning phases of each project, principally through gaseous emissions from power generation of vessels. Emissions from flaring and venting from offshore oil and gas installations have substantially reduced in recent years, with no routine flaring considered necessary for some new development proposals, mainly due to the availability of existing gas process and export infrastructure. Similarly, regulation of combustion equipment and inclusion within EUETS requirements promotes efficient use of equipment and fuel. These savings may in part be reduced in future due to increased energy requirements of mature fields, however in the medium-term, decommissioning of facilities will also lead to an overall reduction in emissions from the sector.

Major sources of emissions to atmosphere from offshore gas storage and carbon dioxide storage, are internal combustion for power generation by installations (e.g. for compression and injection), 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. Though the use of carbon dioxide storage may alter the emissions portfolio of a given coal or gas power plant (e.g. see an increase in the emissions of ammonia, NH_3), it is not a consideration of this SEA and would need to be considered at the project specific level.

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, local air quality effects from atmospheric emissions are not expected. Few new effects are expected in terms of the siting of gas storage and carbon dioxide storage facilities in existing hydrocarbon reservoirs. However, the use of vessels for construction and maintenance and the potential transportation of liquid CO_2 by ship to some carbon dioxide storage reservoirs make shipping the greatest potential source of routine atmospheric emissions from these technologies.

Emissions to air from plan activities will be incremental to those from a range of other terrestrial and marine sources, and those transboundary sources from other countries. Cumulative effects are more likely to be significant where plan related activities affect problem areas, such as air quality management areas. For offshore oil and gas, emissions have progressively reduced through reduced flaring and more efficient plant, and the point sources of such emissions are generally too far from shore to significantly contribute to cumulative effects at a local level. Any further exploration and development would be expected make a minor increment to such emissions, with the overall scale of offshore activity (in view of decommissioning and) not appreciably changing in the currency of this SEA. Significant emissions from renewables technologies are limited to the manufacturing, construction and decommissioning phases, which could produce temporary cumulative effects (e.g. through enhanced shipping and port use), but in the long-term are likely to contribute to overall emissions reductions, and so are broadly not considered likely to act cumulatively. Construction of tidal range devices could produce significant cumulative effects at a local level through emissions from shipping and road haulage transport, or production of dust. Compared to other forms of renewables construction takes place over extended time periods (5+ years) and is coastal in nature. Any emission of pollutants adds to existing elevated levels in the atmosphere. Where activities could take place in close to a boundary with adjacent states or administrations and where they have land masses which are also close proximity (e.g. France, the Isle of Man), there is greater potential for transboundary issues, but given the nature and scale of most activities, these are considered to represent a minor increment with limited scope for significant transboundary effects.

Emissions will also be associated with the construction of any infrastructure to be installed, and the choice of construction materials can make substantial differences to the emissions generated for this part of a project lifecycle, and in many cases, these emissions may take place outside of the UK. The potential expansion of ports to facilitate mainly OWF, but possibly also other renewables development, may have implications for local air quality in these areas. In keeping with national terrestrial and marine policy, and regional policies where applicable, any effect on AQMAs must be considered. Where UK port expansion or significant changes in use occur as a result of plan activities, mitigation measures including those set out in the NPS for ports should be considered to avoid impacting AQMAs or exceeding national limit levels such that new problems are created.

Tidal range developments are shore connected, and therefore emissions may be generated through terrestrial and marine sources, and are associated with long construction times. There is the potential that individually or cumulatively, alterations in ship movement through construction of barrages or lagoons (e.g. see DECC 2010d) could alter the nature of emissions from shipping in these areas.

Operational effects of offshore renewables are expected to be negligible, and effects at the strategic level are not considered to be significant.

In view of regulatory controls and commercial considerations, combustion emissions from power generation are unlikely to represent a major contribution to industry or national totals.

5.12 Climatic factors

Assessment Topic	Box 5.1:Potentially Significant Effect	Oil & Gas	Gas Storage	Carbon Dioxide Storage	Offshore Wind	Tidal Stream	Tidal Range	Wave	Assessment Section
	Contributions to net greenhouse gas emissions	X	X						5.12
	Reduction in net greenhouse gas emissions			X	X	X	X	X	5.12
	Positive socio-economic effects of reducing climate change[1]			X	X	X	X	X	5.12

Note: [1]*outline assessment only*

5.12.1 Introduction

The following section considers the aspects of the current draft plan/programme (see Section 2.1) in relation to anthropogenically augmented climate change and the international and national policy context which has developed in recent years in order to try and avoid its worst effects. The plan/programme is complementary to current policy and legislation (as set out in Section 2 and Appendix 2), e.g. specifically of relevance to this topic, renewable energy generation targets and greenhouse gas reduction commitments. Certain aspects of the plan (oil and gas licensing, gas storage leasing/licensing) also complement activities that contribute to maximising the economic recovery of UK hydrocarbons and energy security. Though these aspects of the plan may be regarded as deleterious to climate change mitigation efforts, projections of the likely energy mix in coming years and other UK Government policy aspirations (e.g. replacement of unabated coal-fired with gas-fired power stations) suggests a continued reliance on fossil fuels, and certainly within the currency of OESEA3.

5.12.2 Consideration of the evidence

5.12.2.1 Climate change

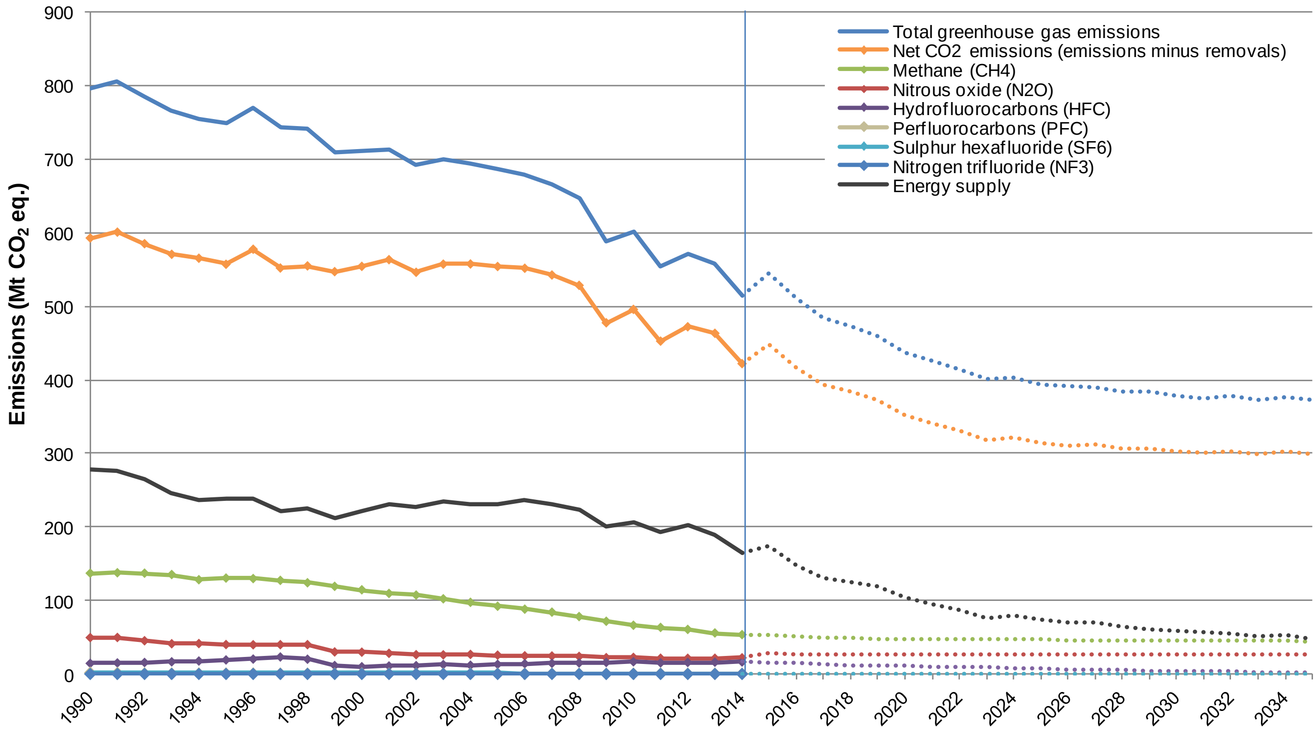
Anthropogenic sources of greenhouses gases (GHGs) are implicated in amplifying the natural greenhouse effect[97] resulting in global warming and potential climate change (IPCC 2013). Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and the "F-gases", hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). are termed "direct" greenhouse gases as they have a direct effect on radiative forcing (RF) 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.

CO_2 is the principle GHG of concern as it constitutes the largest component of combustion emissions (~82% of UK sources in 2014 at 422 million tonnes (Mt), see Figure 5.49) and has a potentially long atmospheric residence time (5-200 to ~1,000 years have been reported, see Houghton *et al*. 2001 and Archer 2005). The residence times of such gases are a key component of metrics used to estimate CO_2 equivalent (CO_2 eq.) emissions, that is, the radiative forcing provided by the emissions of a unit of a particular greenhouse gas species

[97] The absorption of thermal radiation in the atmosphere and re-radiation by water vapour and "greenhouse gases", most abundantly carbon dioxide, but also methane, nitrous oxide, ozone and several others in small amounts.

relative to CO_2, referred to as the Global Warming Potential (GWP), see Myhre *et al*. (2013). The result is a value in tonnes of CO_2 eq. incorporating the "basket" of GHGs listed above (i.e. those covered by the Kyoto Protocol). As atmospheric residence time influences this metric, GWP values differ depending on what "time horizon" is considered (see IPCC 2001, 2007, Myhre *et al*. 2013, and Shine 2009 for a synthesis and critical review). For example, CH_4 has a GWP of 84 times that of CO_2 at 20 years, and 28 times that of CO_2 at 100 years, reflecting its residence time in the atmosphere of ~12 years (see Forster *et al*. 2007). A high degree of uncertainty in the GWP factors for some gases (CO and NOx) means that they are generally not calculated – note that IPCC (2013) indicate that it is virtually certain that these gases have induced a positive RF and a net negative RF respectively. There is no scientific argument for the choice of a particular timescale, but the 100 year time horizon was adopted by the United Nations Framework Convention on Climate Change (UNFCCC) and is used in the Kyoto Protocol (Myhre *et al*. 2013), and is also used nationally for the calculation of carbon dioxide equivalent emissions (Shine 2009).

Figure 5.49: UK greenhouse gas emissions, 1990-2014 and emissions projections to 2035 based on the reference scenario



Source: DECC (2016a, b)

Notes: Final figures 1990-2014. "Reference scenario" projections based on central estimates of economic growth and fossil fuel prices. Contains all agreed policies where decisions on policy design are sufficiently advanced to allow robust estimates of impact (i.e. including "planned" policies). See annex D of DECC (2016) on policy savings for definitions on policy implementation statuses.

Cumulatively, it is the concentration of such gases in the atmosphere globally, augmented by anthropogenic emissions, which are leading to global warming. Global concentrations of CO_2 (391ppm), CH_4 (1,803ppb) and N_2O (324ppb) have increased substantially due to human activity since 1750, exceeding pre-industrial levels in 2011 by 40%, 150% and 20% respectively, and have substantially exceed levels recorded in 800,000 years of reconstructed atmospheric records from ice core data (IPCC 2013). Reducing emissions of GHGs, and therefore the concentration of such gases in the atmosphere, is the principal means by which the worst effects of global temperature rises and related effects can be avoided. It is widely regarded that maintaining any rise below 2°C above pre-industrial will assist in avoiding these effects, and it is likely that if concentrations of 450ppm or lower are achieved by 2100, that warming below this can be maintained (IPCC 2014). This is further reinforced by the Paris Agreement which aims to strengthen global response to the threat of climate change by (Article 2):

- Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change
- Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production
- Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development

There is a high level of scientific understanding with regards to the effect of anthropogenically enhanced levels of GHGs and ozone on global radiative forcing (IPCC 2013), with greater uncertainty about some important factors including aerosols (which partly offset the radiative forcing of GHGs) and predicting future forcing by solar irradiance (i.e. the influence of cyclic solar activity on the Earth's climate). Predicted effects include *inter alia* an increase in global temperate (Kirtman *et al*. 2013, Collins *et al*. 2013), rising sea-levels (Lowe *et al*. 2009, Church *et al*. 2013, Horsburgh & Lowe 2013), changes in ocean circulation (Collins *et al*. 2013) and potentially more frequent extreme weather events (see Woolf & Wolf 2013 for a UK specific discussion), and other effects including ocean acidification generated by enhanced atmospheric acid gas loading, deposition and exchange (see Bates *et al*. 2012). These effects, most recently summarised in the Intergovernmental Panel on Climate Change (IPCC) 5th assessment report (IPCC 2013), are the rationale on which global and national greenhouse gas reduction commitments are made, including the recent Paris Agreement. The UK Climate Projections (UKCP) provides medium- to long-term projections (to 2100) for climate change specific to the UK and UK marine area. The evidence base for climate change in the UK continues to be updated through this programme and the latest reports, UKCP09, remain current albeit with updates to its weather generator model (note that the UKCP18 programme to update this work is now underway). The Marine Climate Change Impacts Partnership (MCCIP) has close ties with UKCP, and these programmes help to provide climate change evidence and advice which may be used to inform policy and decision-makers, for example, a consideration of projections in UKCP09 is recommended in the Marine Policy Statement (MPS) and also in terrestrial plans which may involve coastal elements (see the NPPF) and now also regional marine plans (e.g. East Inshore and Offshore). The potential effects of climate change on each of the topics covered in this SEA is discussed in Appendix 1, and is also a consideration in other assessment sections preceding this in view of the evolution of the baseline.

5.12.2.2 Energy and climate change policy context

The policy context relating to climate and climate change is summarised in Section 2 and discussed in greater detail in Appendix 1f and Appendix 2. The following provides an overview of the policy and legislation and its global context of relevance to the draft plan/programme considered in this SEA.

Given the potentially long residence time of CO_2 in the atmosphere, it is clear that current policy decisions with regards to climate change could have far reaching effects for the medium and long-term trajectory of changes. The economic costs of not attempting to avoid the worst effects of climate change at the earliest opportunity outweigh any subsequent cost of climate change mitigation (The Stern Review 2006). In the absence of mitigation, and in part through its realisation by the decarbonisation of the energy sector, impacts including sea-level rise, coastal flooding and coastal squeeze would occur at a faster rate than if efforts to reduce emissions were realised. Access to water, food and also the health effects of climate change will all have a socio-economic impact in the UK and elsewhere.

The *Climate Change Act 2008* makes provisions for the reduction of carbon equivalent emissions through a number of legislative measures, which includes the setting of a carbon budget. The Act aims to meet this target through a range of measures, but principally the establishment of the Committee on Climate Change (CCC), 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. The carbon budget currently sets a target for the reduction of greenhouse gas emissions by 80% on 1990 levels by 2050, and a specific reduction in CO_2 emissions of 34% by 2020. Net CO_2 emissions in 2014 were 35% below 1990 levels (41% for the energy sector) – see DECC (2016b). A further target of 50% by 2025 has been set (fourth carbon budget) with the expectation that a target will be set of 57% by 2032 for the fifth budget (CCC 2016). DECC are due to set the level of the fifth carbon budget by the end of June 2016. The seventh statutory report to Parliament by the CCC on progress towards meeting the carbon budgets set to date has indicated that despite meeting the first carbon budget, when considering the pace of the underlying emissions reductions, and accounting for the impacts of the recession, the UK is not on target to meet subsequent budgets[98]. The CCC made a series of recommendations, and indicated that it would be necessary for Government to develop and implement further measures/strategies/policy to support the achievement of the statutory carbon budget. Further recommendations were made in a letter to the Secretary of State on the implications of the Paris Agreement which related to the fifth carbon budget (CCC 2016). In addition to the emissions target level these include: the budget should not be met through the purchase of credits outside of the EU ETS, policy approaches should be developed to reduce carbon intensity of the energy sector to below 100 gCO_2/kWh in 2030, and for sectors outside the EU ETS, policies should drive average emissions reductions of 2% per year. In view of the currency of this SEA, the recommendations of the CCC for this parliament include:

- Electricity: extend funding under the Levy Control Framework beyond 2020 and award contracts to low-carbon generators to achieve a total sector emissions intensity below 100g CO_2/kWh by 2030
- CCS: develop urgently a new approach to CCS in the UK

The Carbon Plan (2011) set out how the UK Government intended to achieve the fourth carbon budget, which will include the transition to a low carbon economy while maintaining the security of energy supply[99]. During this transition, which by 2050 is likely to comprise an increasing proportion of energy from renewable sources, plus abated (with CCS) coal, biomass or gas-fired power stations and nuclear energy[100]; gas and oil will continue to play a valuable role for

[98] Projections for 2013 to 2022 suggest that the UK will meet its second and third carbon budgets but that there is a shortfall in the fourth carbon budget assuming no new effort (e.g. additional policy).
[99] See the Energy Security Strategy (2012). There is a statutory duty on Ofgem under the *Energy Act 2004* (as amended) to report annually on the availability of electricity and gas, which also meets UK obligations under, for instance Directive 2009/73/EC, the Gas Directive.
[100] See the DECC 2050 Pathways Calculator: https://www.gov.uk/2050-pathways-analysis, which shows that it is possible to meet the 80% emissions reduction target in a range of ways, and allows people to explore the combinations of effort which meet the emissions target while matching energy supply and demand.

heating and electricity generation. In addition to decarbonising the energy supply sector, wider measures include reducing demand through greater energy efficiency in homes, businesses and in transport. Linked to the above, the UK Government is presently reviewing its energy policy and the contribution to decarbonisation that this will make[101], with gas-fired power stations, new nuclear and offshore wind being indicated as the preferred means to achieve this, with continued commitment to CCS through gas- or coal-fired power station emissions abatement.

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, with requirements set out in the Renewable Energy Directive (2009/28/EC). The UK's contribution will require its share of renewable energy consumption to increase from around 1.5% in 2006 to 15% by 2020. In the UK, the *Energy Act 2008* (as amended) aims to not only help maintain energy supply reliability, promote competitive markets and ensure affordable heating, but also contribute to the reduction in greenhouse gas emissions (most notably CO_2) which have been linked to anthropogenically augmented climate change. *The Energy Act 2010* implemented some of the key measures of the UK Low Carbon Transition Plan (2007, superseded by the Carbon Plan 2011, above), including provisions for a new CCS incentives, the introduction of mandatory social price support to tackle fuel poverty and a number of measures to ensure fairness in the energy markets. *The Energy Act 2011* (as amended), amongst other provisions, includes provisions and consequential amendments in relation to energy security (e.g. access to upstream petroleum infrastructure), and a number of sections outlining measures to reduce carbon emissions, which includes: offshore electricity transmission, the conversion of infrastructure for CCS, and compulsory purchase in relation to CCS pipelines.

In the UK, the deployment of renewable energy has been incentivised through the Renewables Obligation since 2002 (see the *Renewables Obligation Order 2009*, as amended), whereby renewable electricity generators sell their Renewables Obligation Certificates (ROCs) to suppliers which guarantees a premium above wholesale market prices. Suppliers then present their ROCs to Ofgem to show their compliance (i.e. whether they have met their annual obligation), and pay a penalty if they fail to do so. The value of each ROC is decided between the generator and supplier. Under the UK Government's Electricity Market Reform there will be a transition from the Renewables Obligation to "Contracts for Difference" (CfDs), which will be the new support mechanism for renewables, new nuclear and CCS from 2014. The related policy and processes involved in this transition was set out in a consultation which closed in September 2013, also see *The Renewables Obligation Closure Order 2014* (as amended), and also the 2015/16 *Energy Bill*. CfDs will be offered to operators at a fixed price, with the operator paying back any difference between the value of the CfD and wholesale electricity prices for electricity, effectively capping the cost of electricity to the consumer from these sources.

5.12.2.3 Energy consumption, the energy mix, and the draft plan/programme

Primary energy in the UK is derived from a number of sources, but principally comes from solid fuels (e.g. coal), hydrocarbons (gas and oil), bioenergy, and electricity (a mix of hydrocarbon, solid fuel nuclear and renewable sources) – see Figure 5.50 for an overview of the present proportions of these making up the present UK energy mix. Of primary concern in this SEA are primary oil and natural gas production, and electricity generation from renewable sources.

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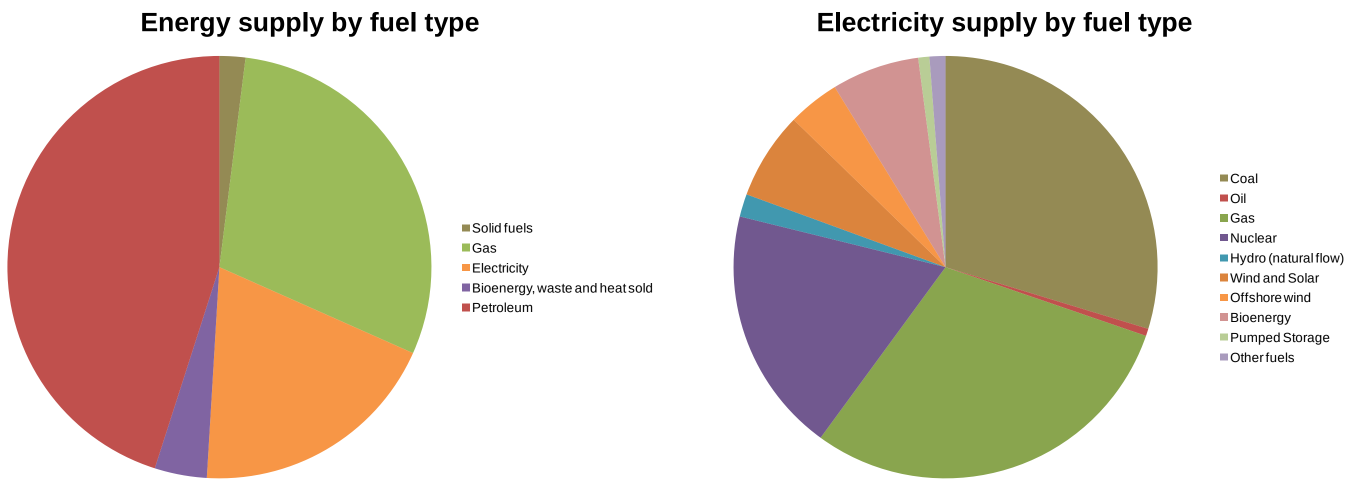
[101] See: https://www.gov.uk/government/speeches/amber-rudds-speech-on-a-new-direction-for-uk-energy-policy

Figure 5.50: Energy mix displayed as supply by fuel type, 2014



Source: DECC (2015c)

Energy consumption is partly a function of weather conditions, though when these are factored into the calculation of energy consumption the broad trend remains the same (Figure 5.51). Use of coal, coke and breeze to produce energy declined substantially through the 1980s and 1990s, to be substituted with natural gas and primary electricity sources (see DECC 2015a). The increase in the total consumption figures through the 1980s and 1990s can be 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, with the more recent decline attributed to a reduced use of gas and petroleum, though economic recession would also have been a factor (DECC 2010a, 2015a).

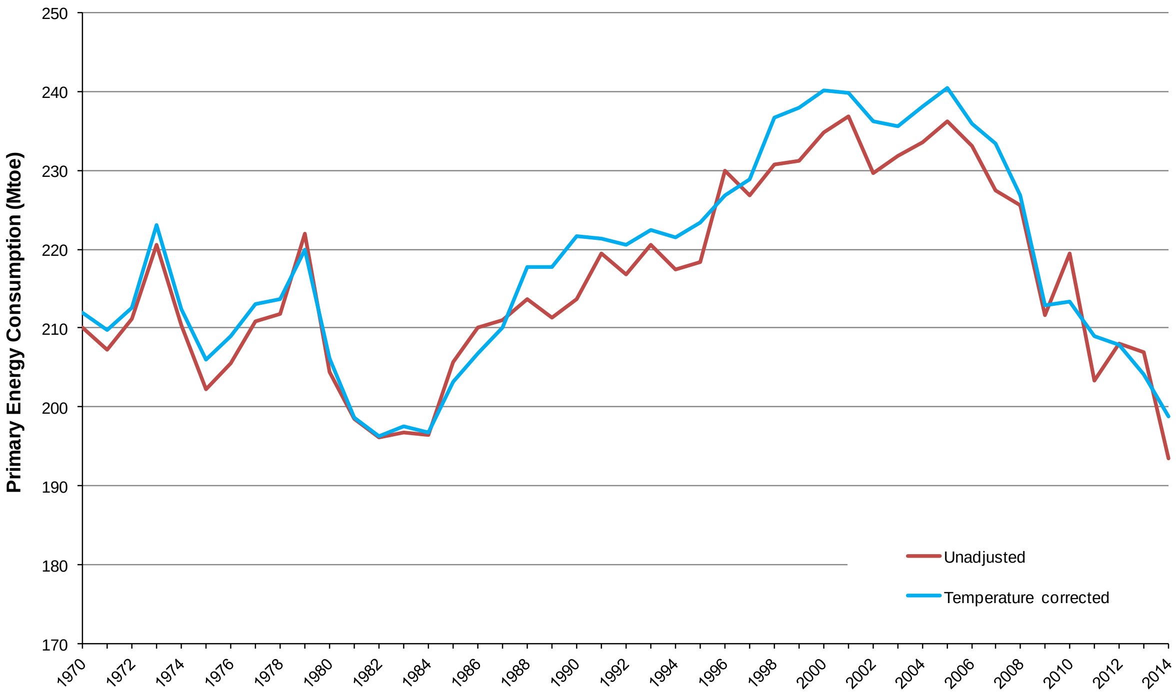
Annual primary energy consumption in the UK averaged about 225Mtoe (2004-2014), with the share of fossil fuel used in energy consumption standing at an average of ~78% over the same period (derived from data in DECC 2015a). The final consumers of energy in the UK can be divided into four groups: industry, domestic sector, transport and services. Table 5.31 shows final energy consumption for the main sectors, indicating that overall energy consumption has generally declined in each sector in the last six years, though in the context of long-term trends for energy consumption, this does not represent a significant reduction.

Table 5.31 – Final energy consumption by sector (Mtoe)

	2009	2010	2011	2012	2013	2014
Industry[1]	24.4	26.1	24.3	23.9	24.2	24.0
Domestic sector	44.6	49.3	39.5	44.5	44.6	38.2
Transport	55.4	54.7	54.5	53.8	53.6	54.2
Other final users[2]	19.6	20.6	20.1	20.3	20.9	19.0
Total final energy consumption	**144.0**	**150.6**	**138.4**	**142.4**	**143.3**	**135.3**

[1] Includes the iron and steel industry, but excludes iron and steel use of fuels for transformation and energy industry own use purposes.
[2] Mainly agriculture, public administration and commerce.
Source: DECC (2015b)

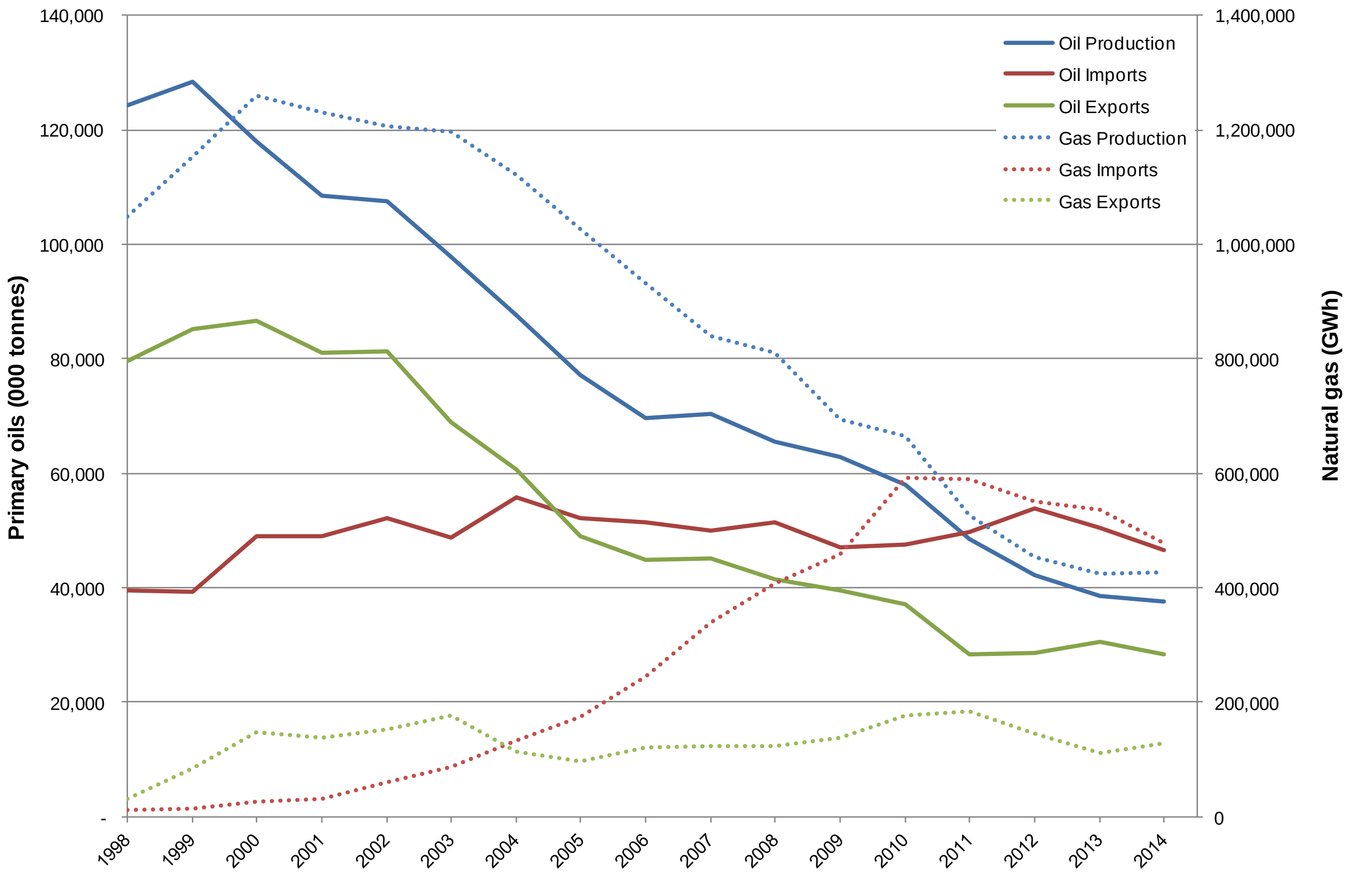
Figure 5.51: Total Primary Energy Consumption (Mtoe), 1970-2014



Source: DECC (2015a)

The UK is presently the EU's third largest producer of oil and fifth largest producer of gas due to energy production and exports from the North Sea (EU Eurostat 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. Oil & gas production peaked during 1999 with an overall decline in production thereafter – the UK has been a net importer of oil and gas since 2010 and 2004 respectively (Figure 5.52). Reductions in the recent production levels and exploration activities on the UKCS led to the Wood Review in 2013 which set out a number of recommendations that were accepted by Government, including maximising economic recovery, and the creation of the Oil & Gas Authority (OGA), an executive agency of DECC which was formally established in April 2015. Most recently, the Maximising Economic Recovery of UK Petroleum Strategy (MER UK) sets out a central obligation that relevant persons must take all steps necessary to secure that the maximum value of economically recoverable petroleum is recovered, and a number of supporting obligations and actions.

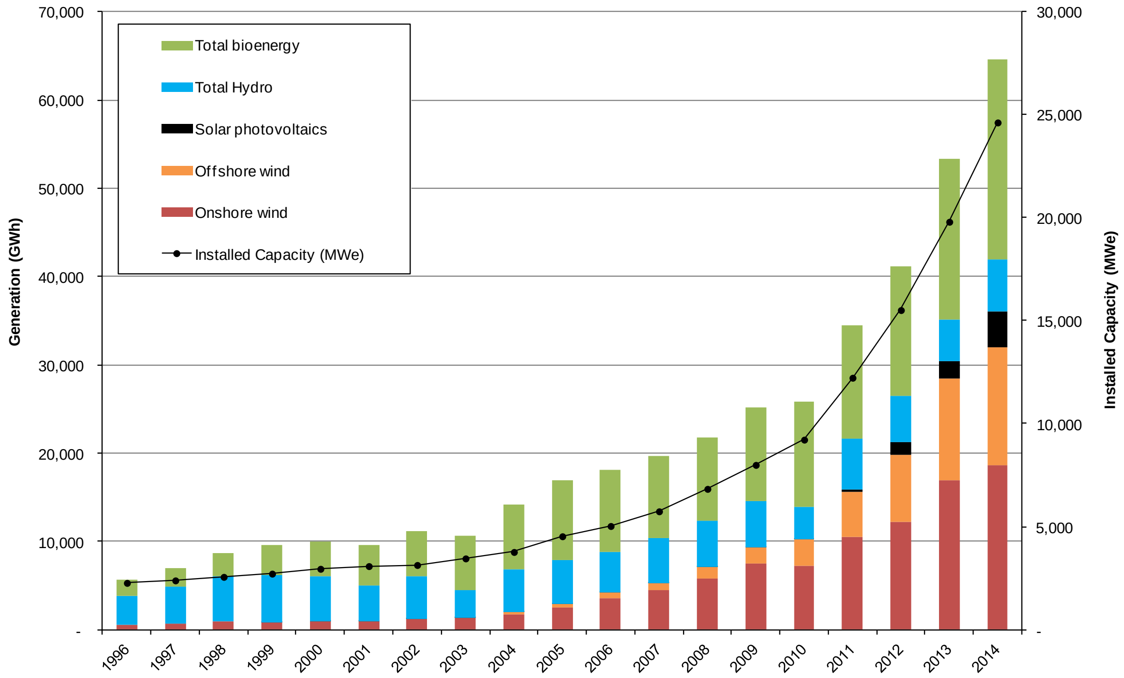
Figure 5.52: Commodity balance of primary oils and natural gas, 1998-2014



Source: DECC (2015b)

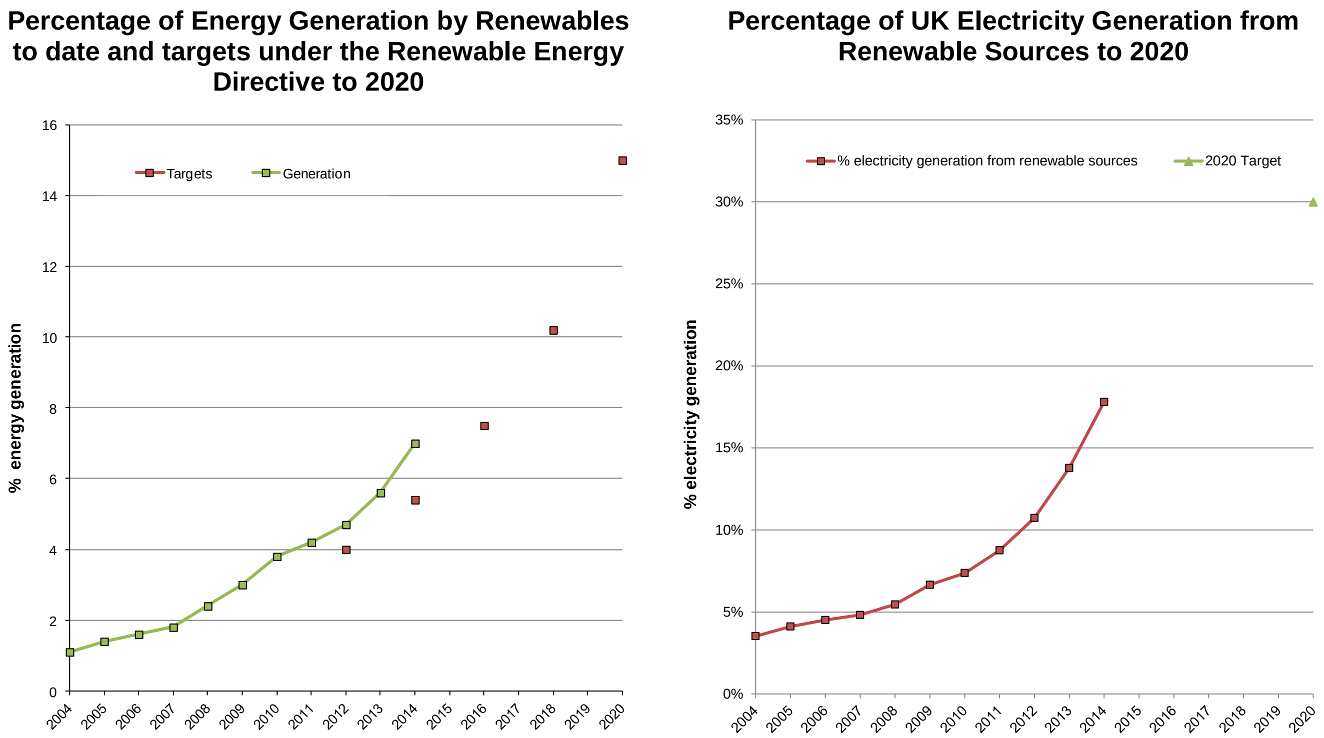
The supply of renewable energy has substantially increased in recent years from a total of 5,685GWh in 1996 to 64,654GWh in 2014, accounting for 13.8% of electricity generation from renewable sources in 2013 and 7% of total energy demand. The largest growth in renewable energy production has been in biomass, though there has been a net increase in all renewables components, particularly onshore and offshore wind. Wind energy has increased substantially up to 2014, accounting for ~20% of energy generation from renewable sources. Figure 5.53 shows the change in energy generation for a range of renewable sources of energy, and the total installed capacity for all renewable technologies up to 2014. The increased deployment of renewables is multifaceted, both aiding a reduction in greenhouse gas emissions while contributing to domestic energy supplies and therefore energy security. It is expected that the UK will meet a target of generating 30% of electricity from renewable sources by 2020 (i.e. within the currency of this SEA) – see Figure 5.54.

Figure 5.53 – Renewable energy generation (GWh) and installed capacity (MWe), 1996-2014



Source: DECC (2015b) - https://www.gov.uk/government/statistics/renewable-sources-of-energy-chapter-6-digest-of-united-kingdom-energy-statistics-dukes Energy Statistics Annex, Table 1.1.5

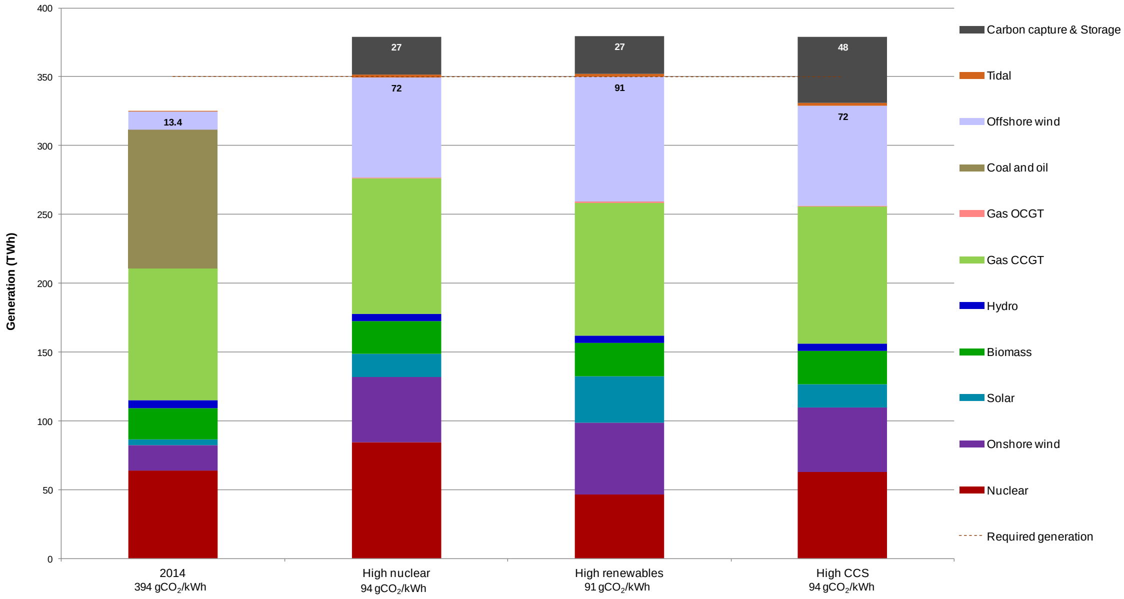
Figure 5.54: Renewable energy and electricity generation in relation to relevant targets



Source: DECC (2015b). Digest of United Kingdom Energy Statistics (DUKES), Renewable sources of energy: Chapter 6. https://www.gov.uk/government/statistics/renewable-sources-of-energy-chapter-6-digest-of-united-kingdom-energy-statistics-dukes

Figure 5.55 reflects the output of calculations by the CCC (2015), also showing the electricity generation mix in 2014 (derived from DECC 2015b), and indicative scenarios of the mix in 2030 which would meet the goal of a sector carbon intensity of approximately 100gCO_2/kWh[102]. For comparison, the 2014 UK carbon intensity of the overall energy generation mix was 394gCO_2/kWh. The installed capacity of energy sources for these scenarios, which includes elements of the draft plan/programme, is shown in Figure 5.56. Between 2009 and 2014 the carbon intensity of energy supply fell slightly (449 to 394g CO_2/kWh, DECC 2012, 2013, 2015b), and has previously declined significantly in the years 1990-2000 due to the "dash for gas" within the electricity generating sector (and to a lesser extent within industry as a whole). This was accompanied by 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 (Baumert *et al.* 2005, Bishop & Watson 2005).

Figure 5.55: Generation scenarios that reach an approximate emissions intensity target of 100g CO_2/kWh in 2030 for an expected demand of ~350TWh/year, and 2014 for reference



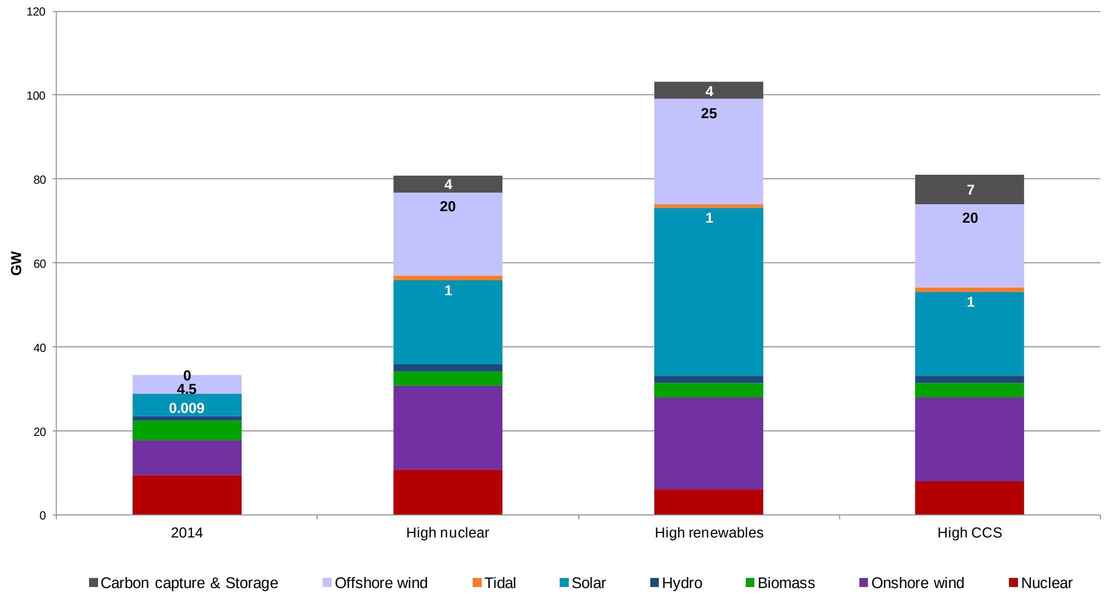
Source: CCC (2015) and DECC (2015b)

In view of the maturity of the technologies covered by this draft plan/programme, it is likely that offshore wind will make the largest contribution to a reduction in the overall UK energy supply carbon intensity. No generation targets have been set in this SEA for specific technologies, and so the relative contribution of these to energy supply decarbonisation is uncertain. If it is assumed, that the additional 10GW the UK Government proposes to support in the 2020s is realised as a minimum, this would equate to approximately an additional ~34TWh/year[103], which in the context of wider electricity demand equates to 10% of total 2014 supply levels (339TWh) or an addition of 35% on total renewable generation on 2014 levels (65TWh). With regard to installed capacity, there is currently 4.9GW operational in English and Welsh waters and an additional 13.8GW in planning (consented or awaiting consent – also see Figure 2.9). This equates to a total of 18.7GW of capacity likely to be installed by 2020 or in the early 2020s (see Figure 2.10). If an additional 10GW were to be installed in the 2020s, this would meet the CCC

[102] This figure underpins the Electricity Market Reform, however no formal decarbonisation target has been set.
[103] Assuming a load factor of 40%, based on recent figures from most recently constructed wind farms. See Section 5.15 for more details.

(2015) projections for this sector under the "high renewables" scenario. The contribution from tidal energy (stream and range) is modest at 1GW, less than projects which are presently in planning or pre-planning (note that financial support decisions on tidal range projects will be made following a Government review that is not due to report until after the publication of this report).

Figure 5.56: Low carbon generation capacity for scenarios leading to an approximate emissions intensity target of 100g CO_2/kWh in 2030, and 2014 for reference



Source: CCC (2015) and DECC (2015b)
Note: capacity figures for gas plant, storage and interconnection are not shown.

Major contributions to carbon emissions reductions could be made from tidal range and CCS. The UK Government announced a review of tidal lagoons in February, largely to investigate the economic feasibility of these, and so there is some uncertainty on whether these will be supported or not at this time. The UK Government has reiterated its commitment to the phasing out of unabated coal-fired power stations, with a consultation due to commence in spring 2016 on the timing of plant closures. Additionally, the CCC have identified this as a key technology required to assist in delivering carbon reduction commitments for the next carbon budget, and an area requiring an alternative approach to be implemented quickly (in addition to there being a wider policy gap in the delivery of the fourth and fifth budgets).

5.12.3 Sources of potentially significant effect

5.12.3.1 Renewables

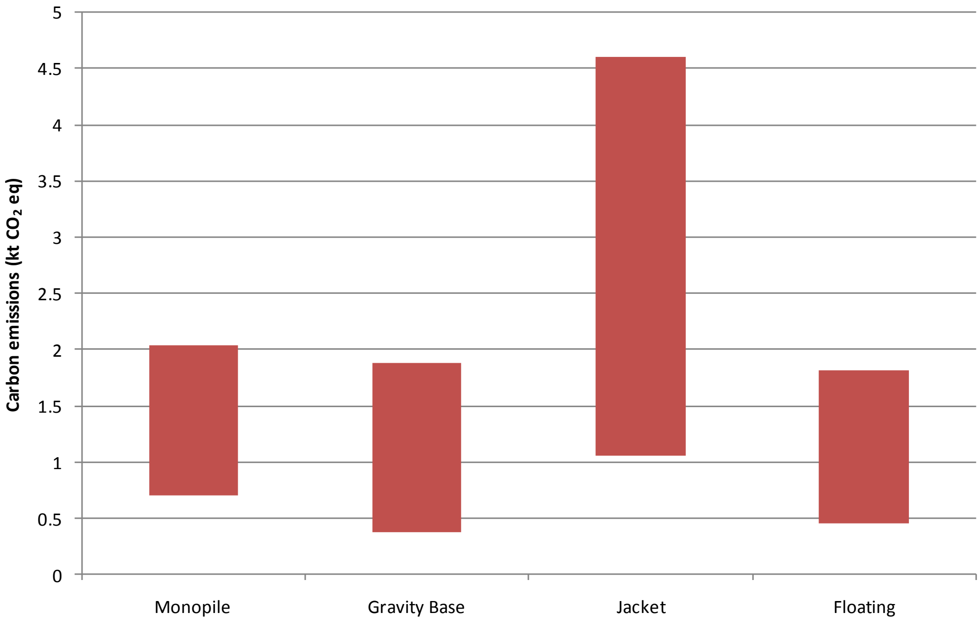
As indicated above, in the coming years offshore renewable energy generation will contribute to a reduction in the overall carbon intensity of UK energy supply, and sufficient capacity would appear to be in planning, or could possibly be deployed (see Section 5.15), to make a substantial contribution from this sector to the energy mix required to reduce energy supply carbon intensity as indicated above in CCC scenarios. By association, the draft plan/programme would therefore also contribute to targets for renewables deployment and greenhouse gas emissions.

Offshore renewable energy will not assist the decline of GHG emissions from the UK in isolation, but will provide for reductions in emissions during the currency of OESEA3 and in subsequent years in combination with other energy sources including abated fossil fuel power stations (via proving CCS at a commercial scale), those other energy supply sources with a lower carbon intensity such as new nuclear (see Table 5.32), and also energy efficiency measures. Despite the overall contribution of the renewables aspects of this plan to contribute to energy supply decarbonisation, there will be emissions associated with the manufacture and installation of projects. Life Cycle Assessment (LCA) is a methodology used to estimate the likely impact of a device or development from its manufacture, deployment, operation, maintenance and eventual decommissioning, and has been variously applied to developments to assess both their environmental and economic impact and feasibility. The Energy Balance or Energy Payback Time (EPT) refers to the time it takes for a generating station to recover the energy used in its manufacture and installation. The EPT for a number of types of marine renewable technologies considered in the draft plan/programme being assessed by this SEA is also summarised in Table 5.32.

One of the principal contributors to the embedded emissions of any offshore wind development is foundation manufacture (see Arveson & Hertwich 2012). For OESEA2, Black & Veatch (2010) calculated a range of carbon emissions for various types of foundation which are likely to be used in Round 3 developments including monopile, gravity, jacket and floating varieties. Jacket type foundations are calculated to produce the greatest emissions due to the large amount of steel required in their construction. In comparison, transport emissions are relatively small though will vary significantly depending on the size of structure and the distance between the site of manufacture and deployment location. Black & Veatch (2010) estimate that for the same scenario[104], the largest CO_2 equivalent emissions will arise from the transport of gravity base structures (124 tonnes compared with 8 tonnes for monopile structures and 21 for a steel jacket). The payback period for emissions produced during this part of the development is therefore likely to be most significant for jacket-type foundations, as despite the relatively large transport emissions involved in deploying gravity bases, this is small in comparison to those from steel production. Foundations used in floating wind turbines have varying designs, with manufacturing emissions largely relating to the proportion of steel and concrete used (e.g. for semi-submersible, spar and tension-leg designs).

[104] Construction materials sourced from the UK and transported to onshore site divided as follows: North 50% from Scotland and transported by sea, ~1,000km, using small bulk carriers, East 30% and transported by rail using diesel freight trains, ~150km, South 10% and transported by rail using diesel freight trains, ~250km, West 10% and transported by rail using diesel freight trains, ~400km. Distance from onshore site to offshore deployment assumed to be ~100km, transported by large bulk carrier.

Figure 5.57: Range of possible emissions (thousand tonnes CO_2 eq.) for offshore wind foundation types



*Notes: based on emissions factors for material used on foundation construction. **Steel**: 1.77 kg CO_2/kg, **concrete**: 0.306 kg CO_2/kg, sand and gravel: 0.0053 kg CO_2/kg. Assumptions are: **monopile**: steel, 400-750 tonnes; **gravity base**: concrete (40%), sand and gravel (60%), 3,000-12,000 tonnes; **jacket**: steel, 600-2,000 tonnes; **floating**: concrete (90%), steel (10%), 1,000-3,000 tonnes.*
Source: Black & Veatch (2010)

Table 5.32: EPT and carbon intensity for a range of marine energy technologies

Device Type	Specifications	Operational lifetime (years)	Carbon Intensity (g CO_2/kWh)	EPT (months)
Wind	Vestas V90 (3MW)[1]	20	5.23	6.8
	Generic fixed offshore turbine (5MW)[2]	20	-	4
	Sway concept floating wind turbine (5MW)[3]	20	-	5.2
Wave	Pelamis (0.75MW)[4]	20	23	13
Tidal stream	Seagen (1.2MW)[5]	20	15	14
Tidal range	Barrage (e.g. Cardiff-Weston – 8.64GW)[6]	120	2.42	5-8
	Barrage (e.g. Shoots – 1.05GW)[6]	120	1.58	5-8
	Lagoon (e.g. Swansea Bay – 60MW)[7,8]	120	-	6-12
Coal	Typical UK coal power plant[9]	-	~990e	-
Coal	IGCC post-combustion CCS[10]	-	170	-
Coal	PC post-combustion CCS[11]	-	243	-
Gas	Based on UK electricity supply using gas combustion in 2014[12]	-	365	-
Nuclear	Harmonised analysis of various light water reactors[13]	40	9-110	-

Note: the values provided should be interpreted as indicative only. Values for individual projects will differ due to the materials used, capacity and generation of the device and distance from shore. Efficiencies in production and economies of scale may be reasonably assumed as technologies progress.
Source: [1]Vestas (2006), [2]Tryfonidou & Wagner (2004), [3]Weinzettel et al. (2009), [4]Harrison (2008), [5]Douglas et al. (2008), [6]Sustainable Development Commission (2007), [7]Entec (2007), [8]AEA (2007), [9]Odeh & Cockerill (2008a), [10]Odeh & Cockerill (2008b), [11]Koornneef et al. (2008), [12]DECC (2015b), [13]Warner & Heath (2012)

With specific regard to tidal range developments, a scoping study for the Severn barrage (DECC 2008) outlined the stages of the project which would have an impact on the sinks or sources of carbon (e.g. decrease in emissions from renewable energy generation, increase emissions due to loss of intertidal habitat for carbon sequestration), and these may be reasonably transposed to any similar development, though the magnitude of changes would be site and project specific. Construction times for barrages and lagoons are typically long (estimates of 4-6 years for Severn proposals and 7 years for La Rance), and will have relatively high emissions associated with construction. The long operation time (~120 years) and high capacity should offset these emissions relatively quickly. Some direct and indirect effects of barrage or lagoon imposition could lead to the loss of intertidal area and changes in sedimentation, and therefore a loss of related sequestration of carbon from these sources (see: Laffoley & Grimsditch 2009, Alonso *et al.* 2012, and also Table 5.33). Overall, the stock of carbon in coastal marginal habitats in the UK is conservatively estimated to be at least 6.8Mt (Jones *et al.* 2011).

Estuarine areas are inherently of interest to tidal range development, and in the UK, most large estuaries fall within the technical requirements for tidal range developments (see Figure 2.12), but not all areas will be suitable for practical deployment. Sea-level rise will contribute to "coastal squeeze" in the coming years (see Appendix 1b) along open coasts and estuaries, and there will be an associated loss of intertidal areas where these cannot migrate landwards and adapt due to the imposition of fixed infrastructure or other barriers. In many areas, and also associated with considerations of flood risk, coastal management has taken place (e.g. Steart in the Severn, also see omreg.net) or has been identified as a priority to provide compensatory habitat to that being lost elsewhere (shoreline management plans, catchment flood management plans, coastal habitat management plans can help to identify such areas). For Natura 2000 sites, there is also a requirement to provide compensatory measures where flood risk management will lead to loss of habitat from coastal squeeze and where a significant effect will be generated (see Defra 2005), and similarly, this would be the case were any project to result in a significant effect on a Natura 2000 site, provided that a case could be made for its consent following assessment. The wide scale loss of intertidal areas and sedimentation that could result from tidal barrages or cumulatively from multiple smaller developments, could lead to the loss of intertidal areas.

Table 5.33: Habitat and related carbon sequestration rates

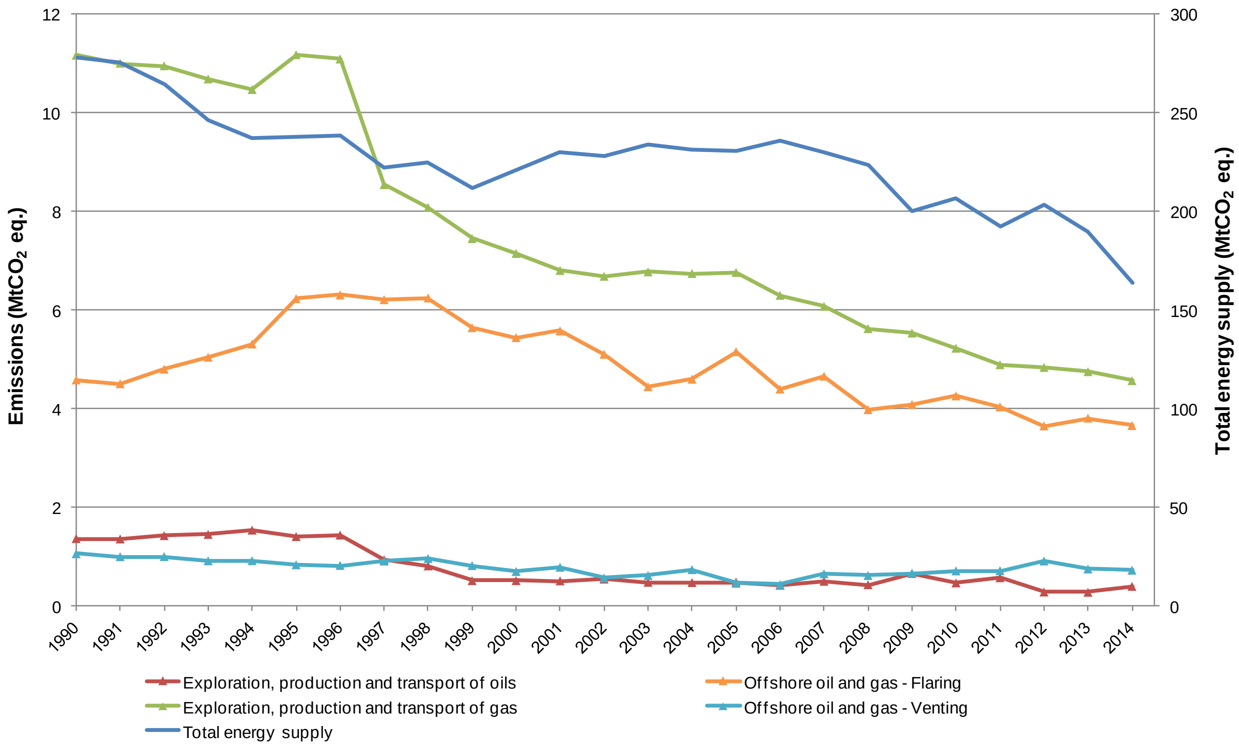
Habitat	Carbon sequestration rate gC/m^2/year
Sea grass meadow	20-200
Kelp forest	~400
Saltmarsh	210
Intertidal mud	16
Sand dunes	58-73
Subtidal coarse sand (to 12nm)	>10

Source: Alonso et al. (2012)

5.12.3.2 Oil and gas exploration and production

Carbon dioxide accounts for the greatest proportion of emissions to air from offshore oil and gas installations with around 30Mt emitted in the OSPAR area in 2011 (OSPAR 2014). Emissions from exploration, production and transport of hydrocarbons are relatively small in the context of wider UK energy supply GHG emissions which were 182Mt CO_2 eq. in 2014 (see Figure 5.58), within which emissions for exploration, production and transport totalled 5Mt CO_2 eq., or 9.3Mt CO_2 eq. when including flaring and venting emissions. Emissions from the sector have generally declined in recent years (also see Section 5.11).

Figure 5.58: GHG emissions from exploration, production and transport in the context of total energy supply, 1990-2014



Source: DECC (2016b)

Shipping emissions are a significant proportion of those associated with the offshore sector and there is unlikely to be a shift away from the use of conventional heavy fuel oil in the short to medium term (Gilbert *et al.* 2010). Technical and operational, or market-based approaches may help to curb emissions from shipping with UK Government and chamber of shipping stating a preference for a cap-and-trade approach. The IMOs Marine Environment Protection Committee (MEPC) undertook work on the technical and operational measures required to reduce GHG emissions from shipping, resulting in the adoption of such measures in July 2011, entering into force in January 2013. These measures, added to MARPOL Annex VI (Regulations on energy efficiency for ships), makes the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Plan (SEEMP) mandatory for new and all ships respectively, over 400 gross tonnes. At a domestic level, shipping emissions are included within the Carbon Budgets framework. The *Climate Change Act 2008* contained a requirement that Government consider their inclusion of international shipping and aviation by the end of 2012, fulfilled through the Parliamentary Report, UK Carbon budgets and the 2050 target: international aviation and shipping emissions, in December 2012. At that time, the Government decided to defer the inclusion of international aviation and shipping within the current net carbon account due to uncertainty of the nature of future global emissions reductions agreements. Despite this deferral, existing UK carbon budgets have taken account of international shipping emissions by constraining the budgets of other sectors to 2027 such that the UK would be on an emissions trajectory consistent with 2050 reductions, including these international emissions.

Improvements in efficiency and other measures have been taken by operators to reduce fugitive emissions (gas escapes, for example, from leaks or processes), and the use of vapour recovery systems at off-loading facilities to reduce emissions of methane and other volatile organic compounds (OSPAR 2010a). Conversely, it would also be expected that emissions associated with mature fields would increase due to greater power demands associated with the use of injection as a method of disposal of produced water and drill cuttings, and the possible use of diesel generation for such activities where there are native fuel gas supply deficits. The decommissioning of fields in the coming years may generate emissions in a similar manner to project installations, however following these temporary activities longer term operational emissions would cease at these locations.

The scale of previous licensing rounds (19th to 28th) is indicated in Figure 2.3. It is typical that each licence issued will have a commitment to drill a well and potentially to conduct other exploratory work (e.g. seismic survey) within a stipulated time period, after which the licence must be relinquished in whole or part (see Section 2.6 for an overview of licence types). Based on previous experience, typically less than half the wells drilled reveal hydrocarbons, and of that half less than half again will yield an amount significant enough to warrant development. On this basis, any potential future rounds are likely to result in relatively small incremental emissions to wider UK energy supply.

The end use of any produced oil or gas that could result from commercially successful exploration resulting from future rounds is not considered here, as this is accounted for elsewhere (e.g. as part of the emissions associated with gas fired power stations, other industrial emissions and transport).

Gas storage

Greenhouse gas emissions associated with gas storage may emanate from the consumption of gas, fuel and diesel, flaring and venting and fugitive and other emissions. As an example, CO_2 emissions from the Rough gas storage facility have remained relatively steady at 106,172 tonnes in 2002 and 83,351 tonnes in 2014 (compared to 102,096 tonnes in 2013, Centrica 2015). 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 CO2 (Bacton Storage Company Ltd 2009).

The construction of facilities for the transport and injection of gas will also have associated emissions. For salt cavern construction, Gateway Gas Storage (2007) estimated that for their East Irish Sea facility, 763 tonnes CO_2 would be released during the drilling of each well (over 15 days), with a total of 20 wells to be drilled. Additional emissions come from the commissioning of the salt caverns and annual maintenance which is estimated to be 25,776 and 83.2 tonnes CO_2 respectively. The Deborah gas storage project (ENI Hewett Ltd 2010) located in the southern North Sea proposes to use depleted gas reservoirs, and is estimated to have installation emissions (i.e. those associated with power generation for the drilling rig and support vessels) amounting to 94,704 tonnes CO_2.

Emissions associated with the installation and operation of offshore gas storage facilities are therefore regarded to be small in a national context, particularly given the relatively small number of extant or planned developments of this type when compared with the present number of producing oil and gas fields.

Carbon dioxide transport and storage

All new fossil fuel power stations of a type covered by the Large Combustion Plant Directive[105] and with a capacity of 300MWe[106] or greater are not to be consented unless it can be

[105] Replaced by the Industrial Emission Directive (2010/75/EU) on 1st January 2016.
[106] DECC (2009). Carbon Capture Readiness (CCR). A guidance note for Section 36 Electricity Act 1989 consent applications. Also see, Carbon capture and storage – Commons Library Standard Note SN/SC/5086, 3rd May 2013, and Overarching National Policy Statement for Energy (EN-1).

demonstrated that carbon capture technology can feasibly be retrofitted. The captured CO_2 must be stored in a suitable geological formation, with the most prospective types being depleted or partially depleted oil and gas reservoirs or saline aquifers – see Appendix 1b. A theoretical P50[107] storage capacity of 78Gt has been estimated collectively for UKCS hydrocarbon fields and saline aquifers (Bentham *et al.* 2014). In view of the emissions from fossil fuel power stations in the UK (149Mt in 2013 and averaging 166,380Mt for 2000-2013) and declines that may be realised through carbon reduction measures (above), it is clear that there is likely to be sufficient capacity available on the UKCS to support storage for UK emissions for some time. The extent and nature of the storage options are presently not fully understood, however initiatives such as CO_2Stored are making data available on relevant formations. The result of widescale deployment would be a significant reduction in CO_2 emissions to the atmosphere from fossil fuel power stations (e.g. see Table 5.32 on carbon intensity), with benefits for climate change mitigation in advance of wider energy decarbonisation and renewables deployment.

For effective transport and storage to take place, CO_2 is captured as a gas and needs to be compressed or cooled for transport for subsequent injection into a storage reservoir, requiring power which will have associated atmospheric emissions. The capture process can add significantly to the overall energy needs and therefore fuel used to generate electricity, termed the "energy penalty". The final report of the CCS cost reduction task force (2013) estimated energy penalties to be in the range 19-25% but with reductions expected as technology improvements are made. Bulk transport is either by pipeline or tanker, with pipelines favoured for large and near shore installations (for example the two UK projects presently in planning have pipelines sized for a collective capacity of up to 23.5Mt per year) and shipping for long distances and areas that cannot be accessed easily by pipeline or are unlikely to be operational for long enough to justify infrastructure investment. For offshore sites, with distances greater than 1,000km ship transport may be economically viable (IPCC 2005), though this would be contingent on a number of factors controlling the technical and economic feasibility of pipelines compared to shipping, with installation and operational costs dominating these forms respectively (Weihs *et al.* 2014). The latest LNG ships have a capacity of 200,000m^3 and could potentially carry 230kt of liquid CO_2 with estimations of losses to the atmosphere from both boil-off and exhaust from the ships engines of 3-4% for 1,000km (IPCC 2005).

The abatement of CO_2 may also confer other positive air quality mitigation. Other significant atmospheric emissions associated with carbon transport and storage result from potential accidental releases from shipping, pipelines or the storage areas themselves. These are not likely, with monitoring evidence from the Sleipner project suggesting that all the gas injected into the formation has remained *in situ*, spreading throughout the formation with no leakage to the surface. Requirements of the CCS Directive are such that extensive site characterisation and monitoring are required to ensure any storage structure is suitable prior to injection (see Section 5.11 and 5.13). The most probable risk source is from abandoned wells, but likely rates of any such leaks are regarded to be low (Jewell & Senior 2012).

As shown above (Figure 5.56), the CCC (2015) have suggested that 4-7GW of CCS would be required as part of an energy mix scenario that would meet a target carbon intensity of 100gCO_2/kWh by 2030, and therefore could make a substantial contribution to emissions reductions targets. The CCC (2016) has indicated that this technology is a key component of the energy mix required to meet emissions reductions targets associated with the fifth carbon budget. Whilst the fifth carbon budget spans a time period beyond the currency of this SEA,

[107] that is, having a 50% certainty of being achieved

proving and adopting this technology in the near term will likely lead to cost reductions in its deployment, in addition to providing a route for large industrial plant and energy supply emissions.

5.12.3.3 Possible impacts of relevance to climate change

The IPCC 5th assessment report (AR5) has a number of principal findings which indicate that it is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century, through anthropogenic inputs of CO_2 and other greenhouse gases. There is medium confidence that global mean surface temperature change for the period 2016-2035 relative to 1986-2005 will likely be in the range of 0.3°C to 0.7°C. For a range of greenhouse gas trajectories adopted as part of AR5 (representative concentration pathways – see Appendix 1f), by the end of the 21st century, temperatures rises are likely to be in the range 1.5-2˚C, and unlikely to exceed 4˚C. Specific to the UK, UKCP09 (see Lowe *et al*. 2009, Murphy *et al*. 2009) project that for the 2020s (2010-2039) under a medium emissions scenario, the annual mean air temperature across the UK will increase by between 0.7°C and 2.0°C on land, and between 0.2°C and 2.0°C in marine areas (for between the 10 and 90 percentile range – note that this work is presently being updated as part of the UKCP18 programme).

Future climate change may generate alterations which threaten ecological and social systems. For instance the 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 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 death, 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'.

Physical environment (refer to Appendix 1b and 1d)

A secondary effect of climate change is the possible increase of coastal erosion and flooding from rises in sea-level (Wong *et al.* 2014, Sayers *et al.* 2015). Though there has been no recent significant observed change in storm surge frequency or magnitude (Horsburgh & Lowe 2013, Wong *et al.* 2014) and there is a low confidence in any significant change in the UK wave climate (Lowe *et al*. 2009), these cannot be ruled out as possible exacerbating factors in coastal erosion and flooding in years to come. Though a high level of confidence in the recent MCCIP report card (Masselink & Russell 2013) is attached to the current knowledge with regard to coastal processes and erosion, a medium level of confidence is applied to what could happen, mainly due to uncertainties about the effect of climate change, rate of sea-level rise and changes in the wave climate, and their interactions with a complex coastal system. It can generally be expected that those coasts for which geology is a primary control (see Clayton & Shamoon 2008) on denudation will continue to erode. Certain areas of low elevation or those geographically constrained by defence works (which includes numerous estuaries) and infrastructure will be unable to respond to sea-level rise in the longer term and will therefore be subject to coastal squeeze (Masselink & Russell 2013).

Ecosystems (refer to Appendix 1a)

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 (see MCCIP report card and Pörtner *et al.* (2014). The Working Group II Report (IPCC 2014) in contribution to the IPCC AR5 considers impacts, adaptation and vulnerability in relation to climate change. Chapters 5 and 6 (Wong et al. 2014, Pörtner *et al.* 2014) consider the impacts of climate change on coastal and ocean systems respectively, Including on ecosystem properties, goods and services. Some particularly relevant conclusions of Wong et al. (2014) and Pörtner *et al.* (2014) are provided below, including confidence in these conclusions:

- Acidification and warming of coastal waters will continue with significant negative consequences for coastal ecosystems (high confidence).
- Ocean ecosystems have responded and will continue to respond to climate changes of different rates, magnitudes, and durations (virtually certain). Human societies depend on marine ecosystem services, which are sensitive to climate change (high confidence).
- Climate change alters physical, chemical, and biological properties of the ocean (very high confidence).
- Vulnerability of most organisms to warming is set by their physiology, which defines their limited temperature ranges and hence their thermal sensitivity (high confidence).
- The warming-induced shifts in the abundance, geographic distribution, migration patterns, and timing of seasonal activities of species (very high confidence) have been and will be paralleled by a reduction in their maximum body size (medium confidence). This has resulted and will further result in changing interactions between species, including competition and predator-prey dynamics (high confidence).
- In response to further warming by 1°C or more by the mid-21st century and beyond, ocean-wide changes in ecosystem properties are projected to continue (high confidence).
- Rising atmospheric CO_2 over the last century and into the future not only causes ocean warming but also changes carbonate chemistry in a process termed ocean acidification. Impacts of ocean acidification range from changes in organism physiology and behaviour to population dynamics (medium to high confidence) and will affect marine ecosystems for centuries if emissions continue (high confidence)
- By the mid-21st century, the spatial shifts of marine species will cause species richness to increase at mid- and high latitudes (high confidence) and to decrease at tropical latitudes (medium confidence), resulting in global redistribution of catch potential for fishes and invertebrates, with implications for food security (medium confidence).
- The expansion of hypoxic regions termed Oxygen Minimum Zones (OMZs) and anoxic “dead zones,” observed over the last 50 years and projected into the future under climate change, especially if combined with nutrient enrichment (eutrophication), will constrain the habitat of O_2-dependent organisms and benefit anaerobic microbes (medium confidence)

Activities covered by the draft plan/programme have the ability to impact the physical environment further both directly and indirectly, for example tidal range developments have the ability to both reduce flood risk in impounded areas and increase the risk elsewhere (e.g. during fluvial flood events in tide-lock conditions – see DECC 2010a). Conversely, the deployment of renewables in successive leasing rounds will contribute to the reduction in global concentrations of atmospheric GHGs.

5.12.4 Controls and mitigation

A number of elements to the draft plan/programme are designed to help abate or offset carbon emissions, or to produce energy (mainly primary electricity) in a low carbon manner. The policy context provided above in relation to legally binding targets and international agreements provides for the principal high level control on emissions from UK sources, with project level controls variously delivered through requirements such as inclusion in the EUETS. National and regional level policy also contains objectives or policy wording relevant to the emissions of greenhouse gases and adaptation (e.g. the Marine Policy Statement, East Marine Plans policies CC1 and CC2), and all developments must take account of relevant programmes of measures which in whole or part have relevance to the potential influence of climate change, particularly on coastal environments (for example Shoreline Management Plans, flood risk management plans).

5.12.5 Summary of findings and recommendations

The following provides a summary of the above considerations:

- Renewable energy and carbon dioxide storage have the ability to contribute to the reduction in UK GHG emissions, and therefore to meet a target carbon intensity for the energy supply sector of 100g CO_2 eq. by 2030, and to meet the interim CO_2 reduction targets of 34% on 1990 levels by 2020, and 50% on 1990 levels by 2025.
- Decarbonisation of UK energy supply would make a substantial contribution to meeting the next (fourth and fifth) carbon budgets, however new measures are required to meet these budgets and deployment of CCS is not expected until after 2020.
- Oil and gas production is declining on the UKCS, though emissions associated with energy generation and shipping in this sector is likely to continue for the foreseeable future. Future carbon emissions from shipping are likely to decline through operational and technical and other controls.
- The UK reliance on fossil fuels for energy generation will continue for the foreseeable future, though a dependence on imports may be reduced through the increased uptake of renewable energy.
- Though there is scientific consensus that anthropogenic emission of carbon dioxide and other greenhouse gases are having a direct effect on global temperature, knowledge of the climate system and impacts on it continue to develop[108].
- The most recent MCCIP Report Card generally places a low confidence in projections of future climate change effects on most parts of the marine ecosystem.

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[108] Also see MCCIP (2014). Marine Climate Change Research Priorities 2014. http://www.mccip.org.uk/annual-report-card/

- UK projections of sea-level change are placed at between 12 and 76cm by 2095 (see Appendix 1d). At a regional to local level the impacts of sea-level rise on the coastal system are uncertain, though are likely to take the form of enhanced flooding of low-lying areas, the exacerbation of coastal erosion and coastal-squeeze. There is no significant evidence for recent changes in storm surge frequency.

5.13 Accidental events

Assessment Topic	Potentially Significant Effect	Oil & Gas	Gas Storage	Carbon Dioxide Storage	Offshore Wind	Tidal Stream	Tidal Range	Wave	Assessment Section
	Accidental events – major oil or chemical spill	X	?	?	?	?	?	?	5.13.2
	Accidental events – major release of carbon dioxide			X					5.13.2
	Accidental events – risk of sediment contamination from oil spills	X	?	?	?	?	?	?	5.13.3.2
	Accidental events – blow out impacts on seabed	X	X	X					5.13.3.2
	Accidental events - contamination of the water column by dissolved and dispersed materials from oil and chemical spills or gas releases	X	X	X	?	?	?	?	5.13.3.1, 5.13.3.2
	Accidental events – potential food chain or other effects of major oil or chemical spills or gas release	X	X	X	?	?	?	?	5.13.3.2
	Accidental events – socio-economic consequences of oil or chemical spills and gas releases	X	X	X	?	?	?	?	5.13.3.2

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; these are relatively infrequent, but 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 during drilling or intervention activities. Previous SEAs have reviewed hydrocarbon spill scenarios and risks associated with exploration and production facilities. The recent Deepwater Horizon accident in the Gulf of Mexico resulted in significant re-examination of operational practices, regulation and contingency planning for E&P; impacts of the Deepwater Horizon event are considered below.

5.13.2 Sources of potentially significant effect

Accidental events related to exploration and production

Oil spills on the UKCS have been subject to statutory reporting 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. Discharges, spills and emissions data from offshore installations are also reported by OSPAR (e.g. OSPAR 2015). DECC data indicates that the most frequent 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.

Since the mid-1990s, the reported number of spills has increased consistent with more rigorous reporting of very minor incidents (e.g. the smallest reported crude spill in 2015 was 0.00002 tonnes). However, the underlying trend in spill quantity (excluding specifically-identified large spills) suggests a consistent annual average of around 100 tonnes. In comparison, oil discharged with produced water from the UKCS in 2014 totalled 2,004 tonnes[109].

An annual review of reported oil and chemical spills in the UKCS is made on behalf of the Maritime and Coastguard Agency (MCA) by the Advisory Committee on Protection of the Sea (e.g. Dixon 2014). This includes all spills reported by POLREP reports[110] by the MCA and PON1 reports to DECC – the latter are published monthly on the DECC website[111]. In 2013 a total of 315 oil releases were attributed to oil and gas installations operating in the open sea. The 2013 annual total was the highest recorded since 2002 and 33 more than the mean annual total of 277 releases reported between 2000 and 2012. Estimated volumes of releases showed that 57% were less than 5 litres. Analysis of oil types showed that 72% of reported releases were lubrication and hydraulic oils, followed by fuel oils at 22% and crude oils at 16%. The majority of spills were small, with some 91% of releases being less than 455 litres (100 gallons).

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 UK data. A review of blowout frequencies cited in UKCS Environmental Statements as part of the OESEA2 gave occurrence values in the range 1/1,000-10,000 well-years. Analysis of the SINTEF Offshore Blowout Database which is based on blowout data from the US Gulf of Mexico, UKCS and Norwegian waters for period 1980 to 2005, provided blowout frequencies (per drilled well) for exploration drilling of normal oil[112] ($2.5x10^{-4}$) and gas[113] wells ($3.6x10^{-4}$), as well as deep high pressure high temperature[114] oil ($1.5x10^{-3}$) and gas ($2.2x10^{-3}$) wells (OGP 2010). Accident statistics for offshore units on the UKCS estimated an annual average frequency of blowouts[115] for mobile drilling units of $6.6x10^{-3}$ per unit year for the period between 2000 and 2007 (based on analysis of a total of 455 unit years, Oil and Gas UK 2009).

Accidental events related to gas storage

The main accidental risk associated with gas storage developments offshore is considered to be accidental hydrocarbon releases, mainly from spills of fuel oils from fixed installations and support vessels. Gas storage in depleted hydrocarbon reservoirs has an associated risk of reservoir fluid release during drilling operations (qualitatively similar to risk associated with E&P), and a theoretical risk of loss of containment through previously capped wells which may have penetrated the reservoir. The environmental risk is considered to be low, given the geological and engineering understanding of the developments, and the (depleted gas) reservoirs likely to be developed for storage. Gas storage in salt caverns has a negligible risk of liquid hydrocarbon release from well operations.

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[109] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/443314/PW_Data_6-14.pdf
[110] POLREP (pollution reports) relate to those issued in accordance with the Bonn Agreement, to alert Contracting Parties to relevant pollution events.
[111] https://www.gov.uk/guidance/oil-and-gas-environmental-data
[112] A well where the formation has an estimated gas/oil ratio less than 1,000.
[113] A well where the formation has an estimated gas/oil ratio exceeding 1,000.
[114] A well with an expected shut-in pressure equal to or above 690 bar (10,000psi) and/or bottom hole temperatures equal to or above 150°C.
[115] An uncontrolled flow of gas, oil or other fluids from the reservoir, i.e. loss of 1.barrier (i.e. hydrostatic head) or leak and loss of 2. barrier, i.e. BOP/ Down Hole Safety Valve (DHSV).

Accidental events related to carbon dioxide storage

The principal sources of leaks from carbon dioxide transport and storage projects are regarded to be either mechanical (e.g. from a pipeline rupture or loss of containment in injection or abandoned wells) or geological (e.g. through fractures and faults or cap rock seal failure (including through educed seismicity), seepage through porous structures) (Czernichowski-Lauriol *et al.* 2006, Blackford *et al*. 2008, Santra & Sweatman 2011, Dewar *et al.* 2013, Caramanna *et al.* 2014, Phelps *et al.* 2015, Williams *et al.* 2014, Verdon 2014).

The probability and consequence of a major accidental release of carbon dioxide from the transportation and offshore storage of CO_2 is difficult to assess, although the technology and risk sources (e.g. mechanical damage to a pipeline through collision) are similar to those for gas production and transportation (although without the potential consequences of ignition of a gas release). To date, accidents associated with development of the UK's offshore gas reserves have been few and of limited environmental effect. Clearly, however, the engineering of transportation systems and injection facilities for carbon dioxide will need to take due account of the physical properties of CO_2 in various phases and consenting of CCS will require predictive assessment of the safety and environmental risks of a large-scale release.

Fourteen years of monitoring of CO_2 storage in a subsea geological formation at the Sleipner platform in the Norwegian sector of the North Sea have provided information on the relatively short-term fate of injected CO_2. Techniques in monitoring the fate of injected carbon dioxide have developed over this time; 4-D (repeated 3-D) seismic survey of the formation, vertical seismic profiling, multibeam echosounding, bubble stream detection, seawater geochemistry and various downhole measurements are some of a suite of techniques which may be applied to monitor CO_2 migration and anticipate and detect leakage.

Accidental events related to renewable energy developments

Offshore wind and wet renewable energy developments have a generally limited potential for accidental loss of containment of hydrocarbons and chemicals, due to the relatively small inventories contained on the installations (principally hydraulic, gearbox and other lubricating oils, depending on the type of installation). In comparison to E&P developments, there is low anticipated frequency and consequence of spills occurring during fuel or oil transfers, maintenance operations and similar activities.

The major risk scenario for offshore renewable energy developments is collision between a fixed installation and vessel, resulting in loss of fuel or cargo from the latter. Collision risk assessment is therefore a key aspect of site-specific planning and consenting. At a strategic level, it can be noted that the anticipated scale and geographical location of development (specifically of offshore wind) must result in some overall increase in vessel collision risk, either through direct collision with a fixed installation or through confinement of available routes for safe navigation, particularly of larger vessels. Provision of effective National Contingency Planning, and adequate response resources at a national level – including Emergency Towing Vessels (ETVs) – are therefore considered to be important mitigation measures to support long-term development of the UK's offshore renewable energy resources.

5.13.3 Consideration of the evidence

5.13.3.1 Fate and trajectory of accidental releases

Accidental events related to exploration and production

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. 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.

To support environmental assessments of individual drilling or development of oil and gas projects, modelling is carried out for crude and condensate blowouts, loss of containment and for diesel oil releases where relevant. Representative modelling cases from various parts of the UKCS have been reviewed by successive SEAs. A review of spill modelling completed for exploration and development projects within those Regional Seas which support the main oil and gas producing areas is provided in Table 5.34. The Oil Pollution Emergency Plans (OPEPs) reviewed are grouped by quadrant (see Figure 5.59). It should be noted that the minimum time to beach estimates in Table 5.34 are from worst case scenarios of unconstrained blowouts and large diesel spills with no intervention, combined with constant winds from one direction over a significant period of time (deterministic modelling[116]), which is improbable. With respect to stochastic modelling[117] requirements, the most recent draft OPEP guidance (DECC 2015)[118] indicates that:

- A minimum two year data-set of hydrodynamic and meteorological parameters must be used.
- A minimum of 100 model runs should be performed (a lower number of runs may be acceptable when accompanied by sound scientific or statistical justification)
- The duration of the model period must be appropriate to the scenario (e.g. if modelling an instantaneous release the minimum duration should be 10 days or until the oil impacts coastlines. If modelling an on-going release the minimum duration should be 10 days). The duration of the release period must be justifiable and should consider any discrepancy between the duration of the modelling and the identified time period required to stop the release (which may include the drilling of a relief well and/or use of a well capping device).

[116] Assumes that a continuous 30 knot onshore wind occurs throughout the spill event - – note that this type of modelling will no longer be a requirement of the latest OPEP guidance.
[117] Stochastic modelling utilises metocean and meteorological inputs to determine likelihood of beaching and possible areas affected
[118] Any applicable new OPEP submissions, five year reviews or new worst case scenario models submitted post 2015 amendments to the OPRC Regulations (see Section 6.4.1) must comply with this Guidance - http://www.hse.gov.uk/osdr/assets/docs/guidance-notes-opeps-rev1-may-2015.pdf

- For temporary operations e.g. drilling/well intervention; the season(s) during which the operation is to be undertaken must be used for modelling purposes. For operations which could be subject to change it is recommended that all four seasons are modelled.

Figure 5.59: Quadrants from which OPEPs reviewed

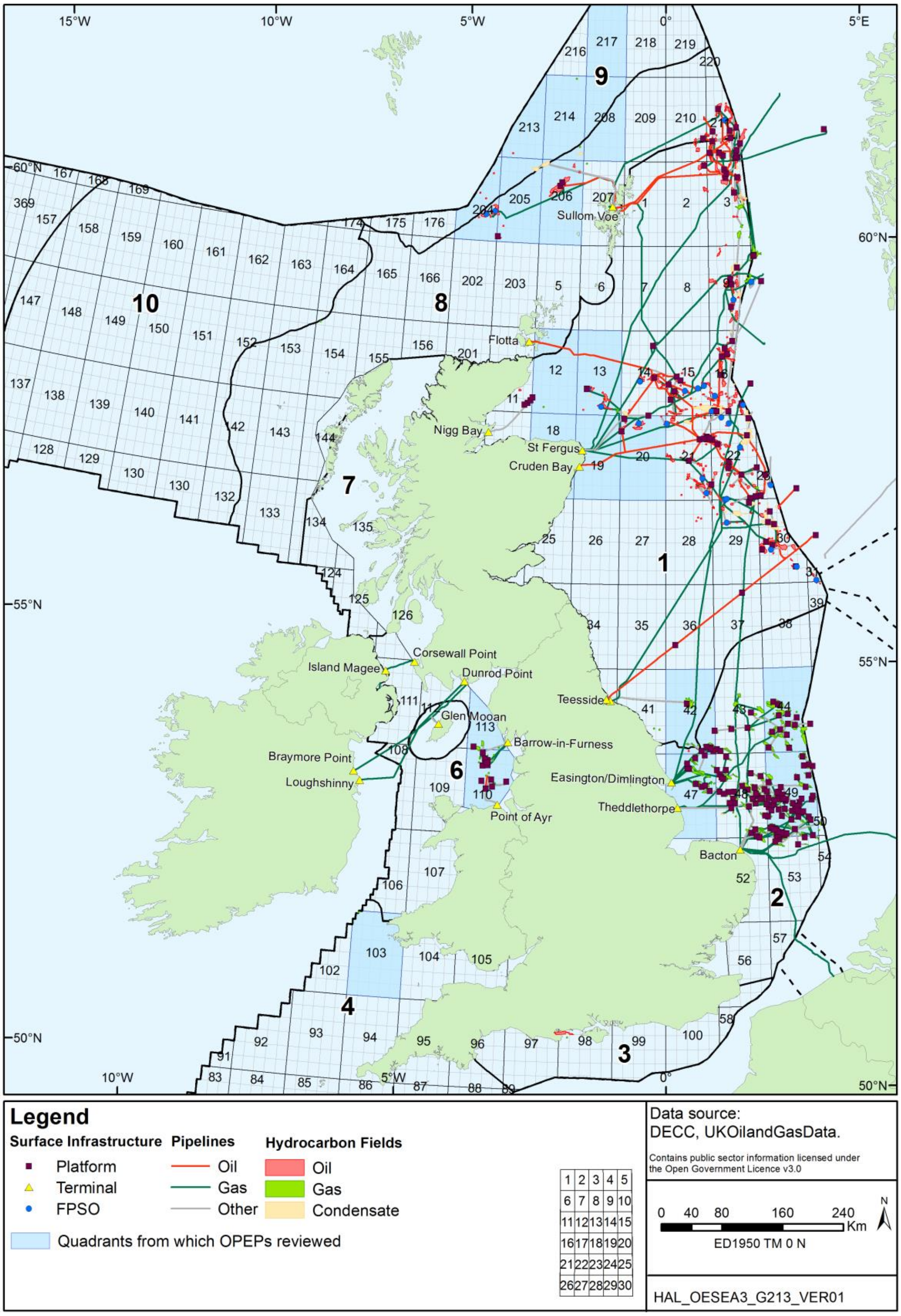


Table 5.34: Review of OPEPs for quadrants in the main oil and gas producing areas

Quadrants	Number of OPEPs reviewed	Spill type & size	Minimum time to beach (hours)	Likelihood of beaching (%)
Regional Sea 1				
12	1	Crude blowout 460m^3 per day (5 days)	14 (NE Scotland)	10 (Scotland)
13	2	Crude blowout 400-660m^3 per day (10 days)	30 (Fraserburgh)	<1 (Scotland, Norway)
18	1	Crude blowout 1,236m^3 per day (2 days)	8 (NE Scotland)	10 (Scotland)
19 & 20	2	Crude blowout 5,814-7,879m^3	26-39 (NE Scotland)	<10 (Scotland)
Regional Sea 2				
42	1	Total rig inventory diesel loss 333m^3	Disperses within 8	0
44	3	Total rig inventory diesel loss 666-715m^3	Disperses within 8	0
44	1	Condensate blowout 17m^3 per day (28 days)	Does not beach	0
47	2	Total rig inventory diesel loss 371-715m^3	Disperses within 8-9	0
47	1	Condensate blowout 286m^3 per day (2 days)	17	7 (England)
49	1	Total rig inventory loss 889m^3 diesel, 150t low toxicity oil based mud	Disperses within 8	0
49	1	Condensate blowout 16m^3 per day (28 days)	Does not beach	0
Regional Sea 6				
103	1	Total rig inventory diesel loss 1,177m^3	Disperses within 8	0-<1 (Wales, Ireland)
110	6	Total rig inventory diesel loss 208-1,075m^3	3 for project adjacent to coast	0-50 (England) <5 (Wales)
110	1	Total loss of crude storage 146,242m^3	10 (England)	2-94 (England) Welsh 1-30 (Wales) 14 (N Ireland) 3-61 (Scotland) 2 (Ireland) 74 (Isle of Man)
110	2	Crude blowout 347m^3 per day (90 days)	18-24 (England)	34-100 (England) Welsh 2-100 (Wales) 26 (N Ireland) 44-96 (Scotland) 10 (Ireland) 100 (Isle of Man)
113	5	Total rig inventory diesel loss 666-1,666m^3	Disperses within 8-9	0-0.7
113	1	Condensate blowout 21m3 per day (28 days)	Does not beach	0
Regional Seas 8 & 9				
204	8	Crude blowout 720-287,280m^3 total spill	42-105 (Shetland)	5-60 (Shetland) 1-<5 (Orkney, Faroe, mainland Scotland) <10 (Norway)
205	2	Crude blowout 720-2,254m^3 total spill	40 (Shetland)	1-10 (Shetland) 1-42 (Orkney)

Quadrants	Number of OPEPs reviewed	Spill type & size	Minimum time to beach (hours)	Likelihood of beaching (%)
206	2	Crude blowout 35,000-287,280m^3 total spill	25-36 (Shetland)	3 (Shetland) 0 (Orkney, mainland Scotland, Faroe) 10-60 (Norway)
208	2	Crude blowout 57,652-169,175m^3 total spill	50-55 (Shetland)	2-10 (Shetland) 2 (Norway)
213	5	Crude blowout 1,000-1,100,822m^3 total spill	35-269 (Shetland)	1-21 (Shetland) 1-10 (Orkney, Faroe, Norway)
214	1	Condensate blowout 318m^3 total spill	Disperses within 10	0
217	1	Crude spill 1,400m^3 total spill	144 (Faroes) 146 (Shetland)	8

The BE-AWARE initiative explored the risk assessment of marine pollution in the Greater North Sea and its wider approaches and ran in two phases (2012-2014 and 2013-2015). The first phase was co-financed by the European Union, with participation and support from the Bonn Agreement Secretariat, Belgium, Denmark and the Netherlands, with co-financing from Norway. The second phase was co-financed by the European Union, Ireland and Germany with participation from the Bonn Agreement Secretariat, Belgium, Denmark, France, the Netherlands, Norway, Sweden and the United Kingdom. Reports of the work are published by Bonn Agreement Secretariat[119]. It is noted that the removal of numerous oil and gas platforms through decommissioning over the next few years was not taken into account when assessing the probability of a ship collision with an offshore installation, and similarly it does not take account that the North Sea is a mature hydrocarbon province and that the majority of oil wells in the region will not flow naturally.

Accidental events related to carbon dioxide storage

Recent modelling studies have informed the potential characteristics of fluid escape from a ruptured pipeline (Wareing *et al*. 2013, 2014) and related instantaneous releases of carbon dioxide from pipelines and longer term releases from geological stores (Blackford *et al*. 2008, Phelps *et al.* 2015). Releases of CO_2 at the seabed may be visible in the form of bubbles (see Blackford & Kita 2013) or droplets with the phase determined by temperature and pressure, with bubbles likely to form in the shallow southern North Sea (Dewar *et al*. 2013). While the presence of natural gas seeps (e.g. through faults and from pockmarks) can provide useful data on bubble or droplet movement (typically of CO_2 and CH_4), the presence of a mixture of gases rather than pure CO_2 (Dewar *et al.* 2013) and the highly site specific nature of both natural (Kirk 2011) and storage site releases (Pearce *et al.* 2014a, b) makes them difficult to directly compare. The latter are more likely to provide insights into chronic, small-scale releases (maximum observed flux rate of a natural seep is up to 8,500t/m^2/year at Panarea, see Kirk 2011) rather than catastrophic or short-term releases.

For a short-term release thought to be representative of a pipeline rupture, Phelps *et al.* (2015) modelled a release over 1 day at two locations in the North Sea; a northern site corresponding to the approximate location of the Forties oil field characteristic of the relatively deep northern North Sea with a depth of 98m, and a southern site representing the approximate location of the

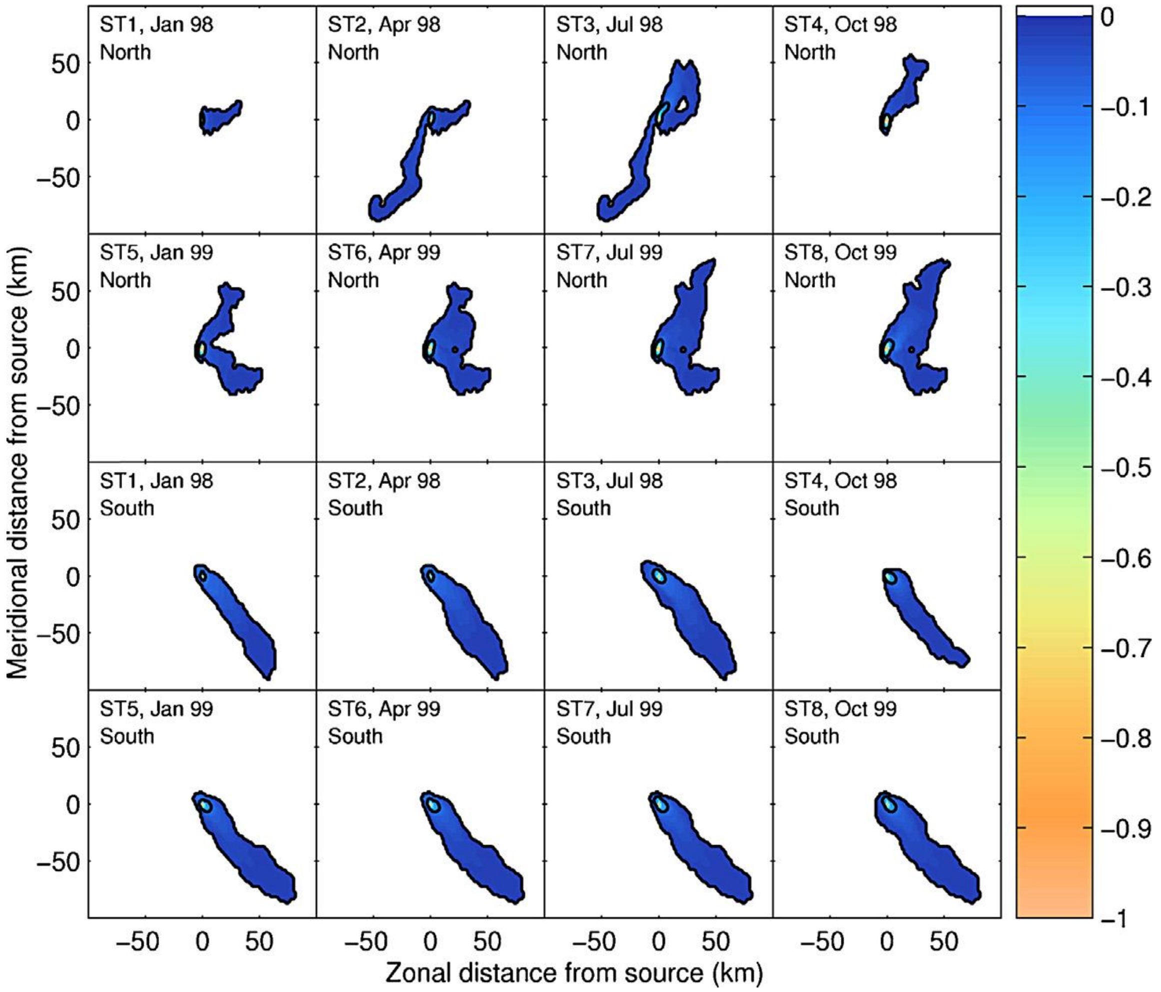
[119] http://www.bonnagreement.org/be-aware

Viking group of oilfields and more typical of the shallow southern North Sea with a depth of 43m. Both locations correspond to potential sites of carbon sequestration. The release rate was 5,000 tonnes of CO_2 per day (tCO_2/day), equivalent to twice the capacity of the current Sleipner pipeline. A 3D model (POLCOMS) was coupled with a carbon speciation sub-model (HALTAFALL) to account for hydrographic conditions and changes in (primarily) dissolved organic carbon and alkalinity, and physical properties including temperature, salinity and pressure – simulations were undertaken for each season (starting in each month of January, April, July and October) for 1998 and 1999.

Significant changes in the marine carbonate system were observed in each of the short term leakage scenarios, however any perturbations were minimal outside the vicinity of the source. Across all eight simulations the largest recorded reductions to seawater pH were 1.92 and 1.22 pH units at the north and south site respectively, both occurring during the October scenario, yet reductions were typically weaker than 0.1 pH units beyond 10km from the release sites (Figure 5.60). Significant perturbations to pH were generally restricted to the bottom layer, even at the vertically mixed south site, and reductions to surface pH were typically weaker than 0.1 pH units. It is evident that any CO_2 plumes arising from leakages of this magnitude are highly localised in the context of the North Sea (Phelps *et al.* 2015).

The carbonate system at the leakage sites quickly returned to background values after the end of the CO_2 release period. This was primarily due to advection of CO_2 away from the leakage sites and tidal mixing rather than outgassing of CO_2 at the sea surface, and a rapid recovery was also observed at the north site during the summer months when outgassing was negligible. During the recovery period the greatest reduction in seawater pH was generally not found at the release sites but at nearby locations, as the CO_2 plumes were gradually advected further away from their source point. Across all leakage scenarios the reductions to pH were weaker than 0.1 pH units (0.1 being regarded as a level where impacts are regarded to be unlikely, Widdicombe *et al.* 2013) within 5 days and below 0.05 pH units within 8 days within the northern CO_2 plume. In the southern CO_2 plume all reductions were weaker than 0.1 pH units within 3 days and below 0.05 pH units within 7 days. By day 30 the greatest reductions to seawater pH were less than 0.014 pH units at both sites. Significant changes in pH were found to be restricted to the bottom layers of water with surface water changes typically of less than 0.1 units, despite the relatively well-mixed waters of the southern North Sea, consequently, there was no discernible seasonal signal in the behaviour of the release (note that northern North Sea waters showed distinct seasonal changes related to the presence of a thermocline). Dewar *et al.* (2013) noted that the largest changes in pH and dissolution of CO_2 were likely to be found near the base of the leak source due to the greater density of CO_2 compared to the surrounding seawater, which means plumes will tend to sink (McGinnis *et al.* 2011).

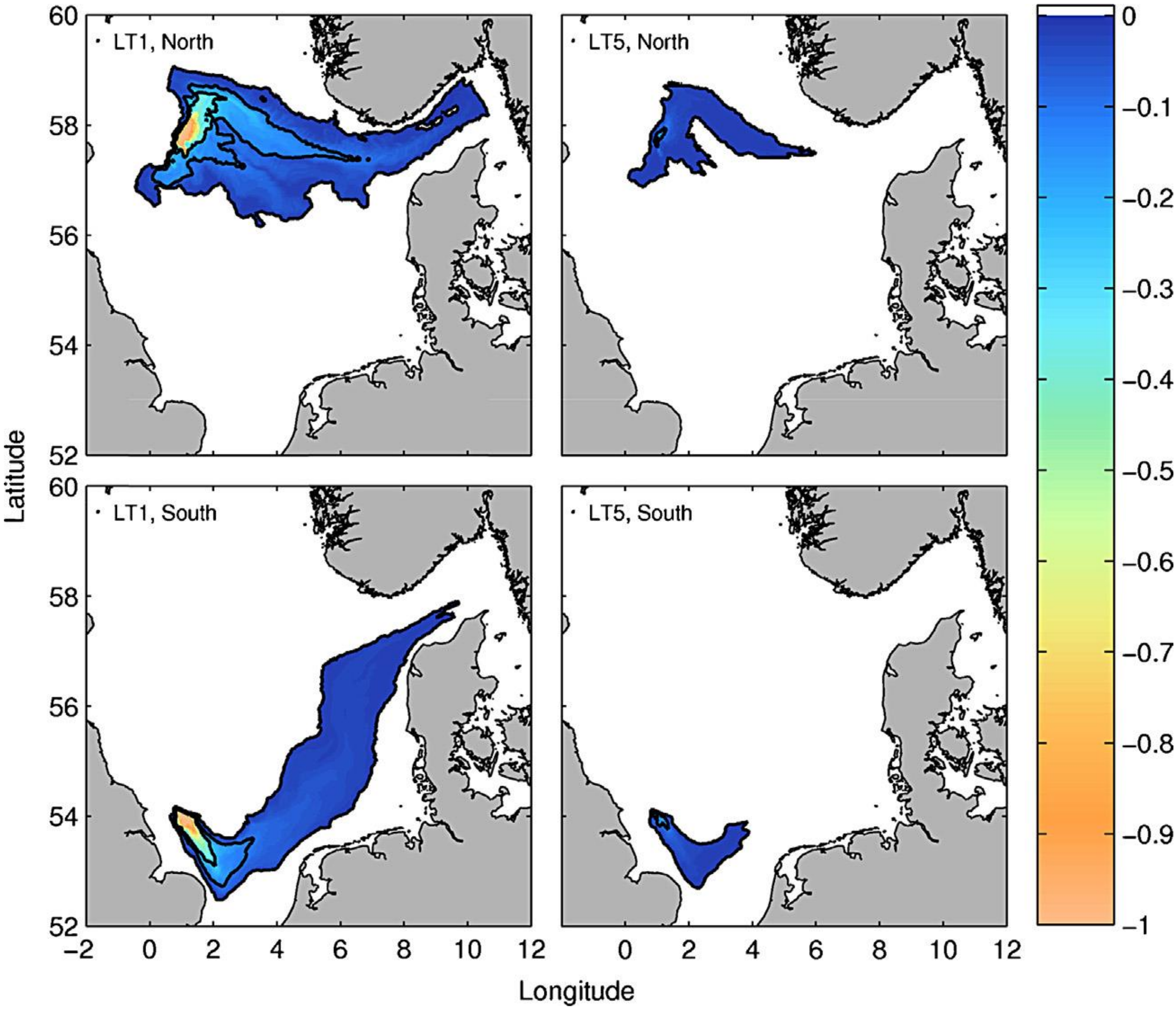
Figure 5.60: Maximum changes in pH at the seabed during short-term simulations



Notes: Simulations of release of 5,000 tCO2/d over 1 day. Grid size is 200x200km. The contours shown are for -0.25, -0.1 and -0.01 pH units.
Source: Phelps et al. (2015)

Longer-term releases with release rates of 1,000 tCO_2/d and 10,000 tCO_2/d were modelled over 365 days, representing chronic leakages such as those which might occur through geological faults. As with the short-term release scenario, the leaks were modelled beginning of each season. At the north site most of the CO_2 was carried initially northward then eastward by the mean circulation, broadly reflecting the Dooley Current, and gradually spread laterally to the north and south. However, a considerable proportion was also advected south of the release station (LT1 in Figure 5.61). The pathway of CO_2 released at the south site appeared to be much more persistent, initially flowing in a slow and narrow south-eastward pathway adjacent to the English coastline, then rapidly advancing north-eastward towards the Skagerrak in a much weaker concentration. The greatest reductions to pH were 2.67 and 2.32 pH units at the north and south site respectively, whilst acidification by 1.0 pH units (long-term reductions in pH approaching or exceeding 1.0 unit can be considered as significantly harmful, Widdicombe *et al*. 2013) could be found as far as 39km from the north site, and 24km from the south site. The smaller release scenario of 1,000 tCO2/d (LT5 in Figure 5.61) generated plumes which followed the same trajectory as the larger releases, though with changes an order of magnitude less (largest reductions to seawater pH were 1.1.9 and 0.98 pH units at the north and south site respectively. The carbonate system was found to return to natural values almost instantly following cessation of each release, however, analogous to the modelled short-term releases, this was in part due to advection away from the site rather than outgassing to the atmosphere (Phelps *et al*. 2015).

Figure 5.61: Maximum changes in pH at the seabed from long-term simulations



Notes: Simulations of release of 10,000 tCO2/d (LT1) and 1,000 tCO2/d (LT5) over 365 days. Each release was modelled starting in January 1998. The contours shown are for -0.25, -0.1 and -0.01 pH units.
Source: Phelps et al. (2015)

Phelps *et al.* (2015) indicate that any predicted acidification should be considered in the context of natural variability of pH in the North Sea, which can exceed 1.0 pH units in coastal regions of freshwater influence, although further offshore in regions of low biological activity annual variability is typically around 0.1-0.2 pH units (Blackford & Gilbert 2007). Furthermore, the North Sea is expected to acidify by an average of 0.2 pH units compared to pre-industrial levels by the year 2050 due to anthropogenic CO_2 emissions, and by an additional 0.13–0.28 pH units by 2100 (Blackford & Gilbert 2007). They highlight however that any acidification due to CO_2 leakages would be in addition to natural variability, and the rate of acidification would be considerably faster than the long-term trend associated with rising atmospheric CO_2 (Phelps et al. 2015).

The influence of stratification upon the fate of a CO_2 plume was evident. Strong seasonal thermoclines are able to inhibit the exchange of CO_2 between surface and bottom waters, and ultimately prevent outgassing of CO_2 into the atmosphere. Overall the carbonate system at the south site appeared to be considerably less sensitive to CO_2 additions than the north site, primarily because the shallow depths and generally well mixed vertical profile meant CO_2 could readily escape to the atmosphere, and strong tidal currents ensure that CO_2 was well mixed within the water column. Although seasonal variability to the air–sea flux was significant at both sites, on average the CO_2 injected at the south site reached the atmosphere twice as fast as the corresponding CO_2 at the north site (Phelps *et al.* 2015).

As part of the quantifying and monitoring potential ecosystem impacts of geological carbon storage (QICS) project, a small-scale leak (between 10kg/d and 210kg/d) was simulated in Ardmucknish Bay in western Scotland (Blackford & Kita 2013, Blackford *et al*. 2014, Taylor *et al*. 2015). The experiment used a narrow directionally drilled borehole which terminated in a 5m long diffuser contained in unconsolidated sediments 12m below the seabed, in 12m of water. A series of instruments were deployed at various distances from the simulated release location (epicentre, 10m, 25m, 75m and a control at 400m), and surveys undertaken before, 7 and 30 days after the release commenced and then 7, 30 and 90 days after cessation of the simulated leak. In addition to faunal experiments, changes in seawater pH were also monitored.

The QICS study provided insights into the reaction of pore water in seabed sediments, which absorbed much of the emitted CO_2, though underwent physical changes immediately above the release site in the form of CO^2 chimneys (and gas columns in the waters above), which were seismically resolvable (Blackford *et al*. 2014, Cevatoglu *et al.* 2015). As pore water became supersaturated with CO_2 a greater proportion of the leak reached the seabed surface and therefore the water column (Dewar *et al.* 2015), being either subject to dissolution or outgassing. Sedimentary interactions with bubbles or droplets may change depending on shallow geological heterogeneity, with sudden large escapes possibly caused by accumulation of CO_2 in pockets which eventually exceed hydrostatic head (Caramanna *et al.* 2014).

Blackford *et al*. (2008), Phelps *et al*. (2015) and Dewar *et al*. (2013) indicate that tidally driven mixing is the primary CO_2 dispersal mechanism, and that small-scale catastrophic releases and smaller chronic releases tend to generate localised changes in pH and the carbonate system which rapidly recover following cessation of the release. While the largest release scenarios were found to generate widespread acidification, such leaks are highly unlikely to occur.

5.13.3.2 Effects of accidental releases

Environmental effects

Accidental events related to exploration and production

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. Seabirds are affected by oil pollution in several ways, including oiling of plumage resulting in the loss of insulating properties and the ingestion of oil during preening. Pollution of the sea by oil, predominantly from merchant shipping, can be a major cause of seabird mortality.

Fortunately, there is little experience of major oil spills in the vicinity of seabird colonies in the UK. In January 1993 the Braer ran aground at Garth's Ness in Shetland and began leaking Norwegian Gulfaks crude oil, spilling a total 85,000 tonnes of oil. 207 birds were received at the cleaning centre set up to deal with oiled birds, of these 23 were successfully rehabilitated, while an estimated 31 out of 34 seals were successfully rehabilitated. There was difficulty in determining the number of birds that died as a result of the oil as some would never have been found and stormy weather at the time of the spill caused a high mortality of storm victims that became oiled after death. 1,538 dead birds were found on the beaches including shag (857), black guillemot (203), kittiwake (133), and long-tailed duck (96), as well as great northern diver (13), eider (70) and great black-backed gull (45). There was a clear excess of females over males found. The main groups of breeding seabirds affected by the spill were locally resident species, as summer visitors were not in Shetland waters at the time of the spill. In general the 1993 breeding season was successful for most species that may have been affected by the oil spill, with the exception of shag and black guillemot (SOTEAG 1993, DTI 2003). The stormy weather during the Braer spill resulted in the rapid dispersion of the oil in the water column. Long term effects on wildlife have proved to be less than first feared with the most notable impact on breeding populations of resident seabirds closest to the spill (SOTEAG 1993).

The impact of the Macondo (Deepwater Horizon) well blowout on birds offshore is difficult to quantify due to the low resolution of antecedent seabird surveys and the paucity of observed carcasses during the oil spill response, potentially due to the rapid decomposition rates of bird carcasses in the relatively warm seas, opportunistic scavenging (e.g. by tiger sharks), and due to in situ burning of surface oil slick (Haney *et al*. 2014a). Modelling (Haney *et al*. 2014a, b) estimated mortality of 200,000 in coastal and open waters immediately after the blowout, when considered across the range of species known to be affected by the spill, would represent <10% of their breeding population. When considering those birds exposed in coastal and estuarine environments, Haney *et al*. (2014b) estimated that bird mortality was approximately 700,000. Within coastal waters, mortality was estimated to have mainly affected four species: northern gannet *Morus bassanus* (8%), brown pelican *Pelecanus occidentalis* (12%), royal tern *Thalasseus maximus* (13%) and laughing gull *Leucophaeus atricilla* (32%). Both studies suggest future work is required to understand the demographic consequences to the Gulf's coastal birds from this large marine spill.

As the major breeding areas for most wildfowl and wader species are outside the UK (in the high arctic for many species), population dynamics are largely controlled by factors including breeding success (largely related to short-term climate fluctuations, but also habitat loss and degradation) and migration losses. Other significant factors include lemming abundance on arctic breeding grounds (e.g. white-fronted goose). Variability in movements of wintering birds, associated with winter weather conditions in continental Europe can also have a major influence on annual trends in UK numbers, as can variability in the staging stops of passage migrants.

Oil spill risks to marine mammals have been reviewed by successive SEAs for previous licensing Rounds and in a number of supporting technical reports (e.g. Hammond *et al.* 2004, Hammond *et al.* 2008).

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, and any accidental ingestion or breathing of oily fumes could cause physiological stress (Law *et al*. 2011). 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 (Hammond *et al*. 2002).

The effects of the Macondo blowout on marine mammals in the Gulf of Mexico were evaluated using an area known have received heavy and prolonged oiling (Barataria Bay, Louisiana) and a control site (Sarasota Bay, Florida) (Schwacke *et al.* 2013). Disease conditions in Barataria Bay dolphins were significantly greater in prevalence and severity than those in Sarasota Bay dolphins, as well as those previously reported in other wild dolphin populations. Many disease conditions observed in Barataria Bay dolphins were uncommon but consistent with petroleum hydrocarbon exposure and toxicity (Schwacke *et al*. 2013). The mortality signal from the Macondo blowout is made less clear by an ongoing Unusual Mortality Event (UME) declared by NOAA Fisheries that covers the broader northern Gulf of Mexico region. This UME began two months prior to the Macondo blowout, and since that time the frequency of strandings has fluctuated both spatially and temporally. The timing and underlying pathologies for the strandings are being examined as part of the UME investigation to understand the potential differing causal factors, including the Macondo spill.

Grey and harbour seals come ashore regularly throughout the year between foraging trips and additionally spend significantly more time ashore during the moulting period (February-April in grey seals and August-September in harbour seals) and particularly the pupping season (October-December in grey seals and June-July in harbour seals). Animals most at risk from oil coming ashore on seal haulout sites and breeding colonies are neonatal pups, which rely on their prenatal fur and metabolic activity to achieve thermal balance during their first few weeks of life, and are therefore more susceptible than adults to external oil contamination.

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 un-oiled areas.

Coastal otter populations are also vulnerable to fouling by oil, should it reach nearshore habitats. They are closely associated with the sea surface and reliant upon fur rather than blubber for insulation.

Fish are at greatest risk from contamination by oil spills when the water depth is very shallow. In open waters deeper than 10m, the likelihood that contaminant concentrations will be high enough to affect fish populations is very small, even if chemical dispersants are used. In shallow or enclosed waters (note that chemical dispersants are not generally appropriate for use in such areas), high concentrations of freshly dispersed oil may kill some fish and have sublethal effects on others. Juvenile fish, larvae and eggs are most sensitive to the oil toxicity (Law *et al*. 2011). Available evidence suggests that salmon smolts utilise shallow water depths (1-6m) and that adults show varying behaviour, swimming generally close to the surface (0-40m depth), with occasional deeper dives – e.g. Holm *et al.* (2005, cited by Malcolm *et al.* 2010) noted dive depths of between 85 and 280m. The most sensitive period for Atlantic salmon is likely to be during the peak smolt run, rather than when adult salmon are returning to rivers. This is because Atlantic salmon return to natal rivers throughout the year, whereas the smolt run is more seasonally defined (April and May). It should be noted that salmonids play a critical role in the life cycle of the freshwater pearl mussel.

Benthic habitats and species may be sensitive to deposition of oil associated with sedimentation, or following chemical dispersion. The proportion of a surface spill that is deposited to the seabed might be expected to increase as a result of high turbulence and suspended solids concentrations in the water column, both associated with storm conditions in shallow water. Studies of seabed infauna following the Braer spill (Kingston *et al.* 1995), which occurred under such conditions, found no significant changes in benthic community structure, as characterised by species richness, individual abundance and diversity, which could be related to the areas of seabed affected by the spill. This may have been because Braer oil was of low toxicity, or because the sampling programme was carried out too soon after the spill to enable the full effects of its impact to be detected. In recognition of this as part of the DECC SEA programme, further sampling of the study area was undertaken ten years after the spill, results from which have indicated a substantial decline in sediment hydrocarbon concentrations.

In contrast, evidence from the Florida barge spill (Buzzards Bay, Massachusetts, September 1969, in which 700m^3 of diesel fuel were released) suggests that in certain circumstances, contamination from oil spills could be long-term. Monitoring immediately following the spill suggested rapid recovery (reviewed by Teal & Howarth 1984), while subsequent studies (sampling in 1989) indicated that substantial biodegradation of aromatic hydrocarbons in saltmarsh sediments had occurred (Teal *et al.* 1992). However, thirty years after the spill, significant oil residues remain in deep anoxic and sulphate-depleted layers of local salt marsh sediments (Reddy *et al.* 2002, Peacock *et al.* 2005). The ecological consequences of this residual contamination are unclear, although there is potential for remobilisation of sediment-bound contaminants through bioturbation or storm events (in which case, aerobic biodegradation would be expected to be rapid).

The concentration of petroleum hydrocarbons in sediments was measured in three Louisiana estuaries before Macondo well oil entered the wetlands, and nine times afterwards, from September 2010 to June 2013. The average concentrations of alkanes and PAHs were 604 and 186 times the pre-spill values respectively (Turner *et al*. 2014). The concentrations of alkanes and PAHs in June 2013 were about 1% and 5%, respectively, of the February 2011 concentrations, but were higher than in the May 2010 baseline. The concentration of alkanes has declined rapidly and Mahmoudi *et al.* (2013) suggested that baseline conditions for alkanes may be reached in 2015. Work undertaken offshore in proximity to the blowout location (see Montagna *et al.* 2013), revealed that benthic effects (e.g. faunal abundance and diversity) was greatest within 3km of the Macondo wellhead covering an area of around 24km^2 with a zone of ‘moderate effects’ observed to extend up to 17km towards the south-west and 8.5km towards the north-east of the wellhead, covering an area of around 148km^2. Recovery time of the benthos is unknown, but is likely to take years or decades; the presence of numerous natural oil, gas and brine seeps and associated microflora and other biota in the Gulf of Mexico may allow a more rapid recovery than would be the case in other deep sea areas. White *et al.* (2012) and Fisher *et al*. (2014) investigated 13 deepwater coral sites, most of which did not show evidence of impacts from the spill. Despite extensive survey and sampling, no compelling evidence of acute impact from the spill at any coral sites between 400 and 850m depth or more than 30km from Macondo has led Fisher *et al*. (2014) to suggest that this is the footprint of acute impact to deepwater coral communities from the blowout.

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 events related to gas storage

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.

Accidental events related to carbon dioxide storage

A range of effects are possible from an accidental release of CO_2 from a pipeline or storage site, with the change in seawater pH being the main source of effect for short-term releases, and additionally disturbance to the carbonate system for longer-term releases (e.g. through a reduced ability of some organisms to produce hard shells and increased erosion of shells, particularly sessile forms which are in close association with the seabed – Pearce *et al*. 2014a, also see Hennige *et al*. 2014). The effects of enhanced CO_2 and ocean acidification on marine organisms has been subject to numerous laboratory and field experiments and literature syntheses (Kirk 2011, Pearce *et al*. 2014a, Hennige *et al*. 2014), which have been reviewed and summarised below.

While many marine species are able to cope with short-term perturbations of reduced pH and elevated CO_2, having some resistance due to natural variability, they are unlikely to be able to cope with larger, longer-term changes that could occur from chronic leaks depending on their magnitude and the nature of the receiving physical environment (Pearce *et al*. 2014a). With regards to long-term leaks, Hennige *et al*. (2014) indicates that calcifying organisms such as echinoderms, molluscs, corals and specific algae are more vulnerable to the effects of enhanced levels of CO_2, with fish (Hennige *et al.* 2014) and annelids (e.g. see Calosi *et al*. 2013) having a greater tolerance to acidification and hypercapnia. Most organisms which have been investigated tend to tolerate a large change in pH (to 7.3) before significant effects including mortality are observed at lower levels (<7.0) (Dorey *et al*. 2013, Hu *et al.* 2014, Murray *et al.* 2013, Morgan *et al*. 2014). Experimental results from the RISCS (research into impacts and safety in CO_2 storage) project[120] suggest that benthic shell gravel marine communities in cool temperate shallow marine environments are able to withstand at least 10 weeks of exposure in pH levels not less than 7.5 (Pearce *et al*. 2014a).

Hu *et al.* (2014) found that the brittlestar (*Amphiura filiformis*) experience a naturally low oxygen and pH environment in their burrows, being relatively robust down to pH 7.3, but showed the onset of metabolic depression at exposure to pH 7.0. Murray *et al*. (2013) similarly found that the species was robust to changes in pH, though exhibited emergent behaviour during simulated rapid acidification (down to pH 6.5). Pearce *et al*. (2014a) notes that sea urchins living at higher levels of CO_2 tend to show reduced reproductive success (though no specific pH value is given). With regards to effects on larvae, Dorey *et al.* (2013) found larvae of the green sea urchin (*Strongylocentrotus droebachiensis*) to be resistant to reductions in pH to levels as low as 7.0, but with changes in body symmetry, morphology and respiration, which were significant and caused mortality after 13 days at pH ≤6.5, which contrasts with previous findings of Dupont *et al.* (2008), who found mortality in brittlestar (*Ophiothrix fragilis*) larvae at a change of just 0.2 pH units being exceeded for 8 days, which may reflect variations in individual responses of echinoderm species to rapid pH changes, as they have been generally found as resistant to enhanced pH (see review in Dupont *et al.* 2011).

Caged mussels *Mytilus edulis* and king scallops *Pecten maximus* were subject to the QICS simulated CO_2 release in Ardmucknish Bay (see above for experiment parameters) with no evidence of significant impacts noted for ion or CO_2 regulation (Pratt *et al.* 2014). Earlier laboratory experiments (Gazeau *et al*. 2007) indicated a linear decrease in calcification rates of *M. edulis* with increasing pCO_2, with longer-term experiments (6 months) indicating continued shell growth with increased pCO_2 concentrations of a magnitude expected through anthropogenic CO_2 input by 2100 (see Ciais *et al.* 2013), though with a reduction in shell integrity (Fitzer *et al.* 2014). While adults may have some resilience to changes in pH, the impact of chronic reductions in pH (e.g. analogous to ocean acidification) are likely to be more pronounced for larval stages in bivalves (Hennige *et al.* 2014).

Polychaetes have received relatively little attention in terms of potential impacts from elevated pCO_2 (Calosi *et al.* 2013, Lewis *et al.* 2013). However, though in a different environment to the southern North Sea, adaptation has been shown in some species in response to elevated levels of pCO_2 associated with natural seeps in the Mediterranean (Calosi *et al*. 2013), while experiments in intertidal areas have shown reduced fertilisation success with pH reductions

[120] http://www.riscs-co2.eu/

from 8.1 to 7.4 and an extreme 7.2 (Lewis *et al*. 2013). The onset of impacts from a reduction in pH of this magnitude is in general agreement with those suggested by Pearce *et al*. (2014a).

Generally, wider benthic macrofaunal community changes were observed at the Ardmucknish release site within a few days (with effects from the release discounted for all stations at 25m, 75m and 450m) which became more severe during the release though showed rapid recovery by 18 days after cessation (Widdicombe *et al.* 2015). Kita *et al*. (2015) observed benthic megafauna in association with the same experimental release which frequently included, *Virgularia mirabilis* (sea pen), *Turritella communis* (snail), Asterias rubens (starfish), *Pagurus bernhardus* (hermit crab), *Liocarcinus depurator* (crab), and *Gadus morhua* (cod), none of which displayed any abnormal behaviour.

The sensitivity of planktonic and pelagic communities (e.g. fish, cephalopods) to high CO_2 concentrations and reduced pH is variable. In the latter group, Hennige *et al.* (2014) notes that fish are generally able to maintain oxygen delivery under higher CO_2 levels (e.g. citing research on Atlantic cod which maintained standard metabolic rates at high CO_2 concentrations after exposure of up to 12 months, Melzner *et a*l. 2009), and reproductive success is variable, but generally robust in species studied to date (e.g. herring (*Clupea harengus*)). Squid have the potential to be affected due to use of the respiratory pigment haemocyanin which is sensitive to CO_2, while the cuttlefish (*Sepia officinalis*) has not shown significant effects of reduced pH unless water temperatures are also enhanced (Hennige *et al*. 2014).

In appropriate circumstances greater CO_2 concentrations can lead to enhanced primary production, particularly of non-calcifying phytoplankton (Hennige *et al*. 2014), however this requires relatively clear, shallow waters which are not present over much of the North Sea and are limited by nutrient supply (Pearce *et al.* 2014a). The phytoplankton community of the North Sea, is dominated by the dinoflagellate genus *Ceratium* (*C. fusus, C. furca, C. lineatum*), with diatoms such as *Thalassiosira* spp. and *Chaetoceros* spp. also abundant. Information on the response of some zooplankton such as copepods is limited, though Arctic mesocosm experiments showed no change in abundance after 30 days of exposure to enhanced CO_2 (>1,000µatm, greater than the projected oceanic pCO_2 in 2100 by IPCC) in *Calanus* spp., *Oithona similis*, *Acartia longiremis* and *Microstella norvegica*, though grazing rates of *Calanus* spp. decreased with increasing CO_2.

Generally, how effects of exposure to high levels of CO_2 and related reduced pH in early life stages may affect later adult growth and reproduction is a key information gap and an area which requires continued research (Hennige *et al*. 2014), particularly in the context of a background trajectory of rising oceanic acidification.

While short-term catastrophic events have been observed to generate significant changes in seawater pH (up to 1.22 units), recovery is likely to be rapid, with effects highly localised around the release location, and dependent upon the communities present and their resilience to changes in pH. Assuming an ambient seawater pH of 8.1, an absolute and highly localised reduction to pH 6.9 is unlikely to elicit long-term responses in most animals, though could generate mortality for some individuals in proximity to the source. The presence of strong tidal currents and turbulent waters in the southern North Sea suggests that any short-term leak will be rapidly dispersed and carried away from the release location reducing any longer-term interaction with areas of reduced pH or enhanced pCO_2. Longer-term chronic emissions from storage site leaks could produce effects at the seabed and in the water column, however even under this scenario, the return to normal pH and pCO_2 levels in seawater can be expected to occur within days for the pelagic system on cessation of CO_2 entering the environment (Hennige *et al.* 2014, Phelps *et al.* 2015). Depending on the release rate or flux, such effects may be comparable to those from natural CO_2 seeps, or those which have been assessed in relation to wider ocean acidification. Set in the context of the wider anthropogenic emission of carbon dioxide to the atmosphere any such leak would be 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 studies (e.g. May & Monaghan 2003, Beegle-Krause & Lynch 2005) suggest that the latter may not be a significant concern.

5.13.4 Controls and mitigation

Spill control and mitigation measures are implemented for offshore exploration and production inter alia through the Merchant Shipping (Oil Pollution Preparedness, Response and Co-operation) Regulations 1998 and the Offshore Installations (Emergency Pollution Control) Regulations 2002. The required measures include spill containment measures, risk assessment and contingency planning. Under the Regulations, all operators of an offshore installation or oil handling facility must have an OPEP in place. The plans are reviewed by DECC, MCA and relevant environmental consultees, such as the Joint Nature Conservation Committee, the relevant country statutory nature conservation body, e.g. Scottish Natural Heritage, and other relevant organisations. An OPEP will only be approved by DECC following consultation and satisfactory operator response to any comments. Approval of an OPEP does not constitute approval of the operations covered by the plan. Operators are responsible for ensuring compliance with all other regulatory requirements. OPEPs set out the arrangements for responding to incidents with the potential to cause marine pollution by oil, with a view to preventing such pollution and minimising its effect. Additional requirements can be imposed by DECC through block-specific licence conditions (i.e. “Essential Elements”). Operators are required to follow international and UK best practice when responding to oil spills (i.e. consistent with DECC’s OPEP requirements) and the OPEP must identify appropriate strategies to facilitate a prompt and effective response to a pollution event, including details of how and when they would be employed. These details must include strategies specific to the location which may include:

- Monitoring and surveillance (from installation, vessel, aircraft, satellite)
- Dispersion (natural or chemically/mechanically assisted)
- Containment and recovery (booming and mechanical recovery)
- Source control (well capping and relief well operations)

The vulnerability of seabirds to surface oiling is related to individual species’ behavioural patterns, distribution and ecological characteristics (e.g. rate of population recovery). 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 recover

By combining OVI with data on spatial distribution, maps of overall seabird vulnerability to surface pollution has been produced. Current OVI maps are based on data from the European Seabirds at Sea (ESAS) database (see Section A1a.7) are used routinely as part of the offshore development impact assessment process to identify (spatially and temporally) areas of very high to low vulnerability. It informs mitigation requirements and spill response planning. Discussions on potential updates are currently ongoing.

In June 2013 the EU Directive 2013/30/EU on the safety of offshore oil and gas operations (The Offshore Safety Directive) was published. The Offshore Safety Directive (OSD) requires that certain specified information regarding emergency response measures is provided in an Internal Emergency Response Plan (IERP) which itself forms part of the Report on Major Hazards (Safety Case). In the UK the IERP will be delivered, in part, by the OPEP. The requirements of the OSD must be fully transposed by July 2018 (with the requirements for existing non-production installations to be in place by July 2016).

The Merchant Shipping (Oil Pollution Preparedness, Response and Co-operation Convention) (Amendment) Regulations 2015 amend the existing requirements in the Merchant Shipping (Oil Pollution Preparedness, Response and Co-operation Convention) Regulations 1998 to have an OPEP. The obligations under the OSD do not extend to internal waters, so the amendments to the 1998 Regulations are limited to an installation in the territorial sea or the continental shelf. To effect this distinction, installations in internal waters are now referred to as “oil handling facilities”. While the required content of OPEPs remains largely consistent with existing guidance, there are a number of amendments introduced by the Merchant Shipping (Oil Pollution Preparedness, Response and Co-operation Convention) (Amendment) Regulations 2015 and updates to OPEP[121] guidance to fulfil specific requirements of the Directive.

Offshore, primary responsibility for oil spill response lies with the relevant operator and their accredited third party pollution responders, although the Secretary of State’s Representative may intervene if necessary. The MCA is responsible for a National Contingency Plan and maintains a contractual arrangement for provision of aerial spraying, with aircraft based at East Midlands and if necessary, Inverness. MCA holds counter-pollution equipment (booms, adsorbents etc.) which can be mobilised within 2-12 hours depending on incident location, in addition to a stockpile of chemical dispersant. The UK Government recently announced that the contract for an Emergency Towing Vessel stationed in Orkney for the waters around the Northern and Western Isles has been extended to September 2016[122]).

The most recent draft OPEP guidance (May 2015) indicates that the potential for shoreline contamination must be determined for all installations using appropriate worst case oil spill modelling. Where modelling indicates the potential for oil to beach, the OPEP must confirm that appropriate response resources are capable of reaching prioritised locations in sufficient time to allow response measures to be implemented to minimise the impact of any oil pollution. In sensitive locations where the risk of shoreline impact is likely to occur before the arrival of resources from existing Tier 2 or 3 stockpiles, consideration should be given to the establishment of dedicated pre-positioned resources.

A Shoreline Protection Plan (SPP) must also be developed for all installations (including pipelines) operating in Blocks wholly or partly within 40km of the coast. The OPEP arrangements for any installation (not pipelines) located within 40km of the coast should also confirm that:

- an appropriate dispersant123 can be applied within 30 minutes of a pollution incident; and
- sufficient dispersant stocks are available to treat a minimum oil release of 25 tonnes,
- appropriate at sea and shoreline response resources can be available on scene within half the time taken for the oil to beach.

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[121] Amendments to the guidance include: requirement for non-production installations to hold an approved OPEP, references to the inventory of response equipment and an assessment of the effectiveness of oil spill response measures, changes to who is required to hold an OPEP (e.g. well operator, installation operator), changes to the nomenclature of different OPEP types, amended worst case modelling requirements, the timeline associated with certain OPEP reviews – see:http://www.hse.gov.uk/osdr/assets/docs/guidance-notes-opeps-rev1-may-2015.pdf

[122] http://www.bbc.com/news/uk-scotland-highlands-islands-35638947

[123] Chemical dispersant use is generally inappropriate in shallow sheltered waters, in water depths of less than 20 metres and in waters extending up to 1.15 miles (equivalent to 1 nautical mile) beyond the 20 metre contour, or on refined oil products such as diesel, gasoline or kerosene which should disperse naturally prior to reaching the coast or any sensitive environments. The use of chemical dispersants will, therefore, be dependent upon several factors including the quantity of oil, oil type, sea temperature, time of year, prevailing weather and environmental sensitivities. There are strict controls on the use of dispersants, with only those on an approved list (https://www.gov.uk/government/publications/approved-oil-spill-treatment-products) permitted for use. All oil spill treatment products are tested for their efficacy (effectiveness) and for toxicological hazard.

In addition to loss of well control, risk of oil and diesel loss resulting from collision is considered for drilling activities. A consent to locate a drilling rig is required in advance of drilling which is subject to consultation with relevant stakeholders (e.g. the General Lighthouse Authority, MCA, MoD). Such consent applications require to be supported by a vessel traffic survey and collision risk assessment, and the consent requires the movement and location of the rig to be notified to other users of the sea (e.g. through notices to mariners). A statutory 500m safety zone is established around the rig when in the field, and a standby and/or guard vessel is also located next to the rig during drilling operations to ensure that vessels do not enter the safety zone, and to provide emergency response.

Activity specific management measures (e.g. implemented through the operator's accredited (and DECC required) Environmental Management System) can reduce the potential for spills of oil and chemicals of all sizes through, for instance, identification of environmentally critical equipment, related maintenance schedules, training and good practice. During onshore emergency pollution control exercises, DECC may request a list of personnel responsible for responding to oil pollution incidents and evidence of training. DECC Environmental Inspectors may conduct an offshore inspection of the installation and gather evidence to prove compliance with exercise requirements, and check training records for offshore personnel to ensure compliance with training requirements.

Whilst the indemnity and insurance group of OSPRAG concluded that the current Offshore Pollution Liability Association Limited (OPOL) level of US $250 million of cover is appropriate in the majority of scenarios, in certain limited cases spill clean up and compensation costs could result in claims above this limit. Guidance issued by Oil & Gas UK (OGUK) in November 2012 outlined a new process by which operators assess the potential cost of well control, pollution remediation and compensation, with a subsequent requirement to demonstrate to DECC financial capability to address these potential consequences. DECC released a guidance note to industry[124] effective from January 1st 2013 on the demonstration of financial responsibility before consent may be granted for exploration and appraisal wells. It was noted in this document that, though not constituting DECC guidance, considerable weight would be given to operators who can show that they have met the criteria set out in the OGUK guidance. DECC require that an operator must demonstrate the cost of well control and the cost of financial remediation and compensation from pollution at the time of OPEP submission, and verify this responsibility by, for instance: insurance, parent company guarantee, reliance on credit/financial strength rating of the operator.

5.13.5 Likelihood of significant effects

The incremental risk associated with activities resulting from the proposed licensing (i.e. additional to existing risk; primarily associated with shipping and other maritime activities) is low. This results from the combination of low probability and low severity (since most spills would be small in volume). The overall risks of a major crude oil spill, which would require catastrophic loss of well control, are quantitatively and qualitatively comparable to those considered ALARP (As Low As Reasonably Practicable) under the relevant UK health and safety regulations.

The potential for accidental spills to have transboundary impacts is recognised in project-level oil spill modelling which includes assessment of travel times to cross boundaries as well as the likelihood of beaching on different countries. The review of oil spill modelling undertaken for the assessment indicates that potential transboundary impacts were identified for large oil spills in

[124] DECC Guidance note to UK offshore oil and gas operators on the demonstration of financial responsibility before consent may be granted for exploration and appraisal wells on the UKCS (December 2012).

Regional Sea 1 (Norway), Regional Sea 6 (Republic of Ireland, Isle of Man), and in Regional Seas 8 and 9 (Norway, Faroes). The prospectivity of much of Regional Sea 2 (natural gas, also present in the eastern Irish Sea) precludes transboundary impacts as significant oil spill is not likely.

5.13.6 Summary of findings and recommendations

The environmental risks of accidental spill events associated with proposed activities following further rounds of oil & gas licensing 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 (and in the future, wave and tidal stream developments) are not considered to represent a significant source of accidental spills where navigational safety risks have been fully considered in the planning and siting of such developments.

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 (primarily condensate or gas) although oil is also present in the Eastern Irish Sea.

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 causes of the recent Deepwater Horizon blowout have been identified and a combination of technical, operational and regulatory measures have been put in place to effectively control the risk of a similar event in UKCS operations. These have been implemented through initiatives by HSE, DECC, OSPRAG and individual operators and further strengthened by the impregnation of the Offshore Safety Directive.

Effective National Contingency Planning, and adequate response resources at a national level, including Emergency Towing Vessels (ETVs), are considered to be important mitigation measures.

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 relevant 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).

Operational risks, principally of large-scale CO_2 risk from transportation or offshore injection facilities are broadly similar to those associated with gas production and relevant experience and effective control will be possible under existing regulatory systems. The environmental consequences of large CO_2 releases are not considered likely to be severe (i.e. comparable with a large hydrocarbon release), although further consideration is needed of the potential consequences of loss of containment from storage reservoirs over long timescales.

5.14 Ancillary development

Assessment Topic	Potentially Significant Effect	Oil & Gas	Gas Storage	Carbon Dioxide Storage	Offshore Wind	Tidal Stream	Tidal Range	Wave	Assessment Section
	Other interactions with shipping, military, potential other marine renewables and other human uses of the offshore environment	X	X	X	X	X	X	X	5.7 5.16.6
	Potential effects of development on seascape including change to character (interactions between people (and their activities) and places (and the natural and cultural processes that shape them))	X	X	X	X	X	X	X	5.8
	Physical damage to biotopes from infrastructure construction, vessel/rig anchoring etc (direct effects on the physical environment)	X	X	X	X	X	X	X	5.4.3.2
	Physical effects of anchoring and infrastructure construction (including pipelines and cables) on seabed sediments and geomorphological features (including scour)	X	X	X	X	X	X	X	5.4.3.1
	Physical damage to submerged heritage/archaeological contexts from infrastructure construction, vessel/rig anchoring etc and impacts on the setting of coastal historic environmental assets and loss of access.	X	X	X	X	X	X	X	5.4.3.3
	Local air quality effects resulting from exhaust emissions, flaring and venting	X	X	X	X	X	X	X	5.11

5.14.1 Introduction

The issue of ancillary development and related potential environmental effects is an important strategic consideration, and although the focus of this SEA is principally the marine environment, this section focuses on onshore works directly associated with offshore energy development, as specified in the draft plan/programme. It also notes potential offshore grid development which may be required to distribute new capacity around the UK. Note that the onshore distribution of imported gas is not part of this plan/programme.

The sources of potentially significant effect identified in the table above are those which may be relevant to ancillary developments, particularly those offshore. Given that ancillary developments are not covered directly by the draft plan/programme but are linked closely to the successful implementation of some aspects of it, these ancillary development effects are considered to be secondary in nature. Therefore, the relevant assessment section in the table above (right hand column) identifies where each of the potentially significant effects are more fully considered. Below is a description of those components from new oil and gas, gas storage (including carbon dioxide) and renewable developments that could lead to potentially significant effects.

5.14.2 Sources of potentially significant effect

5.14.2.1 Oil and gas, gas and carbon dioxide storage

The majority of oil production from the UKCS is exported to shore by pipeline with the remainder exported by tanker; gas being exported by pipeline or converted to liquid and exported by carrier (e.g. liquefied natural gas (LNG) tanker). Similarly, to date pipelines have been used as the means to transfer carbon dioxide from point sources onshore to offshore injection infrastructure and storage sites, though tanker transport is considered possible. There is a well-developed hydrocarbon export pipeline infrastructure on the UKCS, and production from small new developments can be expected to access these existing facilities, and in many cases such new development is therefore entirely subsea in nature.

The development of very large new reserves could justify the installation of new pipelines and terrestrial reception facilities. Tanker offloading requires both oil storage and offloading facilities. New pipelines with onshore components, new processing facilities and development of quayside facilities, could potentially have significant effects on the receiving environments, through the construction, operation and decommission phases. Pipeline landfall for carbon dioxide storage would involve analogous techniques of installation to oil and gas pipelines, and may require onshore facilities should pressure enhancement prior to export offshore be required, or for pipeline inspection gauge (PIG) facilities.

5.14.2.2 Grid system

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 due to their distance from shore, which will require converter stations to interface with the onshore alternating current (AC) system. Switchgear forms a large spatial component of substations. Air Insulated 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) is more costly than AIS but requires 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 typically 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 1,000m; 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 offshore wind generation to the onshore transmission system, upgraded or new overhead power lines may be required to accommodate the changes in power flows, especially across congested areas. Towers used to carry the power lines vary in height (e.g. 46.5m to

49m) and width (e.g. 7m to 14.5m) depending upon whether they are a suspension, deviation or terminal tower. The size, height and spacing of the towers are also determined by the type of conductor required, safety, route topography and environmental considerations.

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.

5.14.2.3 Ports and manufacturing facilities

The expected changes to port facilities and the increase in number of ports required for offshore marine energy manufacturing, construction and installation will have some environmental impacts. These could include acquiring land (loss of possible habitat and reclamation), noise impacts, changes in sediment regime through dredging, increased road and marine traffic, waste discharges and the construction of coastal defences to protect the ports and surrounding vulnerable areas (OSPAR 2010b).

5.14.3 Consideration of the evidence

5.14.3.1 Oil and gas, gas and carbon dioxide storage

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; it is envisaged that maximum use would be made by reusing/adapting existing infrastructure.

To some extent, natural gas and carbon dioxide storage projects will utilise existing infrastructure in terms of existing offshore platforms and onshore power stations; however, some new development will be required, with modifications to existing facilities necessary. For many projects involving the transport of gas or carbon dioxide from onshore facilities to subsea geological storage sites, new pipelines, with onshore sections, will be required. This is particularly true of carbon dioxide transport and storage, with a low proportion of existing pipelines suitably constructed to transport supercritical phase carbon dioxide. Additional onshore works may involve the construction of compressor booster stations for gas transport.

5.14.3.2 Grid system

At a European level, the UK signed up to the North Sea Countries' Offshore Grid Initiative (NSCOGI) in 2009, along with Belgium, France, Denmark, Germany, Ireland, Luxemburg, The Netherlands, Sweden and Norway, supported by their Transmission System Operators (TSO, organised in the European Network of Transmission System Operators for Electricity, ENTSO-E), their Regulators and the European Commission (NSCOGI 2010). The initiative aimed to provide a framework for regional cooperation to find common solutions to questions related to current and possible future grid infrastructure developments in the North Sea. A Memorandum of Understanding signed by the parties in 2010 recognised, amongst other things, the scale of the appropriate offshore infrastructure, as well as reinforcement of the onshore grid needed to facilitate the plans for installation of wind farms offshore, required a strategic, coordinated approach at national, regional and EU level.

Three intergovernmental Working Groups on the design of a future grid, market mechanisms to support regional cooperation and ways to improve the planning process were established, with the most relevant of these for this SEA being the grid configuration working group.

In 2012, this group published a report evaluating the long-term development of an offshore grid structure in the North Sea by providing a view on how such a grid may possibly develop in the future, based on the individual generation and load forecasts for 2030 from all 10 Governments involved. It compared and evaluated the possible advantages and disadvantages of the long term development of an optimised, integrated (or meshed) offshore grid in the North Sea, over the period 2020 to 2030 and evaluated different transmission design technologies (radial and meshed[125]) with respect to various aspects such as cost/benefit, import and export levels and systems' CO_2 emissions (NSCOGI 2012). The two designs represented extreme ends of a spectrum of approaches, with any integrated grid offshore likely to develop in a stepwise manner with coordinated near-shore wind connections and point-to-point interconnectors essential first steps (NSCOGI 2012)

The analysis carried out in the study, based on the forecasts of generation and demand in 2030, found that the meshed solution was slightly better in terms of variable electricity production costs, investment cost into grid assets and related variable operation and maintenance cost. The addition of new offshore wind park connections and new interconnectors would require reinforcement of the onshore grids to accommodate the increased power flows through the offshore network.

A progress report issued in August 2014 re-iterated that Ministers from the NSCOGI would like further work on the validation on the energy scenarios used for long term (offshore) grid planning, assessment of the costs and benefits of a more integrated approach to offshore grid development and possible market and regulatory arrangements for hybrid assets.

Future areas of work for the group include:

- Grid configuration – contribute to the further improvement of the long term (offshore) grid planning exercises by establishing a more structural dialogue between government authorities and TSOs on the appropriateness of scenarios, their assumptions and expected policy developments
- Regulatory and market issues – consider the impact of asset classification and national renewable energy support schemes on trading across and investment in hybrid offshore infrastructure; consider the possible use of long term transmission rights by offshore renewable generators, the need for priority dispatch by offshore renewable generators and the impact of zero or negative prices on hybrid offshore infrastructure
- Planning and authorisation – reduce the length and complexity of procedures by working on country pairings between which interconnector projects might take place (collating, analysing and evaluating information on how these projects might be developed, identifying planning and consenting barriers to transnational projects including practical solutions relating to barriers and identify best practice and share and review them with stakeholders); assist the respective competent authority in taking all necessary steps for efficient and effective cooperation and coordination for projects of common interest which require decisions to be taken into two or more Member States

[125] Radial approach is point to point connection of OWF and shore-to-shore interconnectors (with necessary onshore development) utilising existing and anticipated future transmission technology. Meshed approach is coordinated onshore, offshore and interconnected design utilising anticipated technology, interconnecting offshore platforms, offshore development zones and countries.

At a conference held in October 2015 to consider next steps for the Initiative, calls were made to move the project to the implementation phase; this implementation phase is to start with a series of measured steps rather than an immediate leap towards a European "super-grid" where large offshore installations and circuit breakers collect and re-distribute power from offshore wind farms to onshore grids.

In 2010, the National Grid Electricity Transmission plc (NGET) published the Offshore Development Information Statement (NGET 2010) which described the UK development plans at the time, for electricity transmission networks to support anticipated offshore renewable development until 2025. It provided a wide range of information relating to the possible development of the National Electricity Transmission System (NETS) in offshore waters, including applicable technology, potential offshore transmission design and onshore transmission co-ordination. In 2012, the Electricity Ten Year Statement (ETYS) was first published and this annual publication combined the former National Grid Electricity publications the Seven Year Statement (SYS) and the Offshore Development Information Statement (ODIS). The ETYS is part of an annual electricity transmission planning cycle and shows the likely future transmission requirements of bulk power transfer capability of the NETS. The ETYS describes technical aspects of the NETS, in combination with the Network Options Assessment (NOA) (a new licence obligation under NGET Licence) which describes options for reinforcement to meet system needs.

The NOA facilitates the development of an efficient, coordinated and economical system of electricity transmission and the development of efficient interconnection capacity[126]. In March 2016 the first NOA report and NOA for Interconnectors Report will be published; the NOA Report will describe the options that the Transmission Owners have provided to meet reinforcement requirements of boundaries on the NETS (see Appendix 1h). In advance of the NOA publication, its methodology was published in September 2015, which defines the process by which the NOA is applied to the onshore and offshore electricity transmission system in the UK. The process spans the identification of future reinforcement need, through the assessment of available solutions, to the selection and documentation of recommended option(s) for further development (National Grid 2015).

For the previous OESEA, National Grid analysed the impact of connecting 25GW of offshore wind generation in addition to the 8GW already built or planned to the onshore transmission system and identified where reinforcements to the transmission system would be required (National Grid 2008) – carried out against a set of electricity generation and demand scenarios agreed with DECC. To analyse the impact, National Grid (2008) assumed, based on water depths (areas <60m deep) and interest shown by developers, 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). 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. More information on likely development distribution became available, when The Crown Estate announced the exclusivity zone agreements for nine Round 3 offshore wind zones (in 2010): Moray Firth zone (1.3 GW); Firth of Forth zone, (3.5 GW); Dogger Bank zone, (9 GW); Hornsea zone (4 GW); East Anglia (Norfolk Bank zone), (7.2 GW); Southern Array (Hastings zone), (0.6 GW); West of Isle of Wight zone, (0.9 GW); Atlantic Array (Bristol Channel zone), (1.5 GW); Irish Sea zone (4.2 GW), along with the awarded extension projects at a number of existing wind farms, totalling some 1.5GW. While the total capacity of these

[126] National Grid website: http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/Network-Options-Assessment/

exceeded the 25GW considered by National Grid (2008), the distribution was very similar with the exception of greater forecast capacity in Regional Sea 1. These figures should be noted in the context of actual and potential deployment in these areas from existing proposals outlined in Section 2.

Regional Seas with the potential for several offshore wind developments would require significant reinforcement to both substations and the wider network including overhead power lines. The areas of potential major onshore reinforcements that were identified included north-west Wales, south East Anglia, Lincolnshire, Yorkshire and Derbyshire – areas still relevant to this current SEA. Scenarios presented in NGET (2010) suggested similar areas of major reinforcement, also including north-east and south-east Scotland and further areas in East Anglia.

5.14.3.3 Ports and manufacturing facilities

The achievement of offshore wind generation capacities considered in the draft/programme will require development to port facilities. A number of ports around the UK have the potential to assist project construction, but lack suitable facilities for services such as turbine assembly and manufacture of towers, blades, key nacelle components and foundations.

DECC commissioned an independent study (DECC 2009a) to consider: the requirements of the offshore industry for ports; current UK port capabilities; the opportunity for UK ports and potential port expansion or development to meet the needs for the offshore wind sector. In terms of meeting the obligations of Rounds 1-3 of offshore wind farm development by 2020 and the anticipated number of turbines required, the study outlined a series of requirements for both manufacturing and construction, the most significant issue identified being adequacy of port capacity for construction of projects, due mainly to a lack of additional land of the scale required.

Typical requirements for a construction port include: a heavy lift capacity; large lay-down and storage areas to enable assembly of components and rapid deployment of devices for larger scale developments; suitable space adjacent to quayside for final assembly; dry and potentially wet commissioning of electrical parts and supply of support vessels and personnel (The Crown Estate 2011). DECC (2009a) suggested that to meet the 2020 renewable energy target at least six locations distributed around the UK needed to be available for use from 2014 onwards; several major ports have/are progressing with development plans, which can/will accommodate the offshore renewable industry.

Additionally, Scottish Enterprise and Highlands and Islands Enterprise (2010) produced a National Renewable Infrastructure Plan Stage 2 which indicated that an investment of £223 million would create a set of 11 clustered port sites which could support the manufacturing of 750 complete offshore wind units a year.

In terms of infrastructure requirements for wave and tidal installations which are still evolving, The Crown Estate commissioned a report on the 'Build Out' of the Pentland Firth and Orkney Waters leasing programme, in partnership with Scottish Government, Highland and Islands Enterprise and Local Authorities (The Crown Estate 2011). The plan acknowledged that the delivery of the Pentland Firth and Orkney Waters commercial scale leasing programme from 2016 will require development of port infrastructure proposals alongside development of the technology and deployment techniques (Scottish Enterprise and Highlands and Islands Enterprise 2010).

5.14.4 Controls and mitigation

The UK has a long history of experience in subsea cable and pipeline installation, for which an extensive set of regulatory and planning controls exist, including for environmental aspects such as through EIA.

There is also a growing body of experience and knowledge associated with offshore wind farms, their planning and execution and the assessment of their potential impacts, and these too have a regulatory and consenting process with several stages, including pre-planning (this includes survey work, impact assessment and stakeholder engagement), through to consenting with associated conditions, including monitoring requirements through the construction and post-construction phases.

Most offshore renewables developments are of a size covered by the *Planning Act 2008* and therefore fall within the Nationally Significant Infrastructure planning process. For renewables developments this covers all aspects of the development, including both onshore and offshore elements (see Appendix 3). Onshore "gas transporter" pipelines above a threshold (more than 800 millimetres in diameter and more than 40 kilometres in length) are similarly covered by this process, and while the offshore aspects of gas storage (including CCS) are outside of the *Planning Act* remit, offshore elements may be considered as part of the process to understand the potential combined effects projects as a whole.

5.14.5 Likelihood of significant effects

In general, major additional shore-based infrastructure development for the oil and gas industry is not expected, and is difficult to anticipate as large new discoveries are by their nature exploratory. The likelihood of significant effects from this are not discussed further here, with impacts of any development that does progress identified and assessed at the EIA level.

During construction and operation, each component of the transmission system will have an impact to varying degrees on several different aspects of the environment. 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

Given that licensing of wave and tidal stream development resulting from the plan will likely be at a demonstrator scale and large commercial arrays are not expected, ancillary grid reinforcements resulting from wet renewables development is expected to be on a much smaller scale than those associated with offshore wind. However, wave and tidal developments may be located off relatively remote sections of coastline where, at landfall, additional transmission infrastructure may be required to provide connections into the grid. Tidal range devices have the potential to have significant generation capacity and therefore additional substation capacity may be required to accommodate any such developments, the locations for which are necessarily limited by the available resource.

The expected changes to port facilities will also have some environmental impacts, again through the construction and operational phases. 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.

Despite the range of potential effects described above, the impacts of such activities in the terrestrial environment are generally well understood and their assessment and management are supported by a strong evidence base. Consequently, existing planning procedures and regulatory controls, including project-specific EIA, are considered appropriate for managing any potentially significant effects.

5.14.5.1 Cumulative impact considerations

Gird reinforcement will impact incrementally to existing electricity transmission networks, with noise, habitat loss/modification, landscape impacts and interactions with other users among the key issues. Almost all other forms of terrestrial land use and development have the potential to act cumulatively with grid reinforcements in respect of these key issues.

The majority of port development associated with the draft plan/programme will be extensions of the capabilities of existing facilities and impacts from these activities can therefore be described as incremental to existing/past impacts. There may also be cumulative impacts in terms of association with other coastal activities such as shipping traffic and adjacent construction (e.g. coastal defences). Other users of the marine environment are likely to be major considerations in the assessment of cumulative effects, as is the presence of adjacent conservation designations and existing pressures on such features (e.g. coastal squeeze).

Though beyond the direct scope of OESEA3, ancillary development associated with joint renewable energy projects with other countries involving direct interconnection with the UK may occur in the future.

5.14.6 Summary of findings and recommendations

Major additional shore-based infrastructure is not anticipated as a result of future offshore oil and gas licensing; it is envisaged that maximum use would be made by reusing/adapting existing infrastructure.

Some new onshore development will be required for natural gas and carbon dioxide storage projects, namely modifications to existing facilities, new pipelines, and potentially the construction of compressor booster stations for gas transport. From a strategic perspective, this will be of relatively small scale and likely limited to a very small number of projects, all of which will be subject to planning procedures and regulatory controls, including project specific EIA and Habitats Regulation Assessment (where appropriate).

Ancillary onshore development will be necessary to facilitate, primarily, the achievement of the offshore wind element of the draft plan/programme, with reinforcements to the national electricity transmission system continuing and enhancements to the capacity of the UK's port facilities required. Some ancillary offshore grid reinforcements will also be required. The influence of the likely wave and tidal development on port and manufacturing facilities development will be comparable in nature, but considerably smaller in scale than that associated with offshore wind. These will have some environmental impacts, with habitat loss/modification, noise, landscape impacts and interactions with other users among the key issues to be considered.

Both the onshore grid reinforcements described, for example, in NGET (2010) and enhancement of port facilities recommended in DECC (2009a) remain uncertain in terms of scale and location; in this respect, there are no specific plans, programmes or projects which are sufficiently developed to be fully assessed. These potential developments and their associated environmental effects are secondary effects to the draft plan/programme currently under assessment, and relevant projects will be subject to EIA. The existing planning and regulatory framework, will contribute towards appropriate management of any potentially significant effects.

While it is acknowledged there may be cumulative impacts from the development of any associated ancillary infrastructure (e.g. noise, habitat loss or modification and interactions with other users) from existing activities, the extent and magnitude of these will depend on various factors, including landfall location. These are expected to be fully assessed as part of that consenting process and mitigated at the project stage. In terms of transboundary effects, any ancillary infrastructure associated with future developments in the UKCS, will likely be onshore, or in UK waters, some distance from Median Lines and other national waters. As such, transboundary effects from UK projects are not likely.

5.15 Overall spatial considerations

Assessment Topic	Potentially Significant Effect	Oil & Gas	Gas Storage	Carbon Dioxide Storage	Offshore Wind	Tidal Stream	Tidal Range	Wave	Assessment Section
	Other interactions with shipping, military, potential other marine renewables and other human uses of the offshore environment	X	X	X	X	X	X	X	**5.7, 5.15**

5.15.1 Introduction

The *Marine and Coastal Access Act 2009* is intended to simplify and strengthen strategic management of the marine environment by enabling economic, social and environmental impacts and objectives to be considered simultaneously. A key objective of the Act is to implement a nationwide system of marine planning 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. The Marine Policy Statement (MPS) was jointly adopted in March 2011 by the UK Government, Scottish Government, Welsh Government and the Northern Ireland Executive and applies to all UK waters. The MPS provides an overarching framework within which regional marine plans are presently being drafted.

The Act established the Marine Management Organisation (MMO) with responsibility for marine plan development covering English territorial and offshore waters on behalf of the UK Government. There are 11 marine plan areas within English inshore and English offshore regions and marine plans have been prepared for two of these, the East Inshore and Offshore plans (also see Section 2.3). The South Inshore and Offshore plans are in preparation and are due to be subject to consultation in spring 2016. In Scotland, Wales and Northern Ireland, marine plan development is through the devolved administrations. The Scottish National Marine Plan was adopted in March 2015 and subsequent regional planning has been proposed for a further 11 inshore areas. Other devolved plans are still in development.

Marine planning has a key role in informing strategic and project level spatial considerations, as indicated in the MPS, "*Marine Plans should reflect and address, so far as possible, the range of activities occurring in, and placing demands on, the plan area. The Marine Plan should identify areas of constraint and locations where a range of activities may be accommodated. This will reduce real and potential conflict, maximise compatibility between marine activities and encourage co-existence of multiple uses*.[127]" The first marine plans for English waters contain a number of policies which relate to the potential for spatial conflict and/or the potential for activity co-location, including for areas of defined resource for particular activities but with no existing development so as not to risk precluding future use. Whilst the marine plans acknowledge the potential interactions between activities and map these, they are not spatially prescriptive and therefore provide a limited indication of the location of possible future development. The MMO (2013d, 2014i) commissioned a report to assess whether a feasible approach to the consideration of co-location for all marine activities could be developed which would include

[127] MPS paragraph 2.3.1.5.

physical, environmental, social and economic variables. The authors recommended a three stage approach to the consideration of co-location: an initial screening (largely relating to the identification of activities and hard constraints), an initial assessment (a qualitative/semi quantitative assessment applicable to marine licensing and conservation management, or marine planning as part of a high level qualitative assessment) and a detailed assessment (a monetised assessment undertaken using more complex assessment tools and potentially novel data collection where appropriate). The MMO have indicated that the development of tools to consider this topic are underway and will be informed by the findings of the report. Though not indicating a relative level of constraint, the MMO (2013c) have mapped a gridded[128] dataset showing the number of sectors present at sea for all English marine plan areas and the potential increase in sector numbers over the next 20 years[129]. For Scottish waters, regional locational guidance has highlighted renewable energy activity specific constraints (see Scottish Government 2012a, b, c, 2014), and the most recent (2015) Shetland Islands' Marine Spatial Plan includes modelled mapping of indicative constraints for marine renewables development at the coast and offshore (see Tweddle *et al.* 2013).

In advance of the full implementation of formal marine planning described above and 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 the 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. A similar exercise was also undertaken in late 2009, prior to OESEA2, to help understand the potential spatial constraints to wave and tidal energy development within the then Renewable Energy Zone (REZ) of England and Wales (now part of the EEZ) and to provide a high level indication of the potential energy generation capacity available from wave and tidal devices (AEA & Hartley Anderson 2010). An updated analysis for both offshore wind and wave and tidal energy was carried out for OESEA2 (DECC 2011e). Building on these, a similar exercise has been undertaken for OESEA3 and is presented in Sections 5.15.3 and 5.15.5 below.

The potential resource areas for future oil and gas exploration and production are likely to coincide with areas of existing producing fields (see Appendices 1b and 1h), as these remain the most prospective areas on the UKCS. There is renewed interest in underexplored areas which are also likely to be promoted by the Oil and Gas Authority as part of a 29th seaward round, which could initially see vessel and rig movements in these areas, with subsequent installation of fixed infrastructure should commercially viable finds be made.

The potential footprint of any new development is likely to be very small and isolated, and the interactions with other users from such developments are generally well understood, for example through the other regulatory issues compilations published by DECC in relation to blocks offered in former seaward rounds.

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[128] 0.05 decimal degree resolution.

[129] This layer is based on potential technical opportunity areas for wind, wave and tidal energy, CCS, mineral extraction, and pipelines and cables and is limited by data availability and a range of other potential constraints.

5.15.2 Sources of potentially significant effect

The potentially significant effects of interactions with other users are discussed in Section 5.7. The following section provides a strategic level consideration of potential interactions and constraints, primarily to the deployment of renewable energy, presented by other legitimate users/uses of the sea, followed by a spatial consideration of these.

The following key spatial issues have been identified in the context of offshore energy developments (for additional background information, see Appendix 1h):

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. The strategic importance of shipping is recognised in the MPS and is considered at a regional level through the marine planning processes. Other key issues include the minimisation of any increase to the risk of collision and on vessel passage time through route deviation, and the maintenance of safe under-keel clearance, anchorage areas and the consideration of interaction with harbour administrative and pilotage areas.

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 (originally >15m and since 2012, >12m, as required under Council Regulation (EC) 1224/2009); however, the distribution of smaller vessels (which dominate the UK fleet by numbers) is less well understood (see Appendix 1h and Section 5.7). Detailed information on smaller vessels is held by Inshore Fisheries and Conservation Authorities (IFCAs) and equivalent bodies, although this is restricted to nearshore waters (typically to 6nm offshore), and is not available in a consistent spatial format. 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. It is recognised that as the UK's system of formal marine spatial planning evolves, there is a need to better understand fishing practices, particularly in inshore areas where information continues to be lacking. The MMO is working with the IFCAs to develop a low cost inshore VMS system (I-VMS) to assist in the management of marine protected areas (e.g. MCZs, SPAs, SACs[130]) and inshore fisheries, and a trial was undertaken in Lyme Bay and Torbay SCI between January 2011 and July 2012. A specification of mandatory requirements has been developed for I-VMS and an approval programme for device suppliers has been set up. There is presently no statutory requirement for vessels to carry I-VMS systems but IFCAs and equivalent bodies could implement bylaws to bring this into effect. Present specifications of I-VMS devices indicate that they would only send position report when inside a management area (e.g. MPA), and so the system may not provide wider information on the movements and effort of such vessels which could be of use to wider assessments of sea use.

Conservation sites: The selection and designation of nearshore and offshore Natura 2000 sites (and extension of coastal SPAs and SACs) is ongoing, and the spatial location and extent of a number of sites are not yet finalised. The designation of an area as a Natura 2000 site does not necessarily preclude activities within or close to the site boundaries. However, the potential likely significant effects of an activity on a site must be considered. In England and

[130] Also see: https://www.gov.uk/government/collections/fisheries-in-european-marine-sites-implementation-group

Wales, a series of National Policy Statements (NPSs) set out national policy on significant infrastructure projects (offshore generating stations >100MW but presently not for wave or tidal stream devices). NPS EN-1 (Overarching National Policy Statement for Energy) and EN-3 (Renewable Energy Infrastructure) provide the primary basis for decisions by the Planning Inspectorate (PINS) on applications for renewable energy infrastructure. Section 4.3 of NPS EN-1 states that prior to granting a development consent order, PINS must, under the Habitats Directive and the Birds Directive, consider whether a project (alone or in combination with other projects) may have a significant effect on a Natura 2000 site or any other site to which the same protection is applied (e.g. Ramsar). An applicant must provide the inspectorate with the information required to determine whether an Appropriate Assessment (AA) is required under the Habitats Regulations Assessment/Appraisal (HRA) process (see PINS advice note 10). There is the recent precedent for developers to undertake “shadow HRA”, whereby the consideration of likely significant effects and related assessment, in consultation with relevant SNCBs, is undertaken by the applicant during the examination process (e.g. Tidal lagoon Swansea Bay, Hornsea Project Two). The European Commission has issued specific guidance on how best to ensure that wind energy developments are compatibility with the provisions of the Habitats and Birds Directives and Natura 2000 sites (EU 2010).

Work is ongoing to establish protected areas under the *Marine and Coastal Access Act 2009* and *Marine Act (Northern Ireland) 2013* (Marine Conservation Zones) and *Marine (Scotland) Act* 2010 (Marine Protected Areas), with these and Natura 2000 contributing to sites established for the purposes of the EU Marine Strategy Framework Directive and OSPAR (Recommendation 2003/3). The location and size of recently designated and potential future sites are shown in Appendix 1j. A number of other sites are known to be in preparation, primarily in relation to the conservation of harbour porpoise, and there will be subsequent tranches of MCZ designations. It is acknowledged that there is the potential for new sites to be designated during the currency of this SEA and that any plan related activities would need to take account of these. The East Marine Plans indicate that strategic level assessments including SEA should take account of any impacts on the overall MPA network (policy MPA1), but acknowledges that defining the characteristics of a network at the UK level is at an early stage (i.e. connectivity between different MPAs which enables mutual support within a network which contribute to ecological coherence). There is now a requirement to undertaken MCZ assessment as part of the marine licensing process, the stages and manner of assessment include screening and subsequent detailed assessment[131].

Other sources of potential spatial conflict include:

- Other present and potential future uses of the seabed including: aggregate extraction, communication cables, electricity interconnectors, 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 due to decommissioning.
- Visual intrusion: there are various socio-economic drivers, including the importance of coastal tourism, to minimise significant visual impact of offshore developments.
- The spatial extent of MoD practice and exercise areas; and constraints associated with civilian aviation and helicopter-based Search and Rescue (SAR).

[131] See https://www.gov.uk/government/publications/marine-conservation-zones-mczs-and-marine-licensing

The footprint of offshore wind farms is extensive, and the total area occupied by a development may be very large (e.g. between ~170 and 305km^2 for individual farms in Round 3 developments); but not intensive, in that individual turbines are usually separated by large distances (>1,000m 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 historical data from Rounds 1, 2 and 3 on turbine spacing (and therefore generating capacity and density) to inform the analysis in this section. Information about the likely spatial extent of wave and tidal devices is not widely available due to the relative infancy of the technology which is still largely restricted to demonstration sites rather than full commercial deployment. The deployment and configuration of wave and tidal devices will be governed by the physical environment in which they are placed; further, wave devices will, on the whole, impact the sea surface (although tethering to the seabed is required), whereas tidal current devices will mostly affect the seabed and water column (dependent upon water depth, see NOREL 2014). Tidal range devices are likely to be shore connected in the form of lagoons or barrages, and will impact both the water column and surface. They have the potential to affect large areas (e.g. entire estuaries behind barrages, with additional far field effects) and to potentially exclude some activities.

Note that safety zones may be imposed in some circumstances around renewables devices, though typically for installation, maintenance and decommissioning, with operational safety zones of 50m provided for in regulations, but which are not generally applied for (DECC 2011a). The use of safety zones for wave and tidal developments may differ from wind farms as they may be less visible and be partly mobile at or under the water surface which may affect their navigability. In the case of tidal range devices, safety zones may be used around sluice and turbine housings, for example as proposed for the Swansea Bay tidal lagoon.

Activities considered in this draft plan/programme are subject to a number of leasing/licensing and other consenting regimes. Coordination is necessary between the various consenting bodies (e.g. DECC, MMO, The Crown Estate), particularly for activities which may be granted development consent by DECC and require both a Crown Estate lease and marine licence from the responsible authority (e.g. MMO), and also where developments have an onshore component. This is particularly important with regard to gas storage and carbon dioxide storage offshore, and the possibility that such activities could spatially overlap both with one another and with existing oil and gas extraction activities. These also have the potential to have associated onshore components which might be considered nationally significant and therefore be subject to a separate consenting regime under the *Planning Act 2008* than the offshore parts which would variously be covered by the *Petroleum and Pipelines Regulations.* As the location of prospective basins for gas/CO_2 storage are largely coincident with those basins which have been, or are subject to ongoing oil and gas exploration and production, it may be expected that (also considering other activities such as aggregate extraction, and the location of Round 3 leasing zones – see Appendix 1h), the greatest degree of coordination will be required in the southern North Sea and east Irish Sea.

In considering the need for coordination with regard to marine spatial planning, the responsibilities of the devolved administrations also need to be accounted for. The territorial and offshore waters of Scotland, territorial waters of Wales and Northern Ireland are variously the remit of Scottish, Welsh and Northern Irish Ministers respectively. NRW and MMO are the responsible authorities for issuing marine licences for a range of activities in Welsh and English waters respectively (note that Section 36 consent for marine renewable arrays of <100MW remains with the MMO for Welsh waters), including being the Marine Plan authorities for these areas, therefore a high level of spatial coordination may be expected. With regards to the NSIP process (renewable arrays of >100MW), the MMO, NRW (for those provisions under Part 4 of the *Marine and Coastal Access Act*) and DECC are variously the licensing/consenting authorities. It should be noted that PINS may be the examining authority with regards to NSIPs, NRW and the MMO have a number of roles in the consideration of projects relevant to them, including as a statutory consultee, interested party and also for marine licensing. On granting a Development Consent Order, the MMO/NRW is then responsible for enforcement[132], post-consent monitoring, and varying, suspending or revoking any marine licence[133]. In addition to the regulatory regime which provides the framework for consenting, planning policy is variously covered by the MPS, NPSs for energy, marine plans, and a range of terrestrial policy including the NPPF and Planning Policy Wales.

A higher degree of coordination and cooperation may also be required for ancillary developments which traverse the territorial or offshore waters of a devolved Government, or in English territorial waters where a Crown Estate lease or other consents may also be required. Similarly, oil and gas exploration and development is not a devolved matter, and so the licensing of blocks in the waters of devolved administrations, and any subsequent activities, will need to take account of existing and possible future marine operations subject to devolved consenting regimes. Examples of such an interaction are blocks previously licensed for oil and gas in the Moray Firth which now coincide with/are adjacent to a Scottish territorial wind exclusivity area and an offshore Round 3 Crown Estate leasing zone. Potential future interactions may also arise in Northern Irish waters, for instance oil and gas licences issued around Rathlin Island which has a significant tidal range resource (AECOM & Metoc 2009).

5.15.3 Consideration of the evidence

5.15.3.1 Spatial constraints mapping

Screening of potential spatial constraints has previously been undertaken in relation to offshore renewables (wind, wave and tidal stream) by The Carbon Trust (2008, 2012), AEA & Hartley Anderson (2010), DECC (2009, 2011e), WAG (2011) and more recently Jongbloed *et al.* (2014) and Cavazzi & Dutton (2016). These reports have been reviewed, bearing in mind their principal focus (e.g. economic), and the analysis undertaken for OESEA and OESEA2 (DECC 2009, 2011e) has been modified and updated for this SEA. The analysis was undertaken in a staged manner as outlined below:

Stage 1: geographical scope

The geographical scope for the four technologies being considered in OESEA3 is outlined below (also see Section 2 for more details). The scope builds on input derived from previous SEAs, technical reports by industry bodies and The Crown Estate (2012, 2013), work presented by the MMO as part of their strategic scoping exercise (MMO 2013c) and dialogue with the SEA steering group and others. The geographic areas largely reflect the prime resource (wind, wave tidal) criteria for each technology:

- **Wind (fixed foundations)**: water depths of 0-60m. See Figure 2.9.
- **Wind (tethered foundations)**: water depths 50-200m. See Figure 2.9.
- **Wave**: water depths of 10-200m. Annual mean wave power >20kW/m. See Figure 2.14.

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[132] Note that enforcement functions under Part 4 of the *Marine and Coastal Access Act* were not delegated to NRW and remain with Welsh Ministers, see: http://infrastructure.planninginspectorate.gov.uk/wp-content/uploads/2013/04/Advice-note-11-Annex-A-CCW.pdf

[133] https://www.gov.uk/government/collections/marine-licensing-nationally-significant-infrastructure-projects

- **Tidal stream**: water depths ≥5m. Current speed >1.5m/s. See Figure 2.16.
- **Tidal range**: water depths of up to 25m. Mean tidal range of >5m (considers where both spring and neap tides >5m). See Figure 2.12.

The primary focus of this assessment is the potential for constraint to the deployment of technologies covered by the plan from other user and certain environmental interests. Economic constraints on the geographical scope of certain technologies are also pertinent in defining potential areas where renewables could be deployed. A consideration of the economics of deployment of any of the technologies considered is beyond the scope of this section, however, distance from the coast, proximity to viable ports, suppliers and grid connections are all relevant (e.g. due to cable lengths, viability of using HVAC systems instead of more expensive HVDC systems over 70-100km from shore, increased sailing times for installation and maintenance etc. – see Green & Vasilakos 2011, LCICG 2012a, b, Myhr *et al.* 2014, Astariz & Iglesias 2015, Vazquez & Iglesias 2015, The Carbon Trust 2015, Cavazzi & Dutton 2016).

Stage 2: defining potential constraints

Spatial data (sourced from a number of organisations and agencies in the UK) representing various environmental and socio-economic characteristics, sensitivities and constraints for offshore renewable energy development and operation were input to ESRI's ArcGIS. 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. Many of the data layers used below have been mapped in Appendices 1h, 1i and 1j.

This analysis also distinguishes between "hard" constraints (which are likely to definitively and consistently exclude development) and "other" constraints (which would presume against, but not definitively exclude development, e.g. subject to further assessment, developer dialogue and mitigation). Those constraints identified in Table 5.35 below are considered to be the primary constraints at a strategic level, although it is recognised that other studies have included a range of other users and uses of the sea area or suggest varying levels of constraint for the same activity (see for example Begg and Wadsworth 2009, PMSS 2010, Royal Haskoning 2010c, The Offshore Valuation Group 2010, Welsh Assembly Government 2011, Veum *et al.* 2011, Schillings *et al.* 2012, Tweddle *et al.* 2013, Jongbloed *et al.* 2014), and that despite the continued improvement in the quantity, quality and availability of marine spatial data, there are still limitations in coverage, resolution and confidence. As indicated above, marine planning provides indications to developers with regard to their potential interactions with other users, and on the basis of the content of the first marine plans, what they will need to demonstrate as part of their application (e.g. how they would not adversely impact, or else minimise or mitigate any effect on other users as defined in the plans). For more localised studies, additional constraints will need to be taken into account for a particular area, for example, the Zone Appraisal and Planning (ZAP) process for offshore wind adopted as part of the Round 3 process has assisted developers in choosing locations within wider Round 3 zones to make project proposals.

The following analysis provides a consideration of the theoretical area available to certain activities relevant to the plan. The output from this work is time limited, as the areas used in the underlying constraints analysis have the potential to change over time. During the currency of this SEA, it is anticipated that such changes will include, but not necessarily be limited to:

- Round 3 zones: areas of zones which are not going to be taken forward as part of project proposals are being returned to The Crown Estate (e.g. the Dogger Bank zone).

Alternatively, new areas may be identified and subject to suitable zone appraisal such that they may be offered for lease. Existing lease areas could also be extended.

- Oil and gas infrastructure: the major hydrocarbon basins of the UKCS are generally mature, and infrastructure decommissioning is likely to result in the removal of some physical constraints (e.g. consultation zones and helicopter routes). Conversely, the exploration of previously underexplored areas may result in additional activity or infrastructure in these areas.
- Connected with the above, there is the potential for some changes to ship routes from the imposition of a higher number of wind farms (e.g. as predicted in Round 3 Navigation Risk Assessments – see Section 5.7) and removal of other infrastructure.
- Conservation sites: there is the potential for additional sites to be designated during the currency of this SEA (Natura 2000 and MCZ).

Other changes may include the location, but not necessarily the intensity, of marine aggregate extraction (for example see the wider areas of technical opportunity for aggregates in MMO 2013c) and fisheries interests. Whilst such changes are anticipated and can be qualitatively considered, it is not regarded that enough information is available to be spatially and temporally explicit about them. Understanding the potential future change in use of UK seas is a key component of marine spatial planning, and the MMO has undertaken and commissioned work to try and understand the future aspirations of other sea users for certain areas in plans prepared to date (e.g. MMO 2013e). Unlike terrestrial planning, most of the outputs relating to potential future development of marine plan areas have to date, been aspirational, and reflect the resources and potential of the areas rather than being spatially explicit about preferred areas for particular activities.

Table 5.35: "Hard" and "Other" constraints used in spatial constraint mapping

Constraints	Figure no. or appendix*	Wind	Wave	Tidal stream	Tidal range
"Hard" constraints					
Areas subject to lease by The Crown Estate for offshore wind, wave or tidal energy. *Does not include agreements relating to cables as these tend to be large areas or corridors within which any number of cables may be laid, and which may alter in scale or location depending on final route selections. Also see the area defined in East Marine Plan Policy TIDE1, which should be noted for Regional Sea 2.*	A1h.21-24	✓	✓	✓	✓
Aggregates licence and application areas	A1h.29	✓	✓	✓	✓
Aggregate exploration and option areas. *The area defined in East Marine Plan policy AGG3 should also be noted for Regional Sea 2.*	-	✓	✓	✓	✓
Active offshore marine cables and pipelines: 500m buffer	A1h.15-16, 28	✓	✓	✓	✓
Oil and gas infrastructure: 500m buffer representing safety zones (surface and subsurface)	A1h.15-16	✓	✓	✓	✓

Constraints	Figure no. or appendix*	Wind	Wave	Tidal stream	Tidal range
Oil and gas infrastructure: 6nm buffer *The 6nm buffer represents the distance at which helicopter final approach typically occurs; but note that obstacles within 9nm of an offshore destination would potentially impact some helicopter operations (low visibility or missed approach) and consultation must therefore take place within this distance from a platform.*	-	✓			
IMO vessel routeing measures	A1h.2-3	✓	✓	✓	✓
MoD PEXAs: selected danger areas *Airforce danger areas have vertically defined upper and lower limits and in most cases involve supersonic flight and combat training. Those areas identified to take place to surface level and involve live firing/bombing were considered hard constraints for the purposes of this analysis.* *Also note East Marine Plan policy DEF1.*	A1h.12	✓	✓	✓	✓
Navigation: Primary Navigation Routes 1 (PNR1) with 1nm buffer (derived from MCA 'siting not recommended' areas (draft and unpublished "OREI 1" primary navigation routes) and checked against 2012 MMO AIS annual average data. *Note that routes defined in East Marine Plan policy PS2 are encompassed by this data layer, and policy wording should be noted for Regional Sea 2. These have been included for tidal stream devices for the purposes of this assessment, however it is recognised that some submerged devices in deeper waters which do not reduce under-keel clearance may not affect shipping during operation (see Section 5.7)*	-	✓	✓	✓	✓
Protected wrecks: including military remains, scheduled monuments and those designated under the *Protection of Wrecks Act 1973*.	A1i.3, 5, 6, 8, 10, 11, 12	✓	✓	✓	✓
"Other" constraints					
Natura 2000 sites: designated, candidate, possible, draft, where boundaries known. *European sites are not considered to be hard constraints, consistent with National Policy, although they are subject to strict assessment criteria and must be given due weight in site specific environmental assessments and consent applications. Colocation may not be possible.*	A1j	✓	✓	✓	✓
Marine Conservation Zones	A1j	✓	✓	✓	✓
MoD PEXAs: other areas	A1h.12	✓	✓	✓	✓
NATS radar areas. *Assumes a 200m blade tip which is the largest structure for which safeguarding maps are available and is regarded to be the maximum likely to be deployed during the currency of OESEA3 (e.g. for context, the largest wind turbine to be ordered for installation in the UK to date is the Vestas V164-8.0 MW unit with a blade tip height of 187m).*	A1h.10, 5.7	✓			
Navigation: MCA 'siting potential with comprehensive assessment' areas (draft and unpublished OREI 2 areas)	-	✓	✓	✓	✓
Helicopter Main Routes (HMRs). *Helicopter main routes have been established from heliports to certain offshore installations. These have no statutory basis but CAA guidelines (CAP764) indicate that there should be no obstructions 2nm either side of the routes. Routes are located in the southern, central and northern North Sea, and Morecambe Bay. These are considered "other" constraints as consultation to date has allowed for development within their boundaries.*	A1h.10, 5.7	✓			
Offshore mine lease areas	A1h.29	✓	✓	✓	✓
Gas storage lease areas	A1h.20	✓	✓	✓	✓

Constraints	Figure no. or appendix*	Wind	Wave	Tidal stream	Tidal range
CCS lease areas. *Areas defined by East Marine Plan policy CCS1 should also be noted for Regional Sea 2.*	A1h.20	✓	✓	✓	✓
Agreements for lease *Includes wind farm cable corridors for proposed and consented wind farms. These cover large areas and may not reflect final cable routes or seabed extent.*	A1h.21	✓	✓	✓	✓
Indicative recreational sailing routes, and sailing and racing areas. *Areas defined by East Marine Plan policy TR2 should also be noted for Regional Sea 2.*	A1h.5-8				

Notes: refer to figure or Appendix to see the location of each feature considered in this exercise

Stage 3: application of constraints to the defined resource areas

The spatial extent of the "hard" constraints layer was subtracted from the resource areas identified in Stage 1, providing an area of seabed remaining in which development could theoretically take place, subject to development specific assessment (see Figures 5.62-5.68). Some of these areas may not be viable for development, for instance due to further constraints on cable corridor, landfall and grid connections, or on wider technical, economic or environmental grounds. The analysis has included the area which covers former Round 3 zones such as the Bristol Channel and Irish Sea. Whilst they have not proved technically or economically viable in the past, future development in these areas cannot be entirely ruled out as cost-reduction and technical ability change over time. Conversely, the recent refusal of Navitus Bay in the area to the west of the Isle of Wight has provided a basis for not including this former zone and treating it as a hard constraint. The reasons for this refusal (primarily relating to multiple landscape/seascape issues and its effect on the Dorset and East Devon Coast World Heritage Site) could also reasonably be used to suggest that a wider area landward of this former zone is unlikely to result in approvals for offshore wind. However, the mapped outputs are to provide illustrative guides to areas of most/lease constraint, and whilst the SEA can provide recommendations in terms of areas to avoid (see below), the leasing and planning decisions of relevant authorities are part of a wider planning process which can make more detailed assessments of the suitability of particular areas for development.

The range of "other" constraints has also been mapped to indicate that despite no significant "hard" constraints being present in some areas, there remain a number of other legitimate uses and users of the sea which may present further constraints, particularly when considered cumulatively. The analysis is necessarily strategic, and constraints may be also be experienced other than through direct interaction with certain areas, for instance potential for far field interactions with conservation sites, visual intrusion or where the timing and intensity of use is variable, or our understanding of the use of particular areas is indicative (e.g. recreational sailing and fisheries). Additionally, seabed morphology, process and underlying geology (e.g. see Mellett *et al.* 2015) may present some constraint on infrastructure installation, metocean conditions may similarly introduce additional constraints to deployment, for example areas of high wave energy which can increase cost of deployment (see ETI 2015), and distance from grid connections. These potential issues are noted here, but are not easily considered using the techniques applied in this analysis, and are therefore considered qualitatively later, and also separately in other sections of this Environmental Report.

In the analysis summarised below, an assessment was made of indicative generation capacities for the different resources after hard constraints have been applied. In each case this is considered to be a theoretical value of capacity, as a limited number of assumptions have been made about the practical potential for deployment in specific areas.

The capacity of any individual development is a function of the number and size of the devices installed, with output related to the load factor for a particular technology[134]. Data relating to 47 wind farm sites[135] were analysed to try and understand typical power densities (i.e. MW/km^2) and whether there was any relationship between this factor and wind turbine size. As indicated in Figure 2.10, turbine size has gradually increased from approximately 2MW in 1998 to proposals for turbines of up to 8MW to be installed at the Burbo Bank extension, with devices of up to approximately 9MW expected in the lifetime of this SEA (RenewableUK *pers. comm.*). The analysis did not find a significant relationship between turbine size and power density, which may be expected as fewer, larger turbines may be used to generate the same project capacity as a greater number of smaller devices but requiring a similar area due to enhanced turbine spacing requirements. The review of power densities did indicate a significant range of values between individual wind farms ($1.6MW/km^2$-$17MW/km^2$, with an average of ~$6MW/km^2$ and mode of $9MW/km^2$). The average is consistent with other reported figures for offshore wind (see Wiser 2011 for a summary), however for available data, the calculated average power density has apparently reduced between each leasing round (Round 1: $9.6MW/km^2$, Round 2: $6.2MW/km^2$, Round 3: $3.3MW/km^2$). Assuming that future fixed foundation wind farms will be similar to those now being deployed as part of Round 3 developments, the average for this latest round has been used as the basis for calculating the theoretical potential for installed capacity for areas remaining following the application of hard constraints. It is understood that arrays using tethered foundations may deliver significantly different values, however, no commercial scale deployment has been proposed which could be used to confidently make assumptions about an energy density.

The assumptions surrounding the potential for energy to be generated from the wave resource on the UKCS has been variously estimated, with the most recent studies of The Carbon Trust (2012) and The Crown Estate (2013) using comparable methodologies to derive estimates of the indicative capacities. Of primary interest to this study (for both wave and tidal resources) is the potential practical resource, that is, the resource available once spatial exclusions analogous to those outlined in Table 5.35 have been applied. The above reports use a number of technical inputs including wave power, conversion efficiency of mechanical to electrical energy (70-80%), and the capture width of converters (i.e. the absorbed power relative to the wave power resource), and includes farm-scale effects such as shadowing. The previous analysis of this SEA has use a more simplistic approach to calculating the potential capacity for wave and tidal energy using a range of array sizes and the expected capacities for these (i.e. an energy density based on MW/km^2 for the available resource area). Few proposals have been made on which to definitively generate such assumptions as the technologies are not well developed and commercial arrays have not been deployed. Previous SEAs have used consultation with industry and other sources to provide power density estimates for arrays which had a range of 3-$30MW/km^2$ for wave and 6-$60MW/km^2$ for tidal stream devices. Other summaries provide similar values to the upper value in the ranges used in OESEA2 (e.g. values

[134] Average load factor in 2014 was 37.7% for offshore wind (DECC 2015b). TCE (2015) note more recently completed sites have started to exceed 40%, indicating performance improvements in the technology, also see The Carbon Trust (2015) and Voormolen *et al.* (2016).

[135] Information was gathered from the DECC monthly renewable energy planning database, developer websites and documents for individual developments on the National Infrastructure planning portal.

of 10-30MW/km^2 and 50-70MW/km^2 for wave and tidal stream respectively are derived from AECOM & Metoc 2009 and AECOM *et al.* 2010).

The potential scale of energy supply which could be provided by tidal range to contribute to the renewable aspects of the UK energy mix requires highly site specific considerations. No attempt is made here to calculate a theoretical capacity for tidal range in relevant UK waters, however work undertaken for The Crown Estate is referred to below which provides an indication of the location and potential maximum contribution that could be made from this source.

The area remaining following the application of hard constraints has been used to provide a theoretical maximum capacity for English and Welsh waters, however no minimum separation distance or economic constraint was considered in relation to individual potential projects – the main focus of this section is to highlight areas of potential spatial constraint and provide a high level indication of the areas with the greatest potential resource.

The following technology scenarios were used:

- **Offshore wind**: 3.3MW/km^2
- **Wave**: 10-30MW/km^2
- **Tidal stream**: 50-70MW/km^2

Using the generation capacity scenarios noted above, estimates for total theoretical output for wind, wave and tidal devices have been calculated, based upon the total area of sea (seabed and/or surface) available after hard constraints have been applied. These estimates are shown in Table 5.36 and do not make any allowance for reductions in available area as a result of "other" constraints, which may be appreciable. Representative GIS outputs from the spatial constraints mapping are shown in Figures 5.62 - 5.68.

Table 5.36: Indicative theoretical installed capacity after hard constraints applied

Resource	Area remaining in km^2	MW
Wind		
Fixed foundation: 0-60m	43,091	142,200
Tethered foundation: 50-200m	77,896	257,057
Tidal stream		
Tidal current >1.5m/s	1,931	96,550-135,170
Wave		
Wave power > 20kW/m	48,305	483,050-1,449,150

Note: The total area available does not take account of the size needed for an individual commercial scale wind farm or wave or tidal array. For wave and tidal arrays, the space required between arrays has also not been factored in. Ranges reflect the range in potential energy density above.
Presently installed capacity or capacity in planning for English and Welsh waters is 18.7GW (offshore wind), 363MW (tidal range and stream) and 33MW (wave).

Table 5.37: Area remaining following application of hard constraints (km^2)

Resource	Regional Sea				
	1*	2	3	4	6*
Wind					
Fixed foundation: 0-60m	6,134	17,133	4,578	7,044	8,172
Tethered foundation: 50-200m	25,726	1,333	653	47,187	2,106

Resource	Regional Sea				
	1*	2	3	4	6*
Tidal stream					
Tidal current: >1.5m/s	n/a	179	684	632	431
Wave					
Wave power: >20kW/m	3,142	n/a	n/a	45,106	n/a

Note: does not include Scottish or Northern Irish waters

Consideration of a coastal buffer for offshore wind

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)
- Coastal Natura 2000 sites, either designated or under consideration
- Potential for conflict between different renewable energy generation technologies

The concept of a coastal buffer for offshore wind development was introduced in Round 2, with 0-8km and 8-13km used to assess seascape sensitivity. Reflecting the relative sensitivity of multiple receptors in coastal waters, previous offshore energy SEAs (DECC 2009, DECC 2011e) concluded that the bulk of future wind generation capacity should be sited well away from the coast, generally outside 12 nautical miles (some 22km). The proposed coastal buffer zone was not intended as an exclusion zone, since there may be scope for further offshore wind development within this area (e.g. Rampion offshore wind farm), but instead is included as mitigation for the potential environmental effects of development which may result from this draft plan/programme. As international context, wind farms in the Netherlands and Germany are on average 31.4km and 52.6km from the coast, compared with a current UK average of just 9.4km and a European average of 43.3km (EWEA 2016, also see Section 5.8). The impact of large arrays of devices will become more apparent as the technology progresses towards commercialisation. Currently there are no guidelines for a development buffer.

The complexity of the decisions regarding major developments at or near the coast is reflected in tiers of UK marine and terrestrial planning policy, which includes the MPS, Marine Plans, National Planning Policy Framework (NPPF), National Policy Statements for energy (NPS EN-1, Overarching National Policy Statement for Energy and EN-3, Renewable Energy Infrastructure) and Planning Policy Wales. The majority of major offshore renewables developments will, principally, fall within the remit of the *Planning Act 2008* as nationally significant infrastructure (i.e. being an offshore energy "generating station" with a capacity of >100MW). In England and Wales applications for such developments are considered by PINS which following examination will make a recommendation to the Secretary of State for Energy and Climate Change, who is the ultimate decision maker with regards to making a Development Consent Order for a given project. The consideration of such projects includes any "associated development", which includes coastal landfall and other relevant works (see Section 5.14). The NPSs were made and adopted as part of the *Planning Act* regime, and in recognising the importance of marine planning, NPS EN-1 notes that PINS must, "...also have regard to any local impact report submitted by a relevant local authority, any relevant matters prescribed in regulations, the Marine Policy Statement (MPS) and any applicable Marine Plan, and any other matters which [PINS] thinks are both important and relevant to its decision", which includes the output of the DECC offshore energy SEAs (e.g. see paragraphs 2.6.15-2.6.18 of NPS EN-3) in relation to offshore wind. Similarly, the marine plans also consider relevant provisions of terrestrial policy including the NPSs and make appropriate reference to these throughout.

The MPS, and the Marine Plans 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. The East Marine Plan area encompasses a substantial portion of existing producing or planned offshore wind development and the bulk of Round 3 wind zones in English and Welsh waters. The policies relating to offshore wind make clear that its further development is supported (policy EC3), particularly within existing Round 3 zones (policies WIND1, WIND2), with the support being contingent upon zone appraisal or an equivalent process having being undertaken prior to development proposals being made. The policy reflects existing investment commitments of Round 3 wind developers and also that a comprehensive appraisal should be undertaken to understand the feasibility of developments prior to defining proposed areas. NPS EN-3 provides guidance on the impacts of renewable energy infrastructure on ecology, biodiversity, the historic environment, landscape and other users, and the considerations to which PINS and applicants for development consent should have regard. The NPSs further highlight the importance and sensitivities of biological and ecological networks and designated areas and the need to protect them, but also that with careful monitoring, design and siting, wind turbines can be located in environmentally sensitive areas and may also have positive benefits to ecology and biodiversity (paragraph 2.6.63).

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, some areas at greater distance (more than 12nm) may not be suitable for development. Detailed site-specific information gathering and stakeholder consultation is required before the acceptability of specific major wind farm projects close to the coast can be assessed. 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. For all developments, site specific information, consultation and planning will be required before they can take place.

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 and hence more efficient generation, identified as a major driver of power output and levelised costs for floating technologies by The Carbon Trust (2015); conversely increased costs will be derived from foundation size, transmission distance, and the complexity of installation and operation. Voormolen *et al.* (2016) indicates approximately half of recent cost increases in wider European offshore wind farm capital cost is derived from increased distances from shore and water depths. In a UK context, a number of cost reduction initiatives and studies (e.g. Offshore Wind Cost Reduction Task Force, Offshore Wind Programme Board, the Cost Reduction Monitoring Framework) have been undertaken or are ongoing. DNV GL (2015) report an 11% reduction in the cost of energy from offshore wind in the past four years (£136/MWh to £121/MWh), and that good progress is being made towards the UK Government target (DECC 2012) of a levelised cost of £100/MWh[136] by 2020 (also Offshore Wind Programme Board 2015 and CCC 2015b). Tethered turbine foundations yet to be deployed at commercial scale, but these could deliver energy at levelised costs close to the that of fixed foundation turbines, or at least close to £100/MWh, in the 2020s (The Carbon Trust 2015). Reductions in costs are expected to continue as industrialisation of offshore wind continues, and there is substantial potential for the deployment of offshore wind away from the coast in UK waters.

Within the currency of this SEA, it is expected that most commercial proposals will be for fixed foundation wind farms, with tethered turbines continuing to be demonstrated for commercial deployment in the 2020s.

A representative GIS output from the spatial constraints mapping for offshore wind which includes the influence of a 12nm coastal buffer is shown in Figure 5.64 and Figure 5.65. Table 5.38 below shows the potential reduction of theoretical installed capacity achievable when the buffer has been applied.

Table 5.38: Indicative maximum area and theoretical capacity after hard constraints and 12nm buffer applied

Resource	Area remaining in km^2	Area remaining in km^2 (minus 12nm buffer)	MW
Wind			
0-60m	43,091	19,327	63,779
50-200m	77,896	72,530	239,349

Note: The total area available does not take account of the size needed for an individual commercial scale wind farm.

Summary

The above analysis only considers the area relevant to renewables development for this SEA, namely the territorial and offshore waters of England and Wales. Previous SEAs (DECC 2009, 2011e) have included target generation capacities for offshore wind of 25GW in addition to the 8GW to be delivered from Rounds 1 and 2, providing an overall capacity of 33GW to be covered by the plan, with spatial analysis at the time indicating the potential for this to be delivered. No target generation capacity has been included for this SEA, but the UK Government has indicated that it envisages that approximately 10GW of offshore wind will be installed by 2020[137], which compares with a current UKCS total of 4.9GW, a total consented capacity of 15.6GW, and a total capacity of 18.6GW if all projects in planning are built. The UK Government has also indicated that a further 10GW of offshore wind could be supported in the 2020s provided that further cost reduction occurs in the sector, and also that along with new gas and nuclear power stations will be a key component in the decarbonisation of the energy sector. Given these envisaged installation or support timings and capacities, the area and theoretical

[136] See DECC (2013c) for a comparative overview of energy costs from different technologies.
[137] https://www.gov.uk/government/speeches/amber-rudds-speech-on-a-new-direction-for-uk-energy-policy

installed capacity for fixed and tethered turbines substantially covers this potential (as does the 33GW used in previous SEAs), and provides significant scope for additional projects to come forward in the currency of the SEA. A significant proportion of the theoretical capacity comes from tethered turbines, particularly in Regional Seas 1 (85GW) and 4 (155GW), with much less coming from shallow water areas of the southern North Sea (e.g. Dogger Bank, Regional Sea 2, 4.4GW), nearshore areas of Regional Sea 3 (2.2GW) and the Bristol Channel and Irish Sea (6.9GW) – see Table 5.37. It should be noted that despite a large theoretical resource of offshore wind being present in the south west approaches, distance from land, high extreme wave heights and few grid connections may not make deployment here economically feasible during the currency of this SEA.

Under present technological and environmental constraints, the area indicated as available for tidal current devices in the waters of England and Wales (1,931km^2) is relatively small and confined to sites off Anglesey, the Lleyn Peninsula, the Severn Estuary/Bristol Channel (Regional Sea 6), the central English Channel (particularly off the Isle of White, Portland and Purbeck), Dover Strait (Regional Sea 3), and areas off Norfolk and north of the Humber (Regional Sea 2). With exception of the east coast of England, the present location of tidal project leases accord well with those areas identified as having both potential and fewer constraints. The theoretical installed capacity is 96.6-135.2GW.

For wave devices, the analysis shows that the areas of greatest practical resource are off the coasts of south west Wales and south west England (Regional Sea 4) with a smaller area available in the north east adjacent to Scottish waters (Regional Sea 1). Under the technological and environmental constraints used, the total area available is calculated as 48,305km^2, with an associated theoretical capacity of 483-1,449GW.

The above figures for wave and tidal energy are not directly comparable with estimates made by other authors including The Carbon Trust (2012) and The Crown Estate (2012, 2013) which use a range of other parameters to estimate wave energy resource. The latter study provides estimates of 20.5GW and 8.7GW for tidal stream and wave energy respectively in English and Welsh waters. The disparity in the theoretical wave capacity is derived from differences in the underlying methodologies applies, including a number of complex factors such as removal of energy from the wave spectra by offshore devices which can then not be harvested from devices downstream, as accounted for by The Crown Estate (2013).

The estimation of the potential capacity for tidal range energy is more complex, derived from areas that could be impounded by lagoon or tidal barrage walls, which is highly development/site specific. The areas identified as having a potential resource in Figure 5.68 coincide with many sites previously investigated for tidal range energy and are primarily located around the Humber and Wash (Regional Sea 2), the Sussex coast (Regional Sea 3), Severn (Regional Seas 4 and 6), Morecambe Bay and Solway (Regional Sea 6). The Crown Estate (2015, unpublished) developed a number of tidal range scenarios for barrage and lagoon type developments around the UK, and estimated a total theoretical capacity of 37GW, with over 35GW of this being delivered from the Severn and west coast of the UK, with a figure of approximately 15GW considered more realistic in the medium term (i.e. to 2050).

It should be noted that the figures presented above are subject to technical and commercial feasibility and other site specific constraints.

Figure 5.62: Offshore wind: seafloor area remaining following application of "hard" constraints (0-60m) – refer to Table 5.35

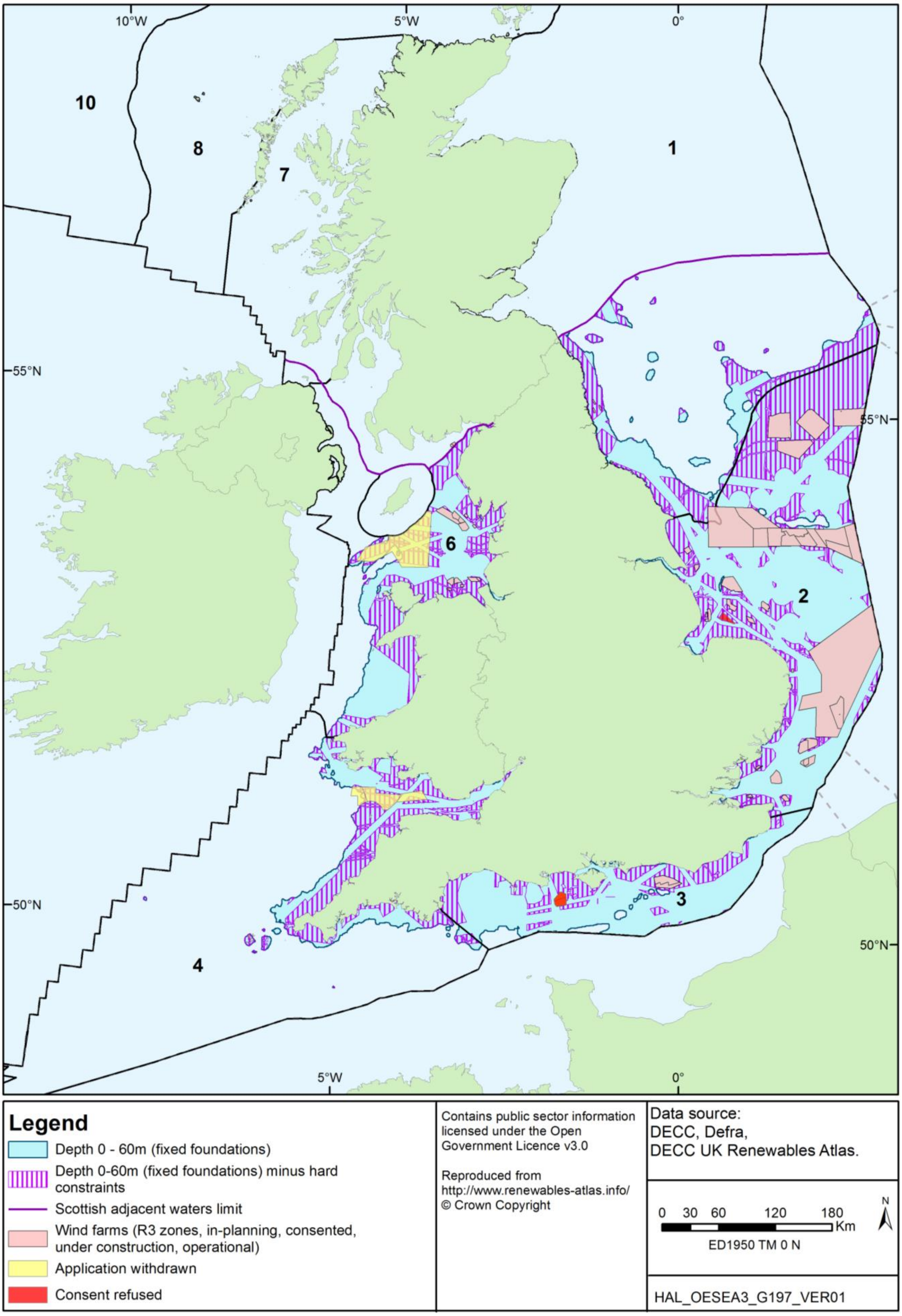


Figure 5.63: Offshore wind: seafloor area remaining following application of "hard" constraints (50-200m) – refer to Table 5.35

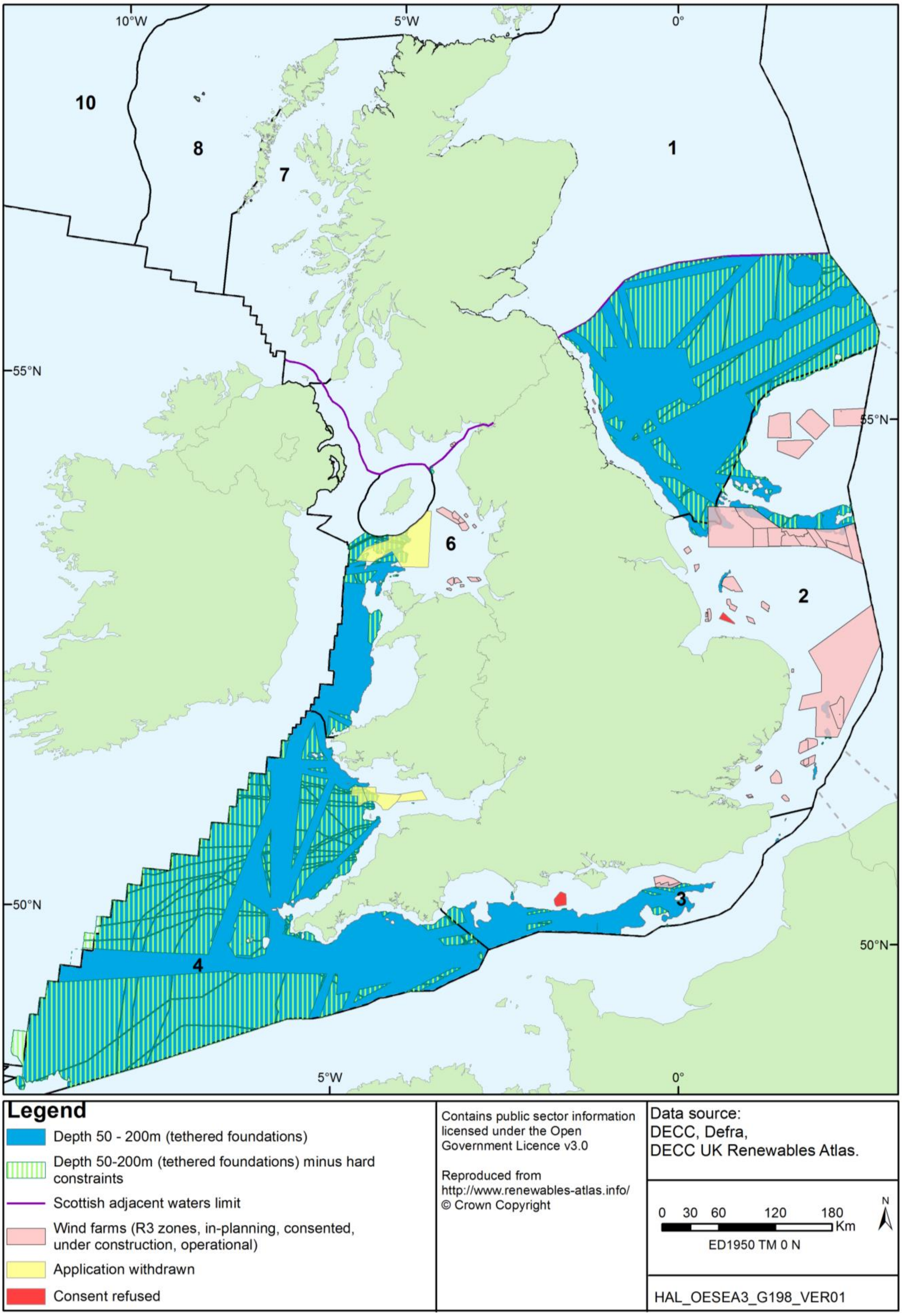


Figure 5.64: Offshore wind: seafloor area remaining following application of "hard" constraints (0-60m) and 12nm buffer – refer to Table 5.35

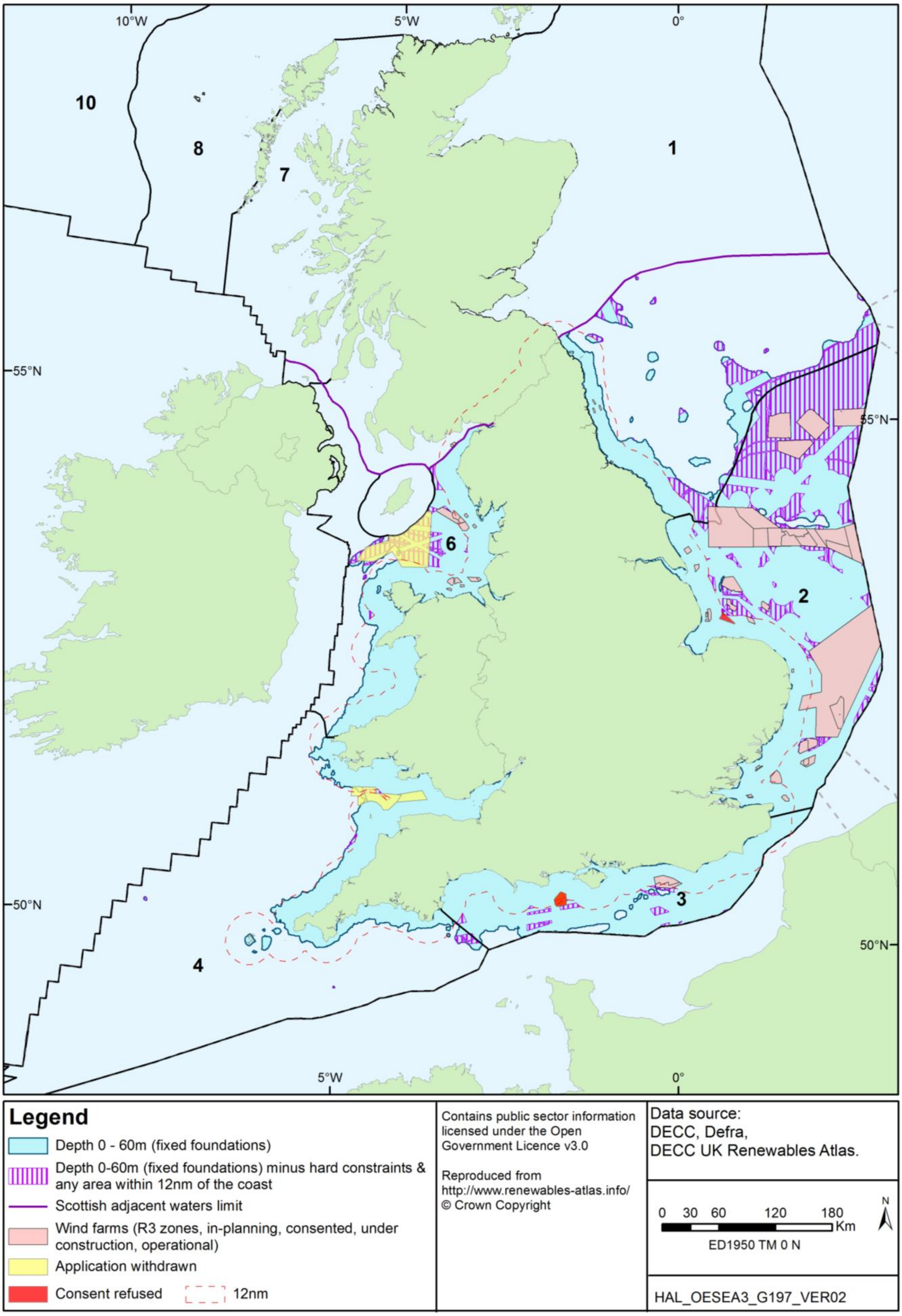


Figure 5.65: Offshore wind: seafloor area remaining following application of "hard" constraints (50-200m) and 12nm buffer– refer to Table 5.35

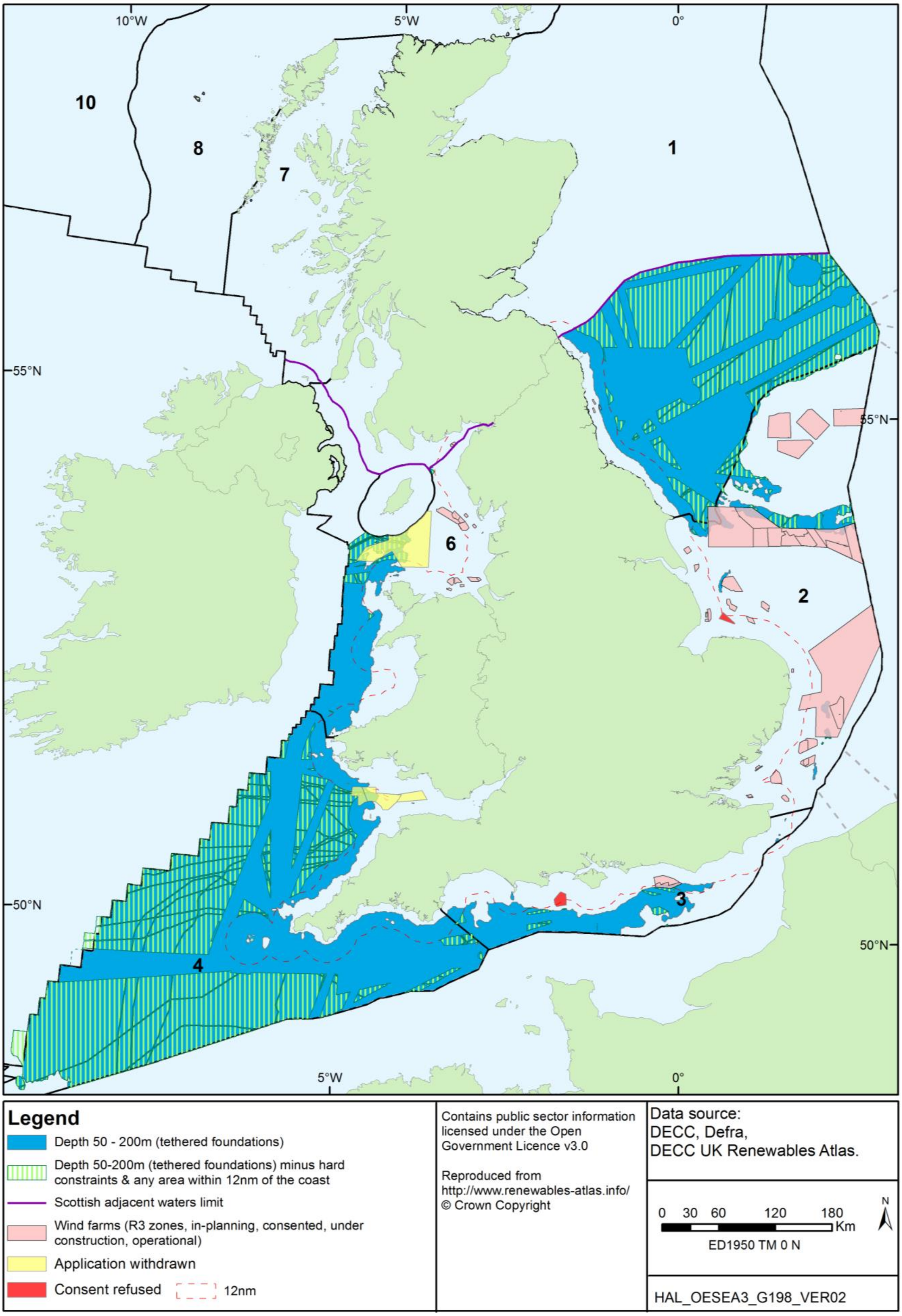
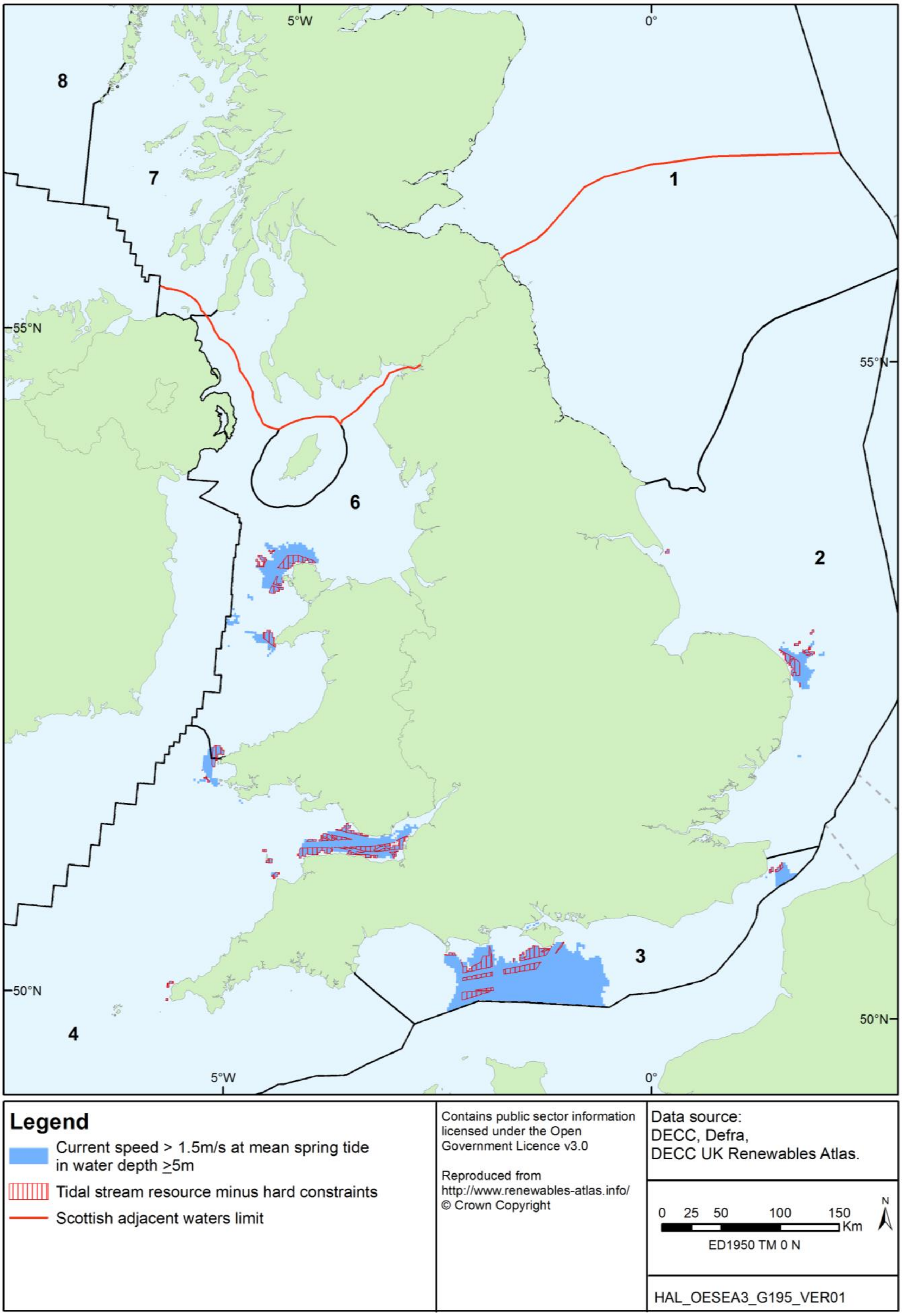


Figure 5.66: Tidal stream: seafloor area remaining following application of "hard" constraints – refer to Table 5.35



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Data source:
DECC, Defra,
DECC UK Renewables Atlas.

HAL_OESEA3_G195_VER01

Figure 5.67: Wave: seafloor area remaining following application of "hard" constraints – refer to Table 5.35

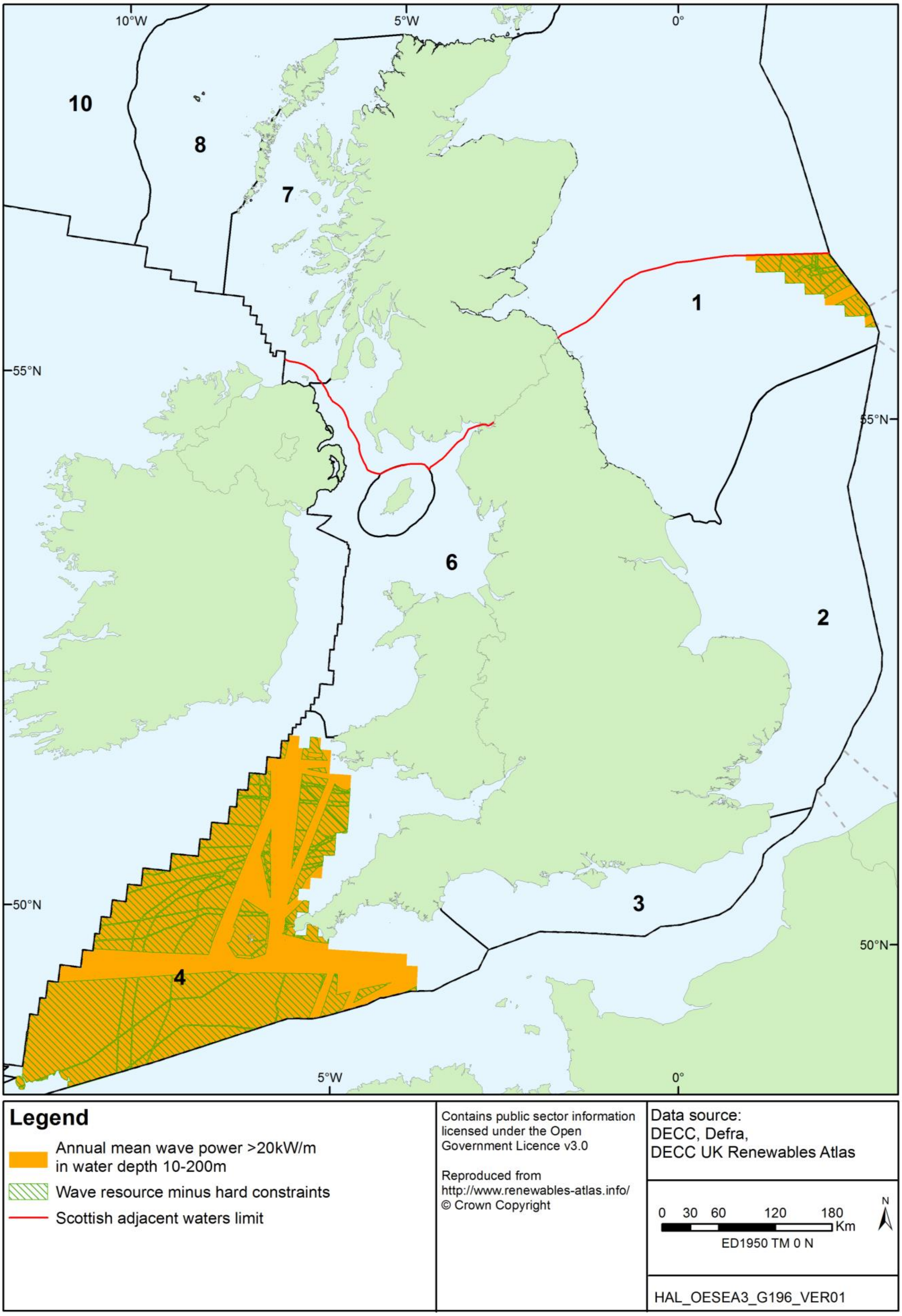
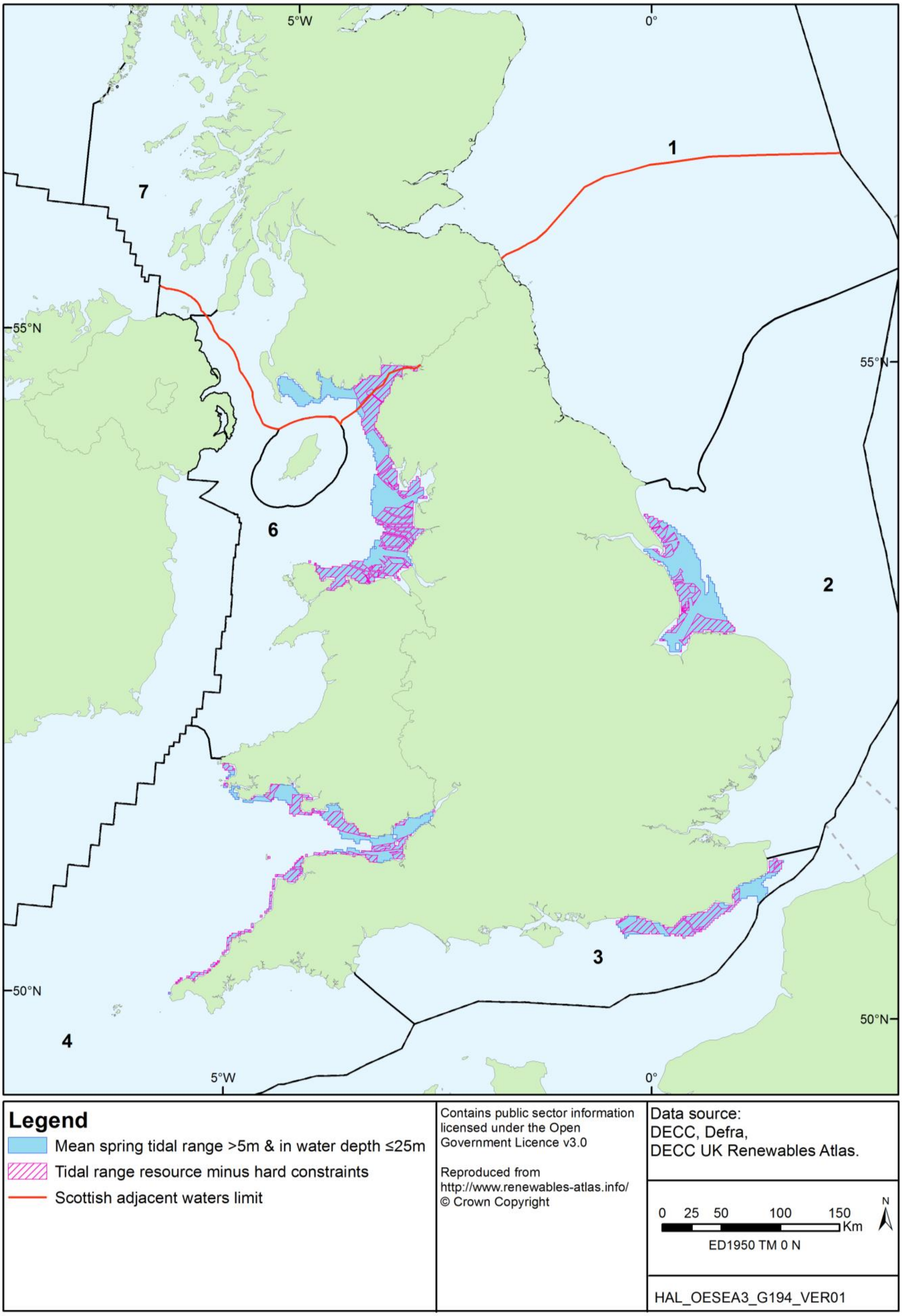


Figure 5.68: Tidal range: seafloor area remaining following application of "hard" constraints – refer to Table 5.35



The following points are also considered in relation to potential conflicts with "other" constraints, and with other legitimate activities (notably fishing) not included in the spatial analysis:

Conservation sites (Figures 5.69-5.72): several areas identified as unconstrained for potential development fall within marine and offshore Natura 2000 sites. The presence of these sites does not preclude development, but there are additional assessment and consenting requirements, and additional mitigation may be required to avoid any adverse effects on site integrity. Development in designated sites would be subject to Habitats Regulations Assessment and be required to meet Appropriate Assessment (AA) tests. Race Bank and Dogger Bank Creyke Beck/Teesside are examples of wind farms which are located entirely within Natura 2000 sites but which have gained development consent following assessment. Far field effects are possible for a number of the technologies covered by the plan, particular in relation to the physical environment (see Sections 5.4 and 5.5) and mobile species (see Sections 5.3 and 5.6), and therefore developments not located within a Natura 2000 site may also have to be subject to AA where likely significant effects are identified for a site. 27 Marine Conservation Zones were designated in 2013, with an additional 23 proposed for designation in a second tranche of sites which were subject to consultation in 2015 and due for designation in early 2016 (See Appendices 1j and 2). These sites have statutory protection, but have different assessment requirements to Natura 200 sites. The conditions relating to consent for marine licences which are capable of affecting MCZs are set out in Section 126 of Part 5 of the *Marine and Coastal Access Act 2009*, and the MMO provides guidance on how it will consider developments in relation to MCZs under Section 126 of the Act, which is broadly analogous to the staged approach typical of HRA[138]. ABPMer (2011) provided an overview of the potential implications for offshore renewables of an MCZ network, which primarily related to additional costs, and concluded that despite potential additional burdens on developers that these should not prevent offshore renewables making a significant contribution to overall renewables targets. There have also been some recent reviews on the potential for some devices or arrays to provide nature conservation value (e.g. Ashley *et al.* 2014).

No specific management measures have been put in place for conservation sites in relation to plan activities to date, however conservation advice is available for sites which provides an indication of the potential for interactions between interest features and certain activities. The location and features of conservation sites relevant to the plan area are given in Appendix 1j.

MoD PEXAs (other areas): with the exception of selected 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, emphasised in the MPS, "*Marine plan authorities, decision makers and developers should consult the MoD in all circumstances to verify whether defence interests will be affected*."

[138] https://www.gov.uk/government/publications/marine-conservation-zones-mczs-and-marine-licensing

Figure 5.69: Draft, proposed and designated conservation sites in relation to areas remaining following application of "hard" constraints (offshore wind)

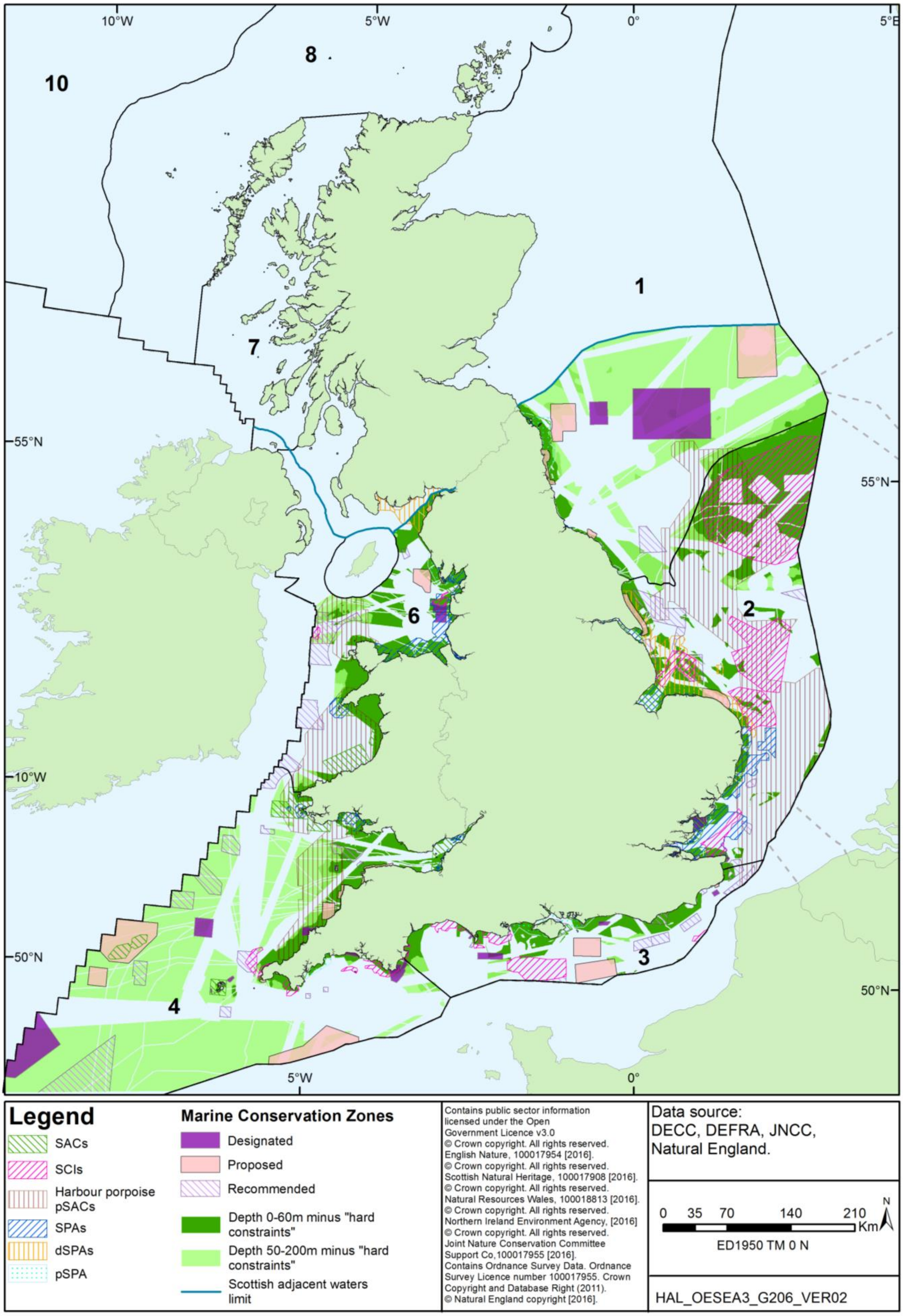


Figure 5.70: Draft, proposed and designated conservation sites in relation to areas remaining following application of "hard" constraints (tidal stream)

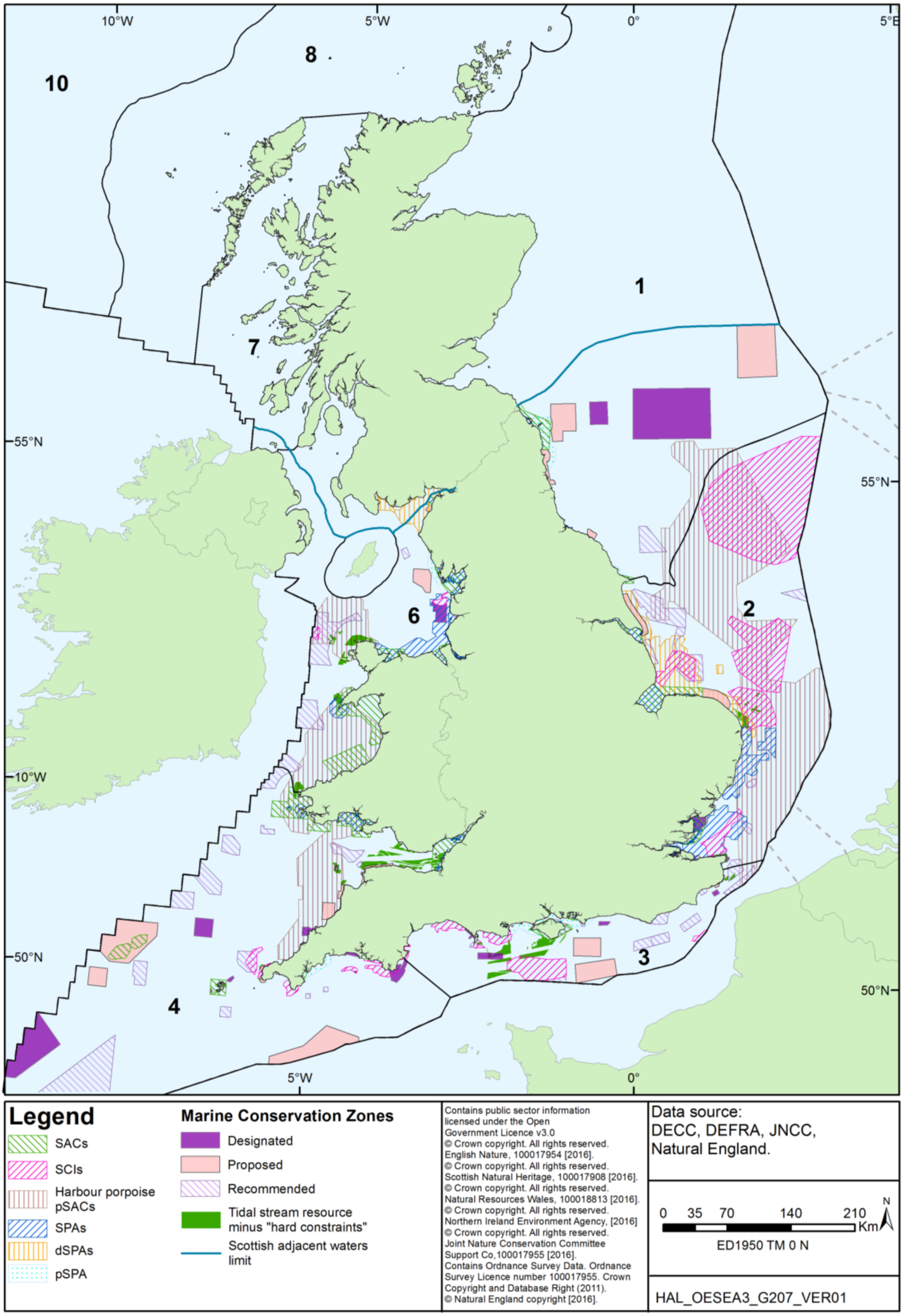


Figure 5.71: Draft, proposed and designated conservation sites in relation to areas remaining following application of "hard" constraints (wave)

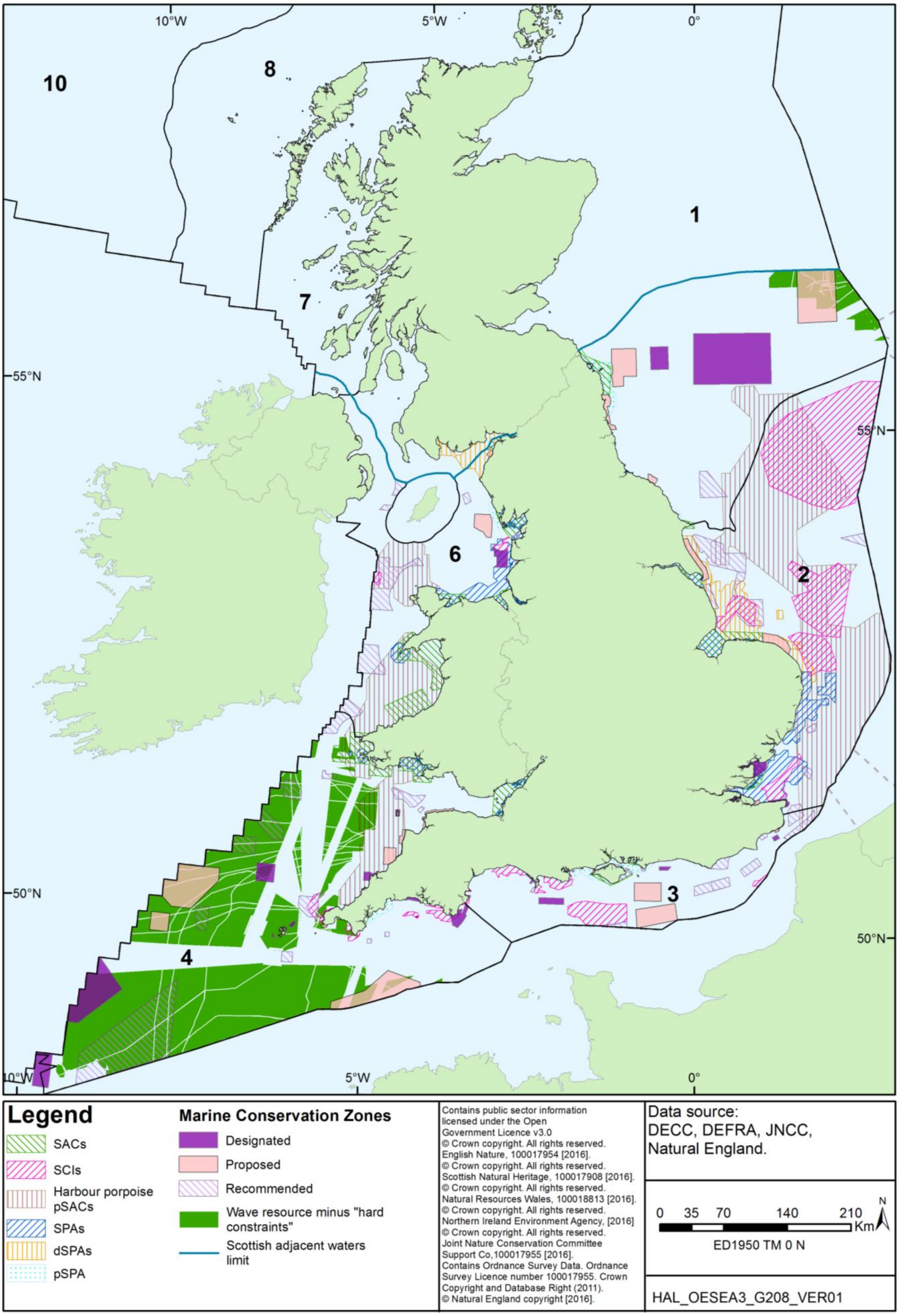
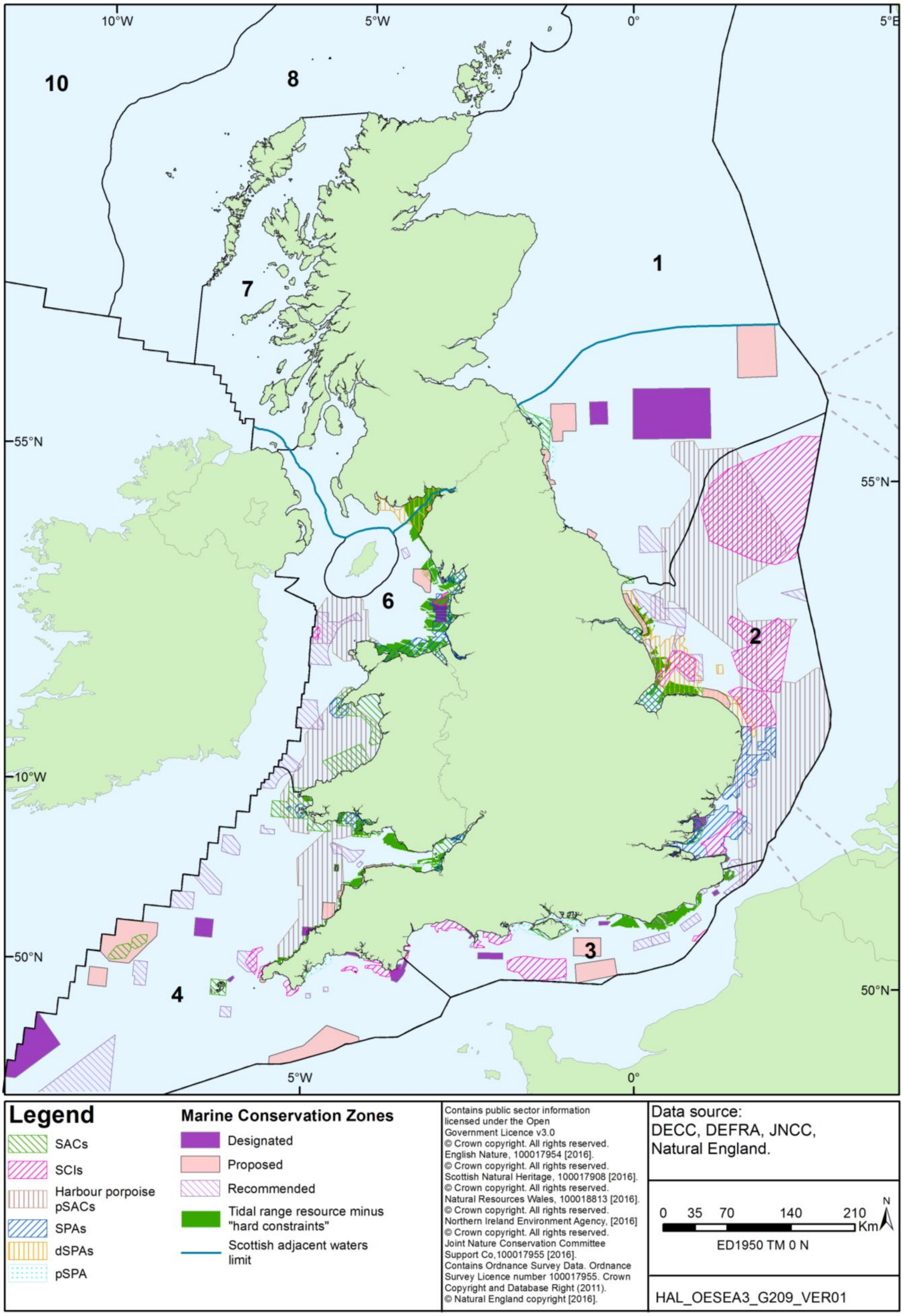


Figure 5.72: Draft, proposed and designated conservation sites in relation to areas remaining following application of "hard" constraints (tidal range)



NATS and other radar areas (offshore wind): with the exception of the Dogger Bank, a large proportion of the possible development area for offshore wind is identified by NERL as "likely to interfere" with air traffic control radar. Technical measures may alleviate this issue to some extent. Some nearshore areas also fall within the range of military radar areas contributing to the UK Air (Surveillance and Control Systems) ASACS network. Technical measures have included the deployment of TPS77 radars which provide mitigation from the effects of wind farms, and commissioning and trials of these upgrades are continuing[139].

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 MPS (Section 3.8) and East Marine Plans (see polices GOV3 and FISH1) recognise the potential for negative effects from displacement, including economic and social impacts, and on the environment of areas that fisheries are displaced to, and require that proposals demonstrate how fishing will not be prevented or how such displacement could be minimised or mitigated. Liaison with the fishing industry should be a key component of a project's planning and EIA process. The principles of best practice in this area are outlined in guidance produced by the Fishing Liaison with Offshore Wind and Wet Renewables Group (FLOWW 2014). A pilot study commissioned by The Crown Estate has been undertaken by NFFO to understand changes in fishing practices following the installation of wind farms (Gray *et al.* 2016). The project involved a review of VMS and other data on landings, fishing effort and surveillance, and interviews with fishermen and developers. The project is expected to be taken forward into a second phase looking at other locations where wind farms have been deployed (e.g. the Wash or outer Thames)[140]. The results of this study and more information on the potential for aspects of the draft plan to interact with other users are given in Section 5.7.

The implementation of a 12nm coastal buffer as indicated above would substantially mitigate conflict with the most sensitive fishing sector (small inshore vessels, which cannot easily relocate and are often of marginal commercial viability). The potential effects of wave and tidal devices on the fishing industry are less well understood due to the lack of commercial development so far. As with offshore wind, the installation of devices on the sea surface and sea floor will constrain fishing activities carried out in the development areas both during construction and operation. For tidal current devices in particular, the areas indicated as suitable for development, although relatively small, are generally in close proximity to the coast, and all tidal range development is likely to be shore connected.

Recreational users: The vast majority of recreational vessels (including yachts, diving and angling) would not be excluded from offshore wind farm development areas. As for fishing, there is potential for interaction between recreational boating and wave and tidal development, again particularly for tidal current devices which are likely to be situated within territorial waters. The MPS recognises the positive social, wellbeing and economic benefits of recreational activities (as well as potential for negative environmental implications), and the East Marine Plans recognise the importance of tourism and recreation (policy TR1), and specifically

[139] See the latest Aviation Plan (2015): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/397208/Aviation_Plan_Update_2015_FINAL.pdf

[140] Minutes of the FLOWW group meeting, 29th May 2015.

recreational boating (policy TR2), and indicates what proposals must demonstrate in terms of their potential impact on these activities. As marine plans are to be consistent with the MPS, similar policy provisions may be expected for other marine plan areas. Guidance available from the Maritime and Coastguard Agency (see MGN 372 (M+F)) suggests that wave and tidal devices may be more difficult to see than wind turbines and that navigation within an array may not be possible, meaning that a development area should be avoided. For offshore wind, it is expected that conflicts with recreational activities would be substantially mitigated by a coastal buffer zone.

Offshore renewables: there may in the future be competition for sea surface/sea floor space between the different offshore energy sectors, including wind, wave and tidal, oil & gas and CCS. The MPS indicates that marine planning will, amongst other processes: manage competing demands on the marine area, and, enable the co-existence of compatible activities wherever possible. The MMO has commissioned two studies which look at the co-location potential of activities, the first providing matrices based mainly on physical constraint and the second scoped the development of a tool to assess co-existence of marine activities identified in the MPS (MMO 2013d, 2014i) – see above.

Disposal areas: it is unlikely that any aspect of the plan will interact with capital dredging operations; however licensed disposal sites are located offshore for dredged material which may need to be avoided. Unexploded ordnance (UXO) is not a hard constraint to any development, though the location of disposal sites and the frequency of encounters particularly in the southern North Sea and in coastal locations (see Appendix 1h) should be considered (also see Cooper & Cooke 2016).

5.15.4 Controls and mitigation

In advance of site specific controls, previous SEAs have attempted to outline the location and nature of potential constraints to relevant development types, which is now being considered in more detail through the marine planning process. The above consideration, and also the other chapters which precede this, also cover the potential issues on siting any of the technologies covered by the draft plan/programme insofar as they can be spatially explicit given our current understanding of the environment.

5.15.5 Summary of findings and recommendations

Significant progress has been made towards the delivery of marine spatial planning in UK waters, and this has both been referenced and reflected in the above consideration and elsewhere in this Environmental Report. This SEA has been carried out in advance of the implementation of a number of formal marine plans for UK waters and the conclusions of this section must therefore be considered in the context of forthcoming strategic marine planning for most these areas which will be completed during the currency of this SEA (expected to be complete by 2021).

At a European level, the construction of marine renewable energy installations (primarily wind) has increased significantly in recent years, principally in the shallow southern North Sea (e.g. in UK, German, Dutch and Belgian waters), and in the east Irish Sea (including a proposal in Manx waters). These areas are also intensively used by activities some of which are cross-boundary, including fisheries, shipping, ferry routes and recreational sailing. Plan activities could act cumulatively with existing offshore activities by generating further spatial restrictions, though marine spatial planning should assist the strategic identification of such impacts and help facilitate appropriate siting of new developments – marine planning is being undertaken across Europe under the auspices of the Marine Spatial Planning Directive, and through a separate but similar process in Manx waters. The potential requirement for further routeing measures or other navigational restrictions is transboundary in nature, as any such routeing requires coordination with adjacent states, with the most important routes formally designated under the auspices of the International Maritime Organisation (IMO).

The consideration of spatial constraints above has concluded that a significant amount of marine renewable energy could be delivered from offshore wind in addition to the Round 3 project areas which have been consented or are in planning. This includes the application of a nominal 12nm coastal buffer as used in previous OESEAs, and no relaxation of the "hard" constraints identified above. It should be noted that this does not suggest that such a buffer should be applied, as every development should be assessed on its own merits, but it is used here in a strategic way to reflect that significant resources remain on the UKCS away from coastal waters. This is in view of their importance, reflected in numerous uses for recreational, shellfishery, fishery, navigational, commercial and other activities, in addition to designations to protect their scenic, geological, ecological and cultural features. The sensitivity of coastal areas is not uniform and the intensity of uses and designations typically declines further offshore away from the coast. All activities and developments covered by the draft plan/programme require site-specific information gathering and stakeholder consultation to inform consenting decisions. The particular sensitivity of the coastal zone and marine spatial plan requirements must be taken into account during site selection for proposed developments within territorial waters (normally 12 nautical miles (some 22km) from the coast).

The above indicates that there are further areas of offshore wind resource available beyond the existing Round 3 lease areas within the 0-60m depth areas and also between 50-200m depth (dependent on the commercial advancement of tethered turbines), and that areas in Regional Sea 2 may be preferred for tethered devices compared to Regional Sea 4 due to reduced technical and cost constraints including distance to shore and calmer metocean conditions. Additionally, the analysis has identified potential resource areas for both tidal current, tidal range and wave devices, subject to technological and environmental constraints. The practical deployment of these will be subject to project level controls and assessment, and their relative proportions deployed in the currency of this SEA remains uncertain as these are to some extent commercially driven. In relation to the contribution of each to renewables deployment and carbon reduction commitments for the UK, this is covered in Section 5.12.

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. At a local site specific level, other constraints may be significant while some hard constraints mentioned here may be less exclusive dependent upon mitigation measures employed. Where information on use is less certain (e.g. fisheries), consultation with relevant representatives or individuals will be required. Some hard constraints (e.g. platform buffers, aggregate extraction zones) are anticipated to be relaxed in the future as infrastructure is decommissioned or resources depleted. Draft and approved decommissioning programmes are available from the DECC oil and gas website[141]; and indicate significant "space" becoming available within the coming years.

[141] https://www.gov.uk/guidance/oil-and-gas-decommissioning-of-offshore-installations-and-pipelines

5.16 Consideration of potential for cumulative impacts

5.16.1 Introduction

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 be considered. A UK wide perspective is being generated *inter alia* through the UK's initial assessment of marine waters (Defra 2012) undertaken under the Marine Strategy Framework Directive (MSFD), and in time may be augmented through the marine planning process (as outlined in the Marine Policy Statement (MPS) paragraph 2.3.1.6). Note that to date the Sustainability Appraisal (SA) of the Marine Plans has also included a cumulative effect consideration; however, this was primarily in relation to policy interactions as the largely generic or criteria-based policies of the first marine plans lacked sufficient spatial definition to determine potential for interactions.

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). Stakeholder consultation has emphasised the importance of cumulative effects within the overall process. In recent years a number of reports and sets of guidance have been published on cumulative impacts assessment, some are technology specific such as: *Guiding Principles For Cumulative Impacts Assessment In Offshore Wind Farms* (Renewable UK 2013), or for specific receptor groups, for example: *Developing Guidance on Ornithological Cumulative Impact Assessment for Offshore Wind Farm Developers* (King *et al.* 2009), *Guidance for Assessment of Cumulative Impacts on the Historic Environment from Offshore Renewable Energy* (COWRIE 2008), *Development of a generic framework for informing Cumulative Impact Assessments (CIA) related to Marine Protected Areas through evaluation of best practice* (Natural England 2014).

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 Gililand *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 practical steps should be taken to collate and make widely accessible marine data from a range of sources. A number of initiatives have contributed towards the latter requirement including: the Marine Environment Data & Information Network (MEDIN) initiative (for which the SEA has a data archiving centre[142]), work undertaken within the remit of European Directive 2007/2/EC on establishing an Infrastructure for Spatial Information in the European Community (the INSPIRE Directive[143]), and more recently, the collection, collation[144] and publishing of marine spatial data in an open format by the MMO and other Government agencies including the Environment Agency and Defra[145].

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[142] http://www.bgs.ac.uk/data/sea/
[143] https://data.gov.uk/location/inspire
[144] https://www.gov.uk/government/publications/master-data-register
[145] See http://www.geostore.com/environment-agency/WebStore?xml=environment-agency/xml/ogcDataDownload.xml

OSPAR piloted an approach that aims to determine the status of ecosystems building on the identification and quantification of the main pressures[146] and their cumulative impacts on species groups and habitat types. The results of a trial assessment are presented in the Utrecht workshop report (OSPAR 2009). The Utrecht workshop focused on assessing, at the scale of OSPAR regions, the impact of pressures from human activities, as listed in the EU Marine Strategy Framework Directive, and those driven by climate change, on a selection of four species groups (fish, cetaceans, seals, seabirds) and four habitat types (rock and biogenic reef habitats, shallow sediment habitats, shelf sediment habitats, deep-sea habitats). The assessment process followed a series of steps:

- Map the geographic distribution of human activities and describe the spatial and temporal extent, intensity and frequency of the pressures resulting from these activities.
- Define the geographic distribution of species groups and habitat types that are sensitive to these pressures.
- Estimate the degree of impact, where pressures and ecosystem elements overlap in space and in time. For this purpose, generic criteria and associated threshold values were developed for geographic range, population size and condition for species groups, and on range, extent and condition for habitats. The threshold values were based on those given in EU guidance for assessing favourable conservation status of species and habitats under the Habitats Directive. The degree of impact, following these criteria, was assessed against a reference status (based on an absence of the pressure). The percentage deviation from this reference status was used to classify the outcome as 'low', 'moderate' or 'high' impact.
- Summarise the different impacts from human activities in order to derive an overall status assessment per species group and habitat type.
- The impacts on all species groups and habitat types were summarised to assess the total impact per pressure and consequently their relative contribution to the total impact in each region.

The Utrecht workshop trialled a generic, large-scale approach to ecosystem assessment. Relevant lessons from the workshop included:

- Mapping of human activities and ecosystem components is promising for the assessment of separate and cumulative impacts on habitats and related sessile species (which are bound to a particular area) but less applicable to mobile species.
- Assessments at the scale of OSPAR Regions are too coarse to identify properly the often area-specific impacts of human activities. Many habitats also occur at a smaller geographical scale. It is therefore important that assessments of human impacts are undertaken at the appropriate scale, which may vary on a case by case basis.

[146] These are variously described through a number of iterations and programmes of work, see: http://jncc.defra.gov.uk/default.aspx?page=6516 and http://jncc.defra.gov.uk/page-7136, and also White *et al.* (2013) in relation to the Options for Delivering Ecosystem-Based Marine Management (ODEMM) linkage framework (http://www.odemm.com/content/linkage-framework), van der Wal & Tamis (2014), and http://www.marlin.ac.uk/species/sensitivity_rationale for an overview of the MarLIN and MarESA approaches.

- Generic assessment criteria and thresholds do not take into account the variation in life history characteristics for some species groups. The assessment criteria should be refined to allow for more differentiation in species and also habitat groups.
- The pilot assessment yields a first indication of cumulative effects. Further development of the method is needed to improve the assessment of cumulative effects.
- Judgement by a designated group of experts following well-defined procedures can complement limited datasets. The credibility of the outcome is enhanced by recording the confidence level and by describing how gaps in data were treated and how issues were addressed for which there was insufficient consensus (OSPAR 2009).

The ICES Working Group on Holistic Assessments of Regional Marine Ecosystems (WGHAME) (ICES 2009) critically reviewed the Utrecht workshop process and suggested an assessment framework to improve the overall effectiveness of the assessment. This was based on a review of existing methods for assessing the cumulative impacts of multiple human activities on large marine ecosystems. The ICES report highlighted the complexities involved in linking the status of ecosystems and ecosystem components with pressures and recommended that a workshop be held in collaboration with other expert groups in the ICES Regional Seas Programme to develop protocols and guidelines for the conduct of Integrated Ecosystem Assessments such as cumulatives effects assessment. In view of the multiple approaches to cumulative effects assessment, at a regional level the Intersessional Correspondence Group on Cumulative Effects (ICG-C) has been set up within the auspices of OSPAR, and with the goal of seeking common approaches to cumulative effects.

With regards to frameworks for cumulative assessment, the MMO (2014) commissioned a project to develop a framework that could be used as part of their day-to-day operations to consider cumulative effects at a strategic level, and therefore has a focus on MMO functions. This framework was intended as a means to identify potential for cumulative effects, and therefore presented no methodology on how an assessment of such effects might be considered. Generally, the identification of cumulative effects involves: defining the purpose and types of activity that are being considered, identifying the pathways of effect and related pressures and also the area of the study, and identify other activities for which those planned could act cumulatively.

A UK Cross-Government Cumulative Effects Assessment Working Group has been established which aims to develop guidance for regulators, advisors and applicants to help increase consistency in application of CEA.

5.16.2 Definitions

The terminology and methodology applied to the application of cumulative effects assessment has to date been various. However, all have had the intention of achieving an assessment of multiple pressures on one or a range of receptors (Judd *et al.* 2015). An overall definition of cumulative effects has been variously modified from that of Cooper (2004), and most recently by Judd *et al.* (2015) as, "...*a systematic procedure for identifying and evaluating the significance of effects from multiple pressures and/or activities on single or multiple receptors. Cumulative effects assessment provides management options, by quantifying the overall expected effect caused by multiple pressures and by identifying critical pressures or pressure combinations and vulnerable receptors. The analysis of the causes (source of pressures), pathways, interactions and consequences of these effects on receptors is an essential and integral part of the process*."

Considering the above, it can be broadly stated that the intent of the consideration which follows is to define, at a strategic level, the potential for cumulative effects for the range of activities covered by the draft plan/programme (Section 2), and informed by the assessments in Section 5, using an understanding of potential pathways of effect for broader activities taking place on the UKCS. These pathways are understood from a range of sources, including previously produced matrices on "pressures" (see above), and the assessment is more widely informed by other work undertaken at a UKCS scale e.g. that for the MSFD initial assessment (Defra 2012).

The assessment recognises the limits of spatial specificity included in the draft plan/programme, due to a combination of its exploratory nature (oil and gas, gas storage and CCS), and commercial viability and interest (marine renewables). However, the overall spatial consideration may be taken to indicate, at a strategic level, the theoretical areas of resource for renewable technologies but does not imply any areas of preference of likely deployment. Similarly, the assessment recognises the limitations of spatial data (resolution, availability) and understanding of individual or cumulative impacts for particular species of receptors. Where cumulative effects are also an inherent part of wider discussions of particular sources of effect (e.g. noise, physical presence) the following summarises wider discussions elsewhere which are cross-referenced.

The approach used here builds on previous OESEAs, recognising other work mentioned above, and a number of terms are defined below which are used to describe the nature of cumulative effects identified, these include: secondary, cumulative and synergistic. Though these are not defined by the SEA Directive, 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 but there are important nuances to these terms. Additionally, incremental effects are defined, which are used to distinguish those effects resulting from activities which may be carried out under the proposed plan together with activities carried out under previous plans. This definition is extended below to include activities (oil, gas, gas storage, CCS, OWF and other marine renewables) which may be carried out under the proposed licensing/leasing.

Cumulative effects are considered in a broader context, to be potential effects of activities resulting from implementation of the plan 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) – i.e. what could be described as the other major "industrial" uses of the sea.

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 exploration and production activities (including gas and carbon dioxide storage), and leasing OWF and marine renewable developments; which have the potential to act additively with those from other licensed/leased activity.

Synergistic effects occur 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 other elements of the plan, 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, and in the coming years, cessation of production and decommissioning).

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 visual impact (e.g. for onshore wind farms, from the point of view of a moving observer: SNH 2012).

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 (see Section 4 and Appendix 1). On the assumption that environmental “problems” are a result of some anthropogenic effect, this section of the SEA document considers the potential interactions between these problems and any activities arising from the proposed licensing/leasing.

Those potentially significant effects, which are also considered to be cumulative, are assessed below.

5.16.3 Underwater noise

The potential effects of underwater noise associated with the draft plan/programme are considered at length in Section 5.3; this includes cumulative impact considerations of the most high intensity noise emitting activities of pile-driving and seismic survey.

Cumulative effects on marine mammals resulting from the proposed licensing/leasing are considered likely. Activity levels are likely to be concentrated in Regional Seas 1, 2 and 6, with additional oil and gas activity likely in Regional Seas 8/9, but there is the potential for oil and gas licences to be awarded in any area of the UKCS. Consideration of this likely activity, in combination with propagation ranges for noise, concluded that it is likely that multiple sources (including seismic surveys and pile-driving) will occur at the same time, that both activities may extend throughout much of the year, and be audible to marine mammals over a large proportion of their range. The JNCC guidelines[147] on the deliberate disturbance of marine European Protected Species also suggest that for most cetacean populations in UK waters, disturbance, in terms of the Habitats Regulations or Offshore Marine Regulations (i.e. *Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007*), is unlikely to result from single, short-term operations, e.g. a seismic vessel operating in an area for 4-6 weeks, or the driving of a dozen small diameter piles. Such activities would most likely result in temporary disturbance of some individuals, which on its own would not be likely to result in significant effects on the local

[147] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/50006/jncc-pprotocol.pdf

abundance or distribution. Non-trivial disturbance, which would constitute an offence under the Regulations, would most likely result from more long-term noisy activities in an area, chronically exposing the same animals to disturbance or displacing animals from large areas for long periods of time.

Evidence obtained over the last 10 years has shown that harbour porpoise are more sensitive to underwater noise than previously thought. Comparison of modelling frameworks designed to analyse the long-term consequences to harbour porpoise of disturbance associated with large scale wind farm construction in the North Sea suggest a high degree of uncertainty in extrapolating from individual to population effects. Nonetheless, these exercises have raised the theoretical possibility for temporal and spatial combinations of large seismic surveys and pile-driving operations to result in significant population disturbance.

Looking forward, project timelines with respect to consented wind farms indicate that on average two pile driving operations will likely take place continuously in the North Sea over the next decade or more – primarily in the central and southern North Sea. The vast majority of seismic survey effort on the UKCS has been undertaken in the developed (in terms of oil and gas) areas of the northern and central North Sea, the Scottish continental shelf and the Faroe-Shetland Channel, and projections of recoverable reserves continue to identify the central North Sea as the area with the largest reserve base and with a significant exploration potential. Therefore, the central and southern North Sea may represent areas with the most potential for incremental underwater noise effects with respect to pile driving activities and seismic survey (note that in many cases, reprocessing of existing seismic data can avoid the requirement for new deep geological survey).

Previous SEAs have recommended consideration of the establishment of criteria for determining limits of acceptable cumulative impact; and for subsequent regulation of cumulative impact. The SEA recognises the advances made in this respect through the establishment of the indicator on low- and mid- frequency impulsive sounds under the Marine Strategy Framework Directive. While criteria have not yet been defined, the establishment of a database to collate occurrences of “noisy activities” (the Marine Noise Registry) represents the necessary precursor.

Incremental Simultaneous and sequential seismic surveys and pile-driving

Cumulative Seismic survey, pile-driving noise and broadband impulse noise, for example military sonars and continuous mobile sources (e.g. shipping)

Synergistic None known

Secondary None known

5.16.4 Physical damage/change to features and habitats

Potential sources of physical disturbance to the seabed, and damage to biotopes are associated primarily with the construction phase of potential plan activities. Some sources are common across many aspects of the plan (e.g. anchoring of vessels, rigs and installations; pipeline and cable installation; rock dumping; seabed dredging and levelling; piling of foundations; placement of jack up rigs, gravity base and suction caisson foundations) with others more specific (e.g. placement of foundations and walls associated with tidal lagoon construction). The physical presence of operating structures in the water column (e.g. offshore wind turbines, tidal stream and wave devices as well as tidal barrages or lagoons) may also cause indirect or secondary disturbance to the seabed through alterations to water movements and associated sedimentation patterns or scour.

The assessment (Section 5.4) indicates that much of the physical disturbance associated with construction activities is largely temporary (e.g. elevated suspended sediment concentrations over a period of a number of hours associated with seabed preparation activities) and localised (e.g. to the seabed footprint of jack up vessels, anchoring scars, cable corridors). The potential for large scale deployment of large gravity base foundations (and prior seabed preparation) to support consented Round 3 wind turbines probably represents a worst case incremental effect with respect to longer-term physical disturbance of the seabed but is only likely to impact small part of development areas (<2%).

Physical effects associated with cable and pipeline laying are expected to increase over the time period of OESEA3 with the construction and installation of Round 1 & 2 extensions and Round 3 OWF, wave and tidal stream demonstrator and small commercial scale arrays and gas storage and demonstrator scale carbon capture and storage projects. Estimates of cabling requirements associated with consented R3 projects indicate that over 10,000km of inter-array and export cables could be installed during the construction of the first phases of development within the Round 3 zones. Where cable and pipeline routes interact with other activities utilising the seabed (e.g. in the southern North Sea) then deep burial (e.g. as advised in the East Marine Plans) or extensive protection may be required, which may potentially cause greater disturbance to the seabed and associated biotopes (in addition to the introduction of new hard substrate to otherwise sedimentary environments). However, detailed site survey will inform the final routes of cables and pipelines and will allow developers to avoid particular seabed features, sensitive habitats and areas of archaeological importance[148].

To date, only one tidal lagoon scheme has been given planning permission although another two schemes are at an early planning stage. They are all proposed within the Severn Estuary region. Given that tidal range schemes have the potential to significantly impact the physical environment and permanently change physical hydrography and sedimentation characteristics, the degree of incremental physical change could be substantial.

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, wave and tidal stream development, but a corollary of this is fisheries displacement. On balance, however, the spatial extents of both positive and negative effects are probably negligible for most seabed habitats.

[148] Note that a high number of guidance documents are now available on recommended approaches to survey design and mitigation for cultural heritage (for example see: Gribble & Leather 2011). Written scheme of archaeological investigation associated with deemed marine licences for nationally significant offshore energy projects ensure cultural heritage is fully considered as part of the planning and installation process.

Incremental Physical footprint incremental to existing offshore activity – minor increment from oil and gas and gas storage and carbon dioxide transport and storage in existing hydrocarbon reservoirs; higher from OWF and potentially wave, tidal stream and gas and carbon dioxide storage in "other" geological formations (e.g. saline aquifers), although data is currently poor; very high for tidal range

Cumulative Cumulative effects dominated by trawling. The disturbance effect of oil and gas and OWF, wave and tidal stream development is likely to be offset by fishing exclusion, however, this could lead to displacement.

Synergistic None known

Secondary Possible changes to water movements and associated sedimentation patterns or scour.

5.16.5 Consequences of energy removal

The impacts of energy extraction by multiple wave and tidal installations on the marine environment are not well understood, due to the fact that these devices are still in the experimental/trial phase. At present it is not clear how applicable scaling-up of impacts from observations on individual or small clusters of devices to commercial scale arrays is. A number of modelling studies have investigated the impacts of different array spacings and arrangements, predominantly on the wake effect and subsequent power availability for both wave and tidal stream technologies, with varying recommendations depending on placement, device type and physical characteristics of the site. Additional studies have started to look at the implications for sediment dynamics, although these are still in their infancy.

Caution should however be used when scaling up demonstrator sized projects to full commercial scale arrays as the effect of additional installations may not simply be additive. A study on tidal stream devices in the Pentland Firth indicates that the impact of an array of devices has a threshold (>85 devices) above which changes to sediment dynamics occurs (Martin-Short *et al.* 2015). However, an alternative study (Fairley *et al*. 2015) suggests that the sum of impacts from 4 arrays of tidal devices in the Pentland Firth are additive suggesting linear cumulative impacts, although the authors also concede that this may become non-linear if the blockage effect[149] increases with larger arrays. This highlights the uncertainty surrounding incremental impacts of arrays of devices, although there are also suggestions of non-linearity associated with tidal barrages (Polagye *et al*. 2011).

Modelling studies have shown that the impacts of energy removal from tidal stream, tidal range and wave arrays may also extend up to hundreds of kilometres from deployment sites (e.g. González-Santamaría *et al.* 2012, Shapiro 2011, Wolf *et al*. 2009). It is therefore possible that the siting and installation of one marine energy type might reduce the energy availability for other marine energy types, potentially at far field sites. One example is the Puget Sound, USA where modelling has suggested that extracting power from near to the outlet to the Pacific Ocean (with the strongest current speeds) would reduce the tidal range in all the other basins in the estuary. Power extraction from the Tacoma Narrows (further upstream, with lower current

[149] Associated with flow increasing in velocity and diverting around arrays of devices thereby reducing the fraction of incident energy which is extractable. The increase in velocity around the turbine array is caused by blockage effects, which occurs when the upper and lower extremities of a turbine is in close proximity to the water surface and the seabed.

speeds and therefore lower power generation capacity) would however not significantly affect the range in other basins apart from the main basin (Polyagye *et al.* 2008), leaving more areas available for subsequent energy generation schemes. Similarly the tidal regime and water depth within parts of the wider Bristol Channel and Irish Sea (areas with potential for deployment of other tidal stream or tidal range) may similarly be affected by the placement of a barrage across the Severn from Cardiff to Western-super-Mare (Fairley *et al*. 2014, Zhou *et al.* 2014b).

The potential trade-off between power generation and environmental costs is also an issue with the scaling up of arrays. For tidal stream technologies commercial feasibility studies have proposed array layouts of regular rows of turbines spread across a channel, with the highest possible blockage ratio (ratio of device swept area to channel cross-section area) desirable for maximum power generation (Garrett & Cummins 2007). However environmental impact studies have shown that across stream "blocking" layouts have the greatest environmental impact (Walkington & Burrows 2009). Conversely, isolating clusters of turbines in particular areas of a tidal channel may be desirable environmentally but would reduce power generation by diverting high speeds around the cluster. Similarly the type of wave devices, layout and distance from shore appears to heavily influence power generation capacity, shoreline impacts and sediment transport from arrays.

The extent of any cumulative effects of multiple devices on organisms and benthic communities is not entirely understood, although the sensitivity of individual species to minor changes in hydrography suggests that at local scales any impacts from multiple devices may be significant.

Incremental Currently demonstrator scale arrays of wave and tidal stream devices provide little information on incremental effects, although modelling evidence suggests the array layout will have a significant effect especially on the incremental overlap of energy removal on subsequent devices within an array.

Cumulative Likely to be minimal at significant distances from devices and arrays, although evidence base is very limited.

Synergistic Unquantified but potentially significant in relation to wave and tidal devices (including for tidal range) whereby additional devices cumulatively remove more energy from the water column than the sum of the same number of single devices.

Secondary Unquantified – but potential impact on other users (e.g. surfing communities) from the reduction in wave height downstream of devices

5.16.6 Physical presence

The physical presence of structures in the marine environment is not expected to increase significantly following further oil and gas, gas storage and carbon dioxide storage licensing. The potential for interactions both from other marine users and relevant ecological receptors (e.g. birds and marine mammals) with offshore oil and gas infrastructure (whether positive or negative) is likely to be insignificant; in part because the number of existing surface facilities is relatively small (of the order of a few hundred and due to decline in the coming years due to decommissioning and use of existing export infrastructure by subsea developments) and because the majority are at a substantial distance offshore, in relatively deep water. However, the larger numbers of individual surface or submerged structures in offshore wind development, 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 incremental physical presence effects.

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, while noting the existence of important uncertainties in relation to bird distribution, statistical power of monitoring methods and the sensitivity of this conclusion to modelling assumptions; notably the variation and suitability of avoidance rates used in collision risk modelling, given the challenges in estimating avoidance rates between and within species.

Relevant cumulative guidance (King *et al.* 2009) and frameworks (Rijkswaterstaat 2015b) to assess the cumulative effects of OWF have identified bird species potentially susceptible to cumulative impacts for Round 3 development zones and the southern North Sea respectively.

A large proportion of the bird sensitivities identified are concentrated in coastal waters. All activities and developments covered by the draft plan/programme require site-specific information gathering and stakeholder consultation to inform consenting decisions, but in view of the particular sensitivity of the coastal zone (including birds but also a wide range of other receptors), proposed developments within territorial waters must be sited appropriately – some developments may not be compatible with a nearshore location.

Given the likely demonstrator or small array scale of wave and tidal stream development over the lifetime of the SEA, they are unlikely to represent a significant cumulative impact to coastal receptors. However, the very specific hydrographic conditions required for tidal stream devices which may overlap with important foraging areas for birds and marine mammals indicates that potential cumulative effects may arise in the future as array sizes increase or more arrays are planned.

Incremental Small increment from oil and gas, CO_2 and gas storage and marine renewables to existing exclusion zones and obstructions, visual intrusion and disturbance; potentially significant increment from offshore wind farms. 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, CO_2 and gas storage licensing round is negligible. Potential cumulative displacement, barrier effects on birds.

Synergistic No conclusive data

Secondary No conclusive data

5.16.7 Landscape/seascape

In view of existing Round 3 developments which have been consented or are in planning, the bulk of offshore wind to be installed in the coming years will be at a distance from the coast where visual effects are not expected, with the exception of ancillary development, much of which could be temporary in nature, or incremental to existing infrastructure (e.g. grid reinforcement). Section 5.15 has highlighted that a significant resource for offshore wind remains in the offshore area for both fixed and tethered turbine foundations, and given the projected cost reductions for this technology in the near-term, there is the potential that turbines could be sited further from shore to mitigate a range of effects (including on coastal seascapes), but it is accepted that where appropriately sited, wind farm development could take place in nearshore waters.

It is difficult to resolve the local implications on seascape from such developments at a strategic level, though in the areas of the East Irish Sea, Thames and Wash, the concentration of wind farms and their proximity to the coast, may lead to the seascapes of these areas being dominated by this use of the sea in the future – this is already being reflected in seascape character area descriptions, such as those for north Wales (Section 5.8). Such industrial uses of the sea have until recently characterised areas in offshore waters (for example, see the marine character area descriptions for the East Marine Plan areas) – the cumulative effects of offshore renewables are considered more likely due to their primarily (to date) nearshore location, with several technologies including tidal stream and tidal range having largely nearshore resources. Some aspects of ancillary development including port expansion could be incremental as this may take place in areas previously used by the offshore oil and gas or other industries, and may be in keeping with the character of these areas.

Resources for wave, tidal and wind technologies tend not to overlap and therefore it is unlikely that different renewable technologies will compete for space, or generate a scenario where there are cumulative effects from different types of renewable technologies. Where this might occur is in views down certain estuaries should tidal stream or range devices interrupt open sea views which are then overlain with, for instance, offshore wind turbines.

Other activities which may result from the draft plan/programme which could lead to cumulative visual impacts include gas and carbon dioxide storage, and any ancillary development of any element of the plan, though this would need to be assessed at the local level as landfall sites for these could be various. It is unlikely that any significant new oil and gas infrastructure will be commissioned within the currency of OESEA3, and in the foreseeable future as UKCS reserves decline.

Incremental In certain Round 1 and 2 leasing areas, incremental effects are characterised by successive developments of offshore wind farms which are intervisible with the coast and one another. Though Round 3 leasing areas are typically further from the coast and therefore have less potential for visual impacts at the coast, further intervisibility with future wind sites and existing sites could lead to significant incremental effects. Tidal stream, tidal range and wave devices have a low surface elevation but may incrementally add to offshore lighting and ship movements for maintenance.

Cumulative The location of wind, wave and tidal energy resources are such that there is unlikely to be any significant cumulative effects between these technologies. With regard to gas storage and CCS, any new surface infrastructure may generate cumulative visual effects. Tidal range schemes are inherently shore connected and therefore will have visual effects which may act cumulatively with other changes at the coast, for example loss of intertidal area from sea-level rise.

Synergistic No conclusive data

Secondary No conclusive data

5.16.8 Marine discharges

Total produced water discharge from UKCS oil production was 156 million m^3 in 2014, with an average oil in water content of 12.84mg/l (DECC website[150]). In comparison with this, the potential discharge from new developments following the proposed rounds 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) in close proximity to the discharge point. 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 the reinjection (or disposal on land) 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 limited planned discharges, although some chemicals are routinely used; selected and used in line with best practice the effects of this chemical usage is considered to have negligible environmental effect.

Carbon dioxide storage activities share many of sources of marine discharges as oil and gas activities (e.g. drill muds and cuttings, cementing and other chemicals associated with drilling, completion operations; discharge of chemicals during pipeline pre-commissioning operations, and operational chemical use). Discharge of saline aquifer water may occur for pressure relief during carbon dioxide injection but rapid dispersion of the brine can be engineered or would occur naturally. Given the limited extent of CO_2 storage activities likely over the life of the SEA and the controls in place, incremental effects will not be significant.

[150] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/443314/PW_Data_6-14.pdf

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, or renewable energy operations.

Secondary None known

5.16.9 Wastes to land

In view of the relatively small number of wells predicted, and the 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.

The oil and gas industry is entering a decommissioning phase for a number of North Sea and other fields. The expected lifetime of OWF turbines is 20 to 25 years and 40 years for cables and other associated infrastructure. DECC guidance indicates a general presumption in favour of the whole of all disused installations being removed and subsequently taken back to land for reuse, recycling, incineration with energy recovery or disposal at a licensed site. Therefore potential cumulative effects associated with the disposal of infrastructure from both industries is some way off given the relative age of the offshore wind industry.

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

5.16.10 Atmospheric emissions

Atmospheric emissions from offshore oil and gas exploration and production activities may contribute to reduction of local air quality (Section 5.11). Greenhouse and acid gas emissions effectively contribute to a mixed regional or global "pool" and can therefore be considered cumulative (Section 5.12).

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 and the Paris Agreement, 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.

Atmospheric emissions associated with offshore renewables are largely from their manufacture and deployment, with maintenance involving less intensive boat-based visits. Cumulative effects from an increase in port capacity or the increased utilisation of ports with existing capacity could lead to local air quality effects if unabated, particularly in existing problem areas. However, recent changes in the permitted sulphur content of marine fuels can be expected to lead to significant improvements in the quality of vessel exhaust emissions. The increased deployment of offshore renewables towards 2020 and beyond will, in association with CO_2 storage and other energy efficiency measures, cumulatively make a positive contribution to both greenhouse gas abatement and air quality improvement.

Operational air quality effects of CO_2 storage are unlikely to be significant and should not pose any cumulative effects.

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

Secondary None known

5.16.11 Accidental events

Accidental events (with environmental consequences) that could potentially occur on offshore E&P, and gas storage facilities (including carbon dioxide), and associated support vessels, include oil and chemical spills and gas releases, although large volume oil spills are only possible from oil exploration, production or export facilities (Section 5.13). Marine renewable energy 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. The increasing numbers of offshore installations in UK waters, and in particular the number and spatial footprint of large wind farms, will affect the relative risk of vessel collision. This risk is expected to be mitigated *inter alia* by siting of developments so that they do not impinge on major commercial navigation routes or significantly increase collision risk – for example see related policy in the East Marine Plans. With this caveat, the predicted scale of activity that could follow adoption of the draft plan/programme would not have a significant influence on the cumulative risk.

Regulatory mechanisms already in place require developers, vessel and facility 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 (Regional Seas 1 and 6) and effective contingency 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). A major well blowout can also result in significant release to sea of oil; however, the probability of such events occurring, and thus influencing cumulative risk, is extremely low.

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 over forty 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.

The scale of CO_2 storage activity likely to take place within the currency of OESEA3 may be reasonably expected to demonstrator scale projects. Considering the scale of likely development, even a large CO_2 leak, when regionally integrated, is likely to be insignificant when compared with that from continued non-mitigated atmospheric CO_2 emissions and the subsequent acidification of the marine system. Consequently, significant cumulative effects from accidental events associated with CO_2 storage are not expected.

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

Secondary None known

5.16.12 Summary and conclusion

A challenge in assessing cumulative impacts in relation to the draft plan/programme lies in the findings that the majority of potential effects identified are of small magnitude, largely sub-lethal and for mobile species; largely associated with behavioural changes. Such effects are difficult to measure in the field and are even more complicated to predict because of numerous other factors which are contributing to overall spatial and temporal variability. To use marine mammals as an example, the most relevant effect from the draft plan/programme is the increase in underwater noise from piling and seismic activity with the consequent risk of disturbance, given that injurious effects are mitigated for. Current attempts at addressing acoustic cumulative effects have focused on the “incremental” effects of plan activities, and while the understanding is that they are unlikely to have an effect at the population level, the uncertainties in these assessments remain very large. The next step in a more complete cumulative assessment would be to combine the effects of noise disturbance with all other pressures, including direct mortality from by-catch, effects from changes in prey distribution (from fishing and climate change), chronic exposure to contaminants etc. These interactions are likely to be even more complex than those that have been modelled so far; the scale at which they act may also vary so that some interactions can occur at certain temporal and spatial scales but not at others. Currently, predicting these kinds of interactions remains highly uncertain and quantitatively dubious. Instead, this should lead to further recommendations of regional scale targeted monitoring efforts to be able to have confidence in the assessment of trends for key ecosystem components.

5.16.13 Potential for transboundary effects

The OESEA3 covers a range of activities, some of which could take place in all UK waters, and others which are considered only for England and Wales. Transboundary effects are therefore 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 and major carbon dioxide releases

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.

5.17 Consideration of alternatives

5.17 Consideration of alternatives

5.17.1 Introduction

The reasonable alternatives to the plan/programme were described in Section 2.3 and were:

8. Not to offer any areas for leasing/licensing
9. To proceed with a leasing and licensing programme
10. To restrict the areas offered for leasing and licensing temporally or spatially

The assessment of these three alternatives is based on the consideration of effects in Sections 5.3-5.16. It is presented below by SEA topic and consists of a two stage process for each topic, which includes:

- Consideration of sources of potentially significant effect (as described in Section 5.2) with a brief explanatory narrative, including comments where effects are considered irreversible
- Consideration of OESEA2 objectives and guide phrases (as described in Section 3)

The consideration of sources of potentially significant effect uses the key below. Note that a "?" denotes where there is uncertainty:

	Potential positive impact on topic
	Potential minor positive impact on topic
?	Neutral impact on topic
	Potential minor negative impact on topic
	Potential negative impact on topic

5.17.2 Biodiversity, habitats, flora and fauna

Consideration of sources of potentially significant effect

Potentially significant effect	Alternatives 1	Alternatives 2	Alternatives 3	Narrative
Physical damage to biotopes from infrastructure construction, vessel/rig anchoring etc (direct effects on the physical environment)				'Footprint' effects associated with OWF, wet renewables, oil & gas and CO_2 storage in saline reservoirs; negligible incremental effect from gas and CO_2 storage in depleted reservoirs. Effects in most areas reversible over time; mitigation may be possible through identification and avoidance of biotopes where this is not the case.
Behavioural and physiological effects on marine mammals, birds and fish from seismic surveys				Geophysical surveys principally associated with oil & gas exploration and development; some seismic potentially required for gas and CO_2 storage. Seismic surveys may generate high source levels with significant potential for propagation.
Behavioural and physiological effects on marine mammals, birds and fish from other geophysical surveys		?	?	Includes echosounders, side-scan sonars and sub-bottom profilers used by all aspects of the plan to provide information on surface or shallow seabed. Sound levels drop off quickly with distance due to high frequency (>10kHz) and high directionality but not all systems have been adequately characterised.
Behavioural and physiological effects on marine mammals, birds and fish associated with construction phase noise[151]				Potential effects associated with pile driving primarily from OWF and to a lesser extent wave, tidal stream and oil & gas; may generate high source levels with significant potential for propagation; negligible incremental effect from gas and CO_2 storage in depleted reservoirs. Construction of tidal range schemes likely to result in significant noise both above and below water.
Behavioural and physiological effects on marine mammals, birds and fish associated with operational noise		?	?	Negligible operational noise from OWF; source levels from oil & gas production, and gas and CO_2 storage (e.g. gas compression) relatively low therefore local effects only. Potential for noise associated with operation of wave and tidal stream devices although limited information.
Behavioural and physiological effects on marine mammals, birds and fish associated with decommissioning noise				Noise emissions associated with decommissioning of all aspects of the plan are likely to be similar in nature to those generated during construction and installation, with the exception of an absence of extensive pile-driving (OWF) and seismic survey (oil and gas) noise.

[151] May include piling noise, and the detonation of unexploded ordnance (UXO).

Potentially significant effect	Alternatives 1	2	3	Narrative
The introduction and spread of non-native species				Possibility of effects mitigated by adherence to ballast water guidance. Presence of OWF and wet renewable foundations may result in localised increases in species diversity but given the widespread natural presence of hard substrates such as glacial dropstones, unlikely that foundations will facilitate the spread non-native species. Depending on species, change may be irreversible.
Behavioural disturbance to fish, birds and marine mammals etc from physical presence of infrastructure and support activities				Potential effects associated with OWF, wet renewables and oil & gas; negligible incremental effect from gas and CO_2 storage in depleted reservoirs
Collision risks to birds		?	?	Principally associated with OWF; mortality rate variable depending on location and weather conditions but unlikely to be significant at a strategic level with locational mitigation. Collision risk to diving birds from wet renewable devices not well understood.
Collision risks to bats		?	?	Limited information to quantify the risk. Principally associated with OWF; mortality rate may vary depending on location but unlikely to be significant at a strategic level.
Collision risks to water column megafauna (e.g. fish, marine mammals).		?	?	Principally associated with wet renewable devices although as yet not fully understood. Unlikely to be significant at a strategic level with locational or operational mitigation.
Barriers to movement of birds				Principally associated with OWF; significance of effect variable depending on location but unlikely to be significant at a strategic level.
				Loss of intertidal areas as a result of tidal range development may have a significant impact on foraging areas for waterbirds causing displacement of birds.
Barriers to movement of fish and marine mammals				Principally associated with wet renewables; significance of effect variable depending on location but unlikely to be significant at a strategic level with locational mitigation.
				Tidal range schemes may represent a significant barrier to the movement of migratory and estuarine fish. Effects potentially irreversible.
Changes/loss of habitats from major alteration of hydrography or sedimentation (indirect effects on the physical environment)				May be associated with OWF and wet renewables although locational mitigation should minimise impacts.
				Tidal range schemes may cause significant changes/loss of habitats as a result of altering hydrography or sedimentation patterns. Effects potentially irreversible.

Potentially significant effect	Alternatives 1	2	3	Narrative
Potential for effects on flora and fauna of produced or treated water and drilling discharges				Associated principally with oil & gas exploration and development; gas and CO_2 storage, and OWF foundations. Produced water discharges limited for new developments, with possible exception of saline aquifer water discharges; drilling discharges limited to WBM.
EMF effects on electrosensitive species		?	?	Principally associated with OWF; albeit limited, current evidence does not indicate significant effects and unlikely to be significant at a strategic level.
The nature and use of antifouling materials				Unlikely to be significant at a strategic level.
Accidental events – major oil or chemical spill				Low risk of occurrence of major spills, predominantly related to oil exploration and production. Very low risk of spills related to navigation for OWF, wave and tidal.
Accidental events – major release of carbon dioxide		?	?	Potential effects associated with CO_2 storage activities. The risk of loss of containment is considered likely to be low, although there is a very limited basis of experience and quantitative risk assessment on which to base this judgement. Potential significant effects likely to be localised and temporary.

Consideration of OESEA3 objectives and guide phrases

- Contributes to conservation of the biodiversity and ecosystems of the United Kingdom and its seas.
- Avoids significant impact to conservation sites designated at an International, European and National level (e.g. Ramsar, Natura 2000, Marine Conservation Zone, Nature Conservation Marine Protected Area and SSSI).
- Avoids significant impact to, or disturbance of, protected species and loss of habitat.

Guide phrases	Alternatives 1	2	3
Plan activities do not lead to the loss of biological diversity, the degradation in the quality and occurrence of habitats, and the distribution and abundance of species.	Neutral effect – no plan activities take place.	With appropriate regulatory control and the implementation of best practice, plan activities are unlikely to lead to significant loss of biological diversity. Habitats Regulations Assessments screenings at both strategic and project-level will consider the potential of proposed leasing/licensing and subsequent activities to affect the site	Restricting the plan spatially or temporally may allow a precautionary approach to be taken. For example, some areas with relevant interests may either not be leased/licensed until adequate information is available, or be subject to strict controls (e.g. sound exposure limits) on potential activities in the field.

Guide phrases	Alternatives		
	1	2	3
		integrity of Natura 2000 sites. Effects on MCZ/MPAs will be assessed at activity consenting and licensing stage.	
Plan activities do not cause adverse effects on marine ecosystems/valued ecosystem components.	Neutral effect – no plan activities take place.	With appropriate regulatory control and the implementation of best practice, plan activities are unlikely to lead to significant adverse effects on marine ecosystems. Tidal range aspects of the plan may represent the most significant threat to marine ecosystems/valued ecosystem components.	Restricting the areas offered spatially or temporally may facilitate protection of marine ecosystems/valued ecosystem components.
Plan activities contribute to the ecological knowledge of the marine and coastal environment through survey and discovery.	No plan activities and associated surveys take place.	Site surveys associated with plan activities may contribute to ecological knowledge, provided that they are suitably archived and made widely available.	Site surveys associated with plan activities may contribute to ecological knowledge, albeit on a more restricted basis than for alternative 2
Plan activities do not lead to disruption in habitat and species connectivity.	Neutral effect – no plan activities take place.	Principally associated with OWF; significance of effect variable depending on location but unlikely to be significant at a strategic level with locational mitigation with the potential exception of large tidal range schemes.	Restricting the plan spatially or temporally may allow a precautionary approach to be taken thereby minimising the risk of disruption in habitat and species connectivity.
Plan activities do not lead to the introduction of noise at levels which adversely affect the marine environment, including by leading to significant effects on conservation sites and sensitive species.	Neutral effect – no plan activities take place.	With appropriate regulatory control and the implementation of best practice, the potential introduction of noise at levels which may adversely affect the marine environment will be minimised. Habitats Regulations Assessments/ screenings at both strategic and project-level will consider the potential of proposed leasing/licensing and subsequent activities to affect the site integrity of Natura 2000 sites.	Restricting the plan spatially or temporally may allow a precautionary approach to be taken. For example, 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.

Guide phrases	Alternatives		
	1	2	3
Plan activities do not lead to the introduction of non-native species at levels which adversely alter marine ecosystems.	Neutral effect – no plan activities take place.	The draft plan will not lead to the introduction of non-native species at levels which adversely alter marine ecosystems. Ballast water from shipping/rigs likely to represent the main potential source of non-native species although guidance should minimise risk. Increased local species diversity may be associated with hard foundations although this is unlikely to cause significant ecosystem effects.	Restrictions on areas licensed are unlikely to reduce potential for introduction and spread of non-native species (as described in Alternative 2). However, it is considered that the draft plan will not lead to the introduction of non-native species at levels which adversely alter marine ecosystems.
The plan recognises the ecosystem importance of land-sea coupling, for instance its role in species migration.	Neutral effect – no plan activities take place.	Tidal range aspects of the plan may represent the most significant threat to fish migration. OWF developments may displace birds from migratory routes but this is unlikely to be significant.	Restricting the areas offered spatially or temporally may facilitate protection of important migratory routes (e.g. for diadromous fish returning to rivers and for birds on seasonal migrations).
The plan promotes the achievement of good ecological/environmental status for water bodies and marine sub-regions as outlined at a European Level.	Neutral effect – no plan activities take place.	The objectives of the WFD (coastal and estuarine waters) and the MFSD (marine) to promote the achievement of good status for water bodies are an integral part of the environmental management context within which the draft plan is set (see Section 2.2).	Restricting the plan spatially or temporally will facilitate attainment of the objectives as will allow a precautionary approach to be taken. Relevant areas may either not be leased/licensed until adequate information is available, or be subject to strict controls on potential activities in the field. Given the paucity of information on infield effects of some aspects of the draft plan, a precautionary approach is recommended.

Guide phrases	Alternatives 1	2	3
Conclusion	Neutral effect – no plan activities take place.	Habitats Regulations Assessments/ screenings, and the MCZ/MPA assessment during consenting/licensing process, in combination with initiatives and commitments relating to the WFD and MSFD, through adherence to regulatory controls and best practice with respect to environmental management, will ensure that the biodiversity, habitats, flora and fauna objectives are met.	Restricting the plan spatially or temporally will facilitate attainment of the objectives and will allow a precautionary approach to be taken. Relevant areas may either not be leased/licensed until adequate information is available, or be subject to strict controls on potential activities in the field. Given the paucity of information on infield effects of some aspects of the draft plan, a precautionary approach is recommended.

5.17.3 Geology, substrates and coastal geomorphology

Consideration of sources of potentially significant effect

Potentially significant effect	Alternatives 1	2	3	Narrative
Physical effects of anchoring and infrastructure construction (including pipelines and cables) on seabed sediments and geomorphological features (including scour)				‘Footprint’ effects associated with OWF, wave, tidal and oil & gas and cable / pipeline installation. Negligible effect from CO_2 and gas storage in existing hydrocarbon reservoirs, more substantial in alternative non-hydrocarbon reservoirs. Effects may be irreversible if deployed structures and materials not recovered.
				Tidal range schemes may have a very large spatial ‘footprint’ which will be effectively permanent. Larger barrage schemes are likely to result in widescale and permanent changes to the sedimentary regime of estuaries they enclose, with potential for far-field effects.
Sediment modification and contamination by particulate discharges from drilling etc. or resuspension of contaminated sediment				Predominantly associated with oil & gas exploration and development. Some drilling required for CO_2 and gas storage in non-hydrocarbon reservoirs and the foundations of OWF, wave and tidal stream devices. Limited extra drilling for CO_2 and gas storage in existing hydrocarbon reservoirs.
				Significant effects associated with the construction of tidal range schemes, which have long (multiple years) construction periods.

Potentially significant effect	Alternatives 1	2	3	Narrative
Effects of reinjection of produced water and/or cuttings and carbon dioxide				Associated principally with oil & gas exploration, gas and CO_2 storage. Effects in geological formations irreversible.
Onshore disposal of returned wastes – requirement for landfill				Associated principally with oil & gas exploration and development and gas storage. OWF, wave, tidal and CO_2 storage have limited waste production other than decommissioning.
Post-decommissioning (legacy) effects – cuttings piles, footings, foundations, *in situ* cabling etc.				Some structures/foundations below seabed level may be left after decommissioning, with potential for future exposure by sediment processes within the area. Effects may be irreversible.
		?	?	Tidal range schemes are unlikely to be removed. Effects may be irreversible
Changes to sedimentation regime and associated physical effects				Localised effects associated with changes to hydrography of the area expected for wave and tidal stream, but potentially negligible at distance although information is limited.
				Tidal range schemes will permanently alter physical conditions, with effects potentially detectable over wide areas, particularly for larger tidal barrage schemes. Effects may be irreversible
Accidental events – risk of sediment contamination from oil spills				Low risk of occurrence of major spills, predominantly related to oil exploration and production. Very low risk of spills related to navigation for OWF, wave and tidal.
Accidental events – blow out impacts on seabed				Low risk of a blow out associated with oil & gas exploration and gas storage.
Offshore disposal of seabed dredged material				Associated principally with seabed preparation and levelling for OWF in certain locations. Resulting sediment plumes temporary and significant deposition localised to disposal location.

Consideration of OESEA3 objectives and guide phrases

- Protects the quality of the seabed and its sediments, and avoids significant effects on seabed morphology and sediment transport processes.
- Protects the integrity of coastal and estuarine processes.
- Avoids significant damage to geological conservation sites and protects important geological/geomorphological features.

Guide phrases	Alternatives		
	1	2	3
Activities arising from the plan do not adversely affect the quality and character of the geology and geomorphology of seabed or coastal sediments.	Neutral effect – no plan activities take place.	Without appropriate planning measures or mitigation there is the potential for cumulative impacts of device 'footprints', especially relating to scour effects, cabling and pipeline laying, although this is still on a significantly smaller scale than the effects of demersal fishing. Some significant local scale sediment effects are expected for wave and tidal stream devices although these are potentially negligible at larger distances, with the scale of effect dependant on location, setting and physical conditions. Tidal range causes permanent large scale changes to the geomorphology of the area.	The large extent of physical effects resulting from tidal barrage construction, and their permanency, mean that very careful site consideration is required at a project specific level. Caution is also required in the planning of scaled up arrays of wave and tidal stream devices until the extent of the spatial effects of energy removal on physical processes and how they affect differing environments are better understood.
Plan activities do not lead to changes in seafloor integrity which could adversely affect the structure and function of ecosystems.	Neutral effect – no plan activities take place.	Most aspects of the plan will result in relatively limited and temporary changes to the seabed which will not have a significantly adverse effect on associated ecosystems. Tidal range schemes may have a much greater impact on the seafloor which could adversely affect the structure and function of ecosystems.	As above.
Plan activities avoid adverse effects on designated geological and geomorphological sites of international and national importance.	Neutral effect – no plan activities take place.	Certain aspects of the plan (predominantly tidal range) have the potential to significantly affect sites of geological and geomorphological importance and as such detailed site specific surveys should be conducted to assess the likely impact.	As above.

Guide phrases	Alternatives 1	2	3
Conclusion	Neutral effect – no plan activities take place.	Most aspects of the plan will have only small scale and temporary impacts on the geology and sediments of an area. Where significant levels of development, particularly OWF, are proposed in areas exposed to significant other uses (e.g. aggregate extraction marine disposal), without appropriate planning and mitigation, there is the potential for significant cumulative effects on seabed morphology and sediment transport processes. Tidal range schemes have the potential to adversely affect all of the objectives.	Restricting the plan spatially or temporally will facilitate attainment of the objectives and will allow a precautionary approach to be taken particularly with respect to the future development of large scale wave and tidal stream arrays. However further information from on site monitoring of demonstrator devices and arrays is required before specific restrictions can be suggested. Given their likely scale and longevity, it is unlikely that the significant adverse effect of tidal range schemes on the objectives would be mitigated by temporal or spatial restrictions.

5.17.4 Landscape/seascape

Consideration of sources of potentially significant effect

Potentially significant effect	Alternatives 1	2	3	Narrative
Potential effects of development on seascape including change to character (interactions between people (and their activities) and places (and the natural and cultural processes that shape them)				There will be visual effects associated with all offshore developments arising from the draft/plan programme. The significance of seascape impacts is largely dependent upon the sensitivity/capacity of individual seascapes, the specific nature of a given development, and the potential for cumulative or incremental effects between plan activities, and other existing and proposed marine activities.

Consideration of OESEA3 objectives and guide phrases

- To accord with, and contribute to the delivery of the aims and articles of the European Landscape Convention and minimise significant adverse impact on seascape/landscape including designated and non-designated areas.

Guide phrases	Alternatives		
	1	2	3
Activities do not adversely affect the character of the landscape/seascape.	Neutral effect – no plan activities take place.	In the absence of appropriate planning and project level mitigation there is the potential for incremental, cumulative effects between existing and future offshore wind zones, and in-combination effects with other elements of the draft plan/programme, particularly in areas identified as having a high number of existing users.	The spatial and temporal restriction of plan activities in relation to seascape concerns would have to be addressed at the project level through SVIA incorporating cumulative impact assessment.
The plan helps to conserve the physical and cultural visual resource associated with the land and sea.	Neutral effect – no plan activities take place.	Plan activities have the potential to generate negative impacts on the physical and cultural resource, as they introduce an industrial element, the character and scale of which will not be compatible with certain areas. Current controls, marine policy and accordance with assessment guidance should provide a suitable level of mitigation.	The spatial restriction of certain plan activities may reduce the potential visual impact at the coast and at sea in certain locations. In addition, current controls, marine policy and accordance assessment guidance should provide a suitable level of mitigation.

Guide phrases	Alternatives 1	2	3
Conclusion	Neutral effect – no plan activities take place.	Plan activities have the potential to have a significant adverse impact on the landscape/seascape objective. Most (oil & gas, gas storage, CO_2 storage, some wind and potentially wave) will take place at sufficient distance offshore that seascape impacts at the coast will be confined to ancillary developments, and these will be largely temporary. The recent trend of wind farms being sited further from shore, the emergence of tethered turbines and expected cost reduction for this technology, means there is scope for continued siting at distance from shore, but the appropriateness of wind farm locations in relation to landscape/seascape is highly site specific. In the absence of mitigation at the project level, those activities most likely to take place within close proximity of the coast (tidal range and stream) could adversely impact the objective.	As for alternative 2. Consideration is required at the project level as to the appropriateness of the siting of a particular development, both in isolation and in combination with existing and potential future developments. Existing controls, including the requirement to undertake a SVIA, should provide a suitable level of mitigation provided that cumulative impacts considerations are made and the latest available guidance followed.

5.17.5 Water environment

Consideration of sources of potentially significant effect

Potentially significant effect	Alternatives 1	2	3	Narrative
Contamination by soluble and dispersed discharges including produced water, saline discharges (aquifer water and halite dissolution), and drilling discharges from wells and foundation construction				Associated principally with oil & gas exploration and development; gas and CO_2 storage, and OWF foundations. Produced water discharges unlikely for new developments; drilling discharges limited to WBM. Effect of saline discharges unlikely to be significant if appropriate mitigation followed.

Potentially significant effect	Alternatives 1	2	3	Narrative
Changes in seawater or estuarine salinity, turbidity and temperature from discharges (such as aquifer water and halite dissolution) and impoundment				Principally associated with gas and CO_2 storage, and tidal range. Consented discharges of aquifer water etc unlikely to have a significant impact although accidental release events may be significant (see below).
				Tidal range schemes have the potential to significantly change seawater properties through impoundment.
Energy removal downstream of wet renewable devices				Unlikely to be significant for wave and tidal stream given the likely demonstrator small array scale of potential projects although location specific.
				Tidal range schemes have the potential for significant energy removal downstream with wide ranging effects on currents, turbidity etc.
Accidental events - contamination of the water column by dissolved and dispersed materials from oil and chemical spills or gas releases				Low risk of occurrence of major accidents. CO_2 and gas storage developments are not considered to represent a significant source of accidental spills where navigational safety risks have been fully considered and where there is knowledge of the reservoir properties. Overall risk associated with oil exploration and development considered low.

Consideration of OESEA3 objectives and guide phrases

- Protects estuarine and marine surface waters, and potable and other aquifer resources.
- Avoid significant impact on flood and coastal risk management activities.

Guide phrases	Alternatives 1	2	3
Plan activities do not result in concentrations of contaminants at levels giving rise to pollution effects.	Neutral effect – no plan activities take place.	With the appropriate regulatory controls and mitigation in place, regular and planned activities resulting from the draft plan should not give rise to pollution effects. Accidental events (e.g. oil/chemical spill), whilst unlikely could lead to pollution effects.	Restricting the areas offered spatially or temporally may protect areas at particular risk from accidental pollution events.

Guide phrases	Alternatives		
	1	2	3
Plan activities do not result in permanent alteration of hydrographical conditions which adversely affect coastal and marine ecosystems.	Neutral effect – no plan activities take place.	Tidal range schemes could permanently alter hydrographical conditions which could adversely affect coastal and marine ecosystems as well as impact flood and coastal risk management activities. Given the demonstrator or small array scale of likely wave and tidal stream projects these are unlikely to significantly affect ecosystems although this will be location- and technology-specific and therefore perhaps better assessed at a project level.	Restricting the areas offered for tidal range devices may limit the potential for alteration of hydrographical conditions. Given the small scale of likely wave and tidal stream projects, these are unlikely to significantly affect ecosystems, although this will be location- and technology-specific, and therefore perhaps better assessed at a project level rather than imposing strategic restrictions.
Plan activities do not result in adverse effects on saline and potable aquifer resources.	Neutral effect – no plan activities take place.	With the appropriate regulatory controls and mitigation in place, regular and planned activities resulting from the draft plan should not give rise to adverse effects on aquifers.	Restricting the areas offered spatially or temporally may increase protection of particular areas at risk from pollution events.
Conclusion	Neutral effect – no plan activities take place.	With the appropriate regulatory controls and mitigation in place, regular and planned activities resulting from the draft plan will not have a significant adverse impact on surface waters, potable and other aquifer resources. Tidal range schemes have the potential to adversely affect estuarine and marine waters as well as impact (potentially both positively and negatively) flood and coastal risk management activities.	Restricting the areas offered spatially or temporally may increase protection of particular areas at risk from pollution events. Restricting the areas offered for tidal range devices may limit the potential for alteration of hydrographical conditions and could facilitate attainment of positive flood and coastal risk management objectives.

5.17.6 Air quality

Consideration of sources of potentially significant effect

Potentially significant effect	Alternatives 1	2	3	Narrative
Local air quality effects resulting from exhaust emissions, flaring and venting				Combustion emissions arise from power generation associated with primarily oil & gas and gas storage (including CO_2 storage). Vessel emissions are associated will all elements of the draft plan.
Air quality effects of a major gas release or volatile oil spill				Offshore renewables and gas storage (including CO_2) are not considered to represent a significant source of accidental spills where navigational risks and geological characterisation have been fully considered. Overall risk of a major gas release or oil spill associated with oil exploration and development considered low.

Consideration of OESEA3 objectives and guide phrases

- Avoids degradation of regional air quality from plan related activities.

Guide phrases	Alternatives 1	2	3
The plan contributes to the achievement of air quality targets for those emissions outlined in the UK Air Quality Strategy.	Neutral effect – no plan activities take place.	Combustion emissions from power generation (e.g. for compression) are unlikely to represent a major contribution to industry or national totals. An increase in port facilities or uptake of existing port capacity could lead to an increase in emissions which can contribute to the perpetuation, or creation, of Local Air Quality Management Areas.	As for alternative 2, though with reduced potential air quality and any associated health or environmental effects from plan activities.

Guide phrases	Alternatives		
	1	2	3
Emissions from plan activities do not contribute to, or result in, air quality issues which adversely affect human health or the wider environment.	Neutral effect – no plan activities take place.	Emissions from oil & gas and gas storage (including CO_2 storage) are not expected to directly contribute to emissions which may lead to detrimental air quality and resultant health effects at a local level. The ongoing reporting of offshore oil & gas emissions through the EEMS process and the reduction of sulphur in shipping fuel through MARPOL represent just a few programmes which will help to reduce the impact of plan activities. The expansion of port activities (as above) has the greatest potential to produce effects at the local level.	As for alternative 2, though with reduced potential air quality and any associated health or environmental effects from plan activities.
Conclusion	Neutral effect – no plan activities take place.	Emissions could lead to local air quality effects around ports from which operations associated with plan activities are concentrated, particularly in existing problem areas. Emissions offshore are unlikely to significantly contribute to national totals, or to human health or wider environmental effects, and are otherwise controlled through appropriate regulation.	Emissions could lead to local air quality effects around those ports from which operations associated with plan activities are concentrated, particularly in existing problem areas. Emissions offshore are unlikely to significantly contribute to national totals, or to human health or wider environmental effects, and are otherwise controlled through appropriate regulation.

5.17.7 Climate and meteorology

Consideration of sources of potentially significant effect

Potentially significant effect	Alternatives			Narrative
	1	2	3	
Contributions to net greenhouse gas emissions				It is not expected that offshore oil and gas activities will result in significant incremental or increased emissions.

Potentially significant effect	Alternatives 1	2	3	Narrative
Reduction in net greenhouse gas emissions				The deployment of a wider range of renewable energy technologies will contribute to a significant reduction in emissions. Carbon dioxide transport and storage will not in itself contribute to emissions reductions, but as part of the wider CCS process will help in the transition to low carbon energy sources.

Consideration of OESEA3 objectives and guide phrases

- Minimises greenhouse gas emissions.
- Resilience to climate change.

Guide phrases	Alternatives 1	2	3
The plan contributes to the achievement of targets relating to greenhouse gases at a national and international level.	The expansion of offshore renewables is significantly reduced and the ability to meet targets relating to GHG emissions and renewable energy generation is reduced accordingly.	The wider deployment of offshore renewables and the storage of CO_2 would offset UK energy generation emissions and make a significant contribution to GHG targets.	A coordinated approach to deployment of new technologies is required in order to both help attain the relevant GHG reduction targets and mitigate climate change while not compromising other existing marine resources and activities.
Plan activities contribute to mitigating climate change.	Emissions potentially avoided through a larger offshore renewables sector and through the storage of CO_2 offshore are instead released to the atmosphere.	In combination with international efforts, it is predicted that a reduction in emissions from the UK can still contribute to the avoidance of the worst effects of climate change. Renewable energy has the potential to provide a long-term solution to reduced fossil fuel dependence. As this transition occurs, the maximisation of domestic fossil fuel reserves, and the storage of CO_2 represent solutions for low carbon energy production and supply security.	As above.

Guide phrases	Alternatives 1	2	3
Plan activities recognise the potential impact of climate change during their lifetime, in relation to their potential impact on coastal change, flood risk, or other climate change adaptation.	Neutral effect – no plan activities take place.	Given their large scale and expected long life, tidal range schemes have the potential to change the nature of the coastal environment and its ability to respond to flooding and other aspects of potential climate change, both negatively and positively.	Careful siting of tidal range schemes may benefit the area's ability to cope with coastal flooding and potential increased sea levels.
Conclusion	In the absence of the plan/programme, any contribution from further offshore renewables, as well as the ability to abate the emissions from terrestrial gas or coal power stations using some of the most prospective geological sites in the UK would not be possible, with incremental effects relating to climate change goals, security of supply and import dependence.	Plan/programme activities will make a significant contribution towards reducing UK GHG emissions. Though oil and gas activities do not confer any climate change mitigation, emissions from these activities are increasingly controlled (e.g. through emissions trading and reduced flaring), and it is not expected that emissions from the sector will appreciably change in the lifetime of this SEA.	The spatial restriction of certain activities could reduce the overall potential of the draft plan/programme to contribute towards reduced net UK GHG emissions.

5.17.8 Population and human health

Consideration of sources of potentially significant effect

Potentially significant effect	Alternatives 1	2	3	Narrative
Potential for effects on human health associated with reduced local air quality resulting from atmospheric emissions associated with plan activities				Negligible negative effects at a strategic level. The contribution of renewable energy should result in a net positive effect.
Potential for effects on human health associated with discharges of naturally occurring radioactive material in produced water				Negligible negative effects at a strategic level.
Accidental events – potential food chain or other effects of major oil or chemical spills or gas release				Negligible negative effects at a strategic level.

Consideration of OESEA3 objectives and guide phrases

- Has no adverse impact on human health and wellbeing.

- Avoids disruption, disturbance and nuisance to communities.

Guide phrases	Alternatives		
	1	2	3
Plan activities do not result in, or contribute to the contamination of fish and other seafood for human consumption at levels which exceed those established by Community legislation or other relevant standards.	Neutral effect – no plan activities take place.	Discharges from plan activities are subject to regulatory controls at the project level, and are not expected to contribute to the contamination of fish or seafood for human consumption.	As for alternative 2, though discharges may be reduced in line with a potentially smaller number of developments, subject to any spatial restrictions.
Plan activities avoid adverse effects on physical and mental health.	Neutral effect – no plan activities take place.	Plan activities will be subject to Health and Safety requirements and other regulatory controls at the project specific level.	As for alternative 2, though spatial and temporal restriction will reduce the number of people potentially affected by plan activities.
Plan activities avoid adverse nuisance to communities, for instance through noise or vibration.	Neutral effect – no plan activities take place.	As above.	As above.
Adverse effects on the quality or access to areas used for recreation (e.g. amenity, sailing, surfing), are minimised or avoided.	Neutral effect – no plan activities take place.	Potentially significant effects could arise (at strategic level) from OWF and other marine renewables due to spatial scale and the location-specific nature of areas used for recreation. Existing leasing/licensing measures and regulatory controls (e.g. EIA) provide a suitable level of control with regard to the location of activities.	As for alternative 2, though spatial and temporal restriction will reduce the number of people potentially affected by plan activities.
Conclusion	Neutral effect – no plan activities take place.	Plan activities should not contribute to wider adverse effects on physical and mental health, subject to project level assessment.	Plan activities should not contribute to wider adverse effects on physical and mental health, subject to project level assessment.

5.17.9 Other users and material assets (Infrastructure, Other Natural Resources)

Consideration of sources of potentially significant effect

Potentially significant effect	Alternatives			Narrative
	1	2	3	
Positive socio-economic effects of reducing climate change				The economic consequences of climate change outweigh the cost of early abatement through GHG reduction.

Potentially significant effect	Alternatives 1	Alternatives 2	Alternatives 3	Narrative
Interactions with fishing activities (exclusion, displacement, seismic, gear interactions, "sanctuary effects")				Potential significant effects (at strategic level) arise 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				Potential significant effects (at strategic level) arise from OWF developments due to spatial scale; location-specific.
Accidental events – socio-economic consequences of oil or chemical spills and gas releases				Associated principally with oil & gas exploration and development, gas storage (including CO_2); low risk of significant event.

Consideration of OESEA3 objectives and guide phrases

- 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.
- Safety of Navigation.
- Reduces waste.

Guide phrases	Alternatives 1	Alternatives 2	Alternatives 3
Plan activities integrate with the range of other existing uses of the marine environment.	Neutral effect – no plan activities take place.	Mitigation between plan activities and existing users is already controlled through a range of licensing and leasing conditions, and regulatory controls. The co-location of activities could take place where it is deemed appropriate. Formal marine planning is presently underway for UK seas, and should be complete during the currency of this SEA. Greater activity coordination should be expected through marine planning.	The spatial restriction of certain plan activities would reduce the potential for interactions with other users of the sea.

Guide phrases	Alternatives		
	1	2	3
Plan activities do not result in adverse effects on marine assets and resources.	Neutral effect – no plan activities take place.	Plan activities should not sterilise areas of potential future use (e.g. potential hydrocarbon resources) or compromise those presently in use (e.g. aggregate extraction areas) through inappropriate siting. Developers and marine plans should take account of this effect (for example, as has been the case for policies in the East Marine Plans).	As for alternative 2, though further spatial restrictions based on environmental and socio-economic considerations would lead to a reduced likelihood of adverse effects on marine assets and resources.
Plan activities avoid adverse effects on, and contribute to the maintenance of, safe navigation, including recognised shipping routes, traffic separation and existing and proposed port operations.	Neutral effect – no plan activities take place.	Potentially significant effects could arise (at strategic level) from OWF and other marine renewables due to spatial scale and the location-specific nature of certain resources, though activities would not take place in specified IMO routeing areas. Existing leasing/licensing measures and regulatory and planning controls (e.g. consent to locate) provide a suitable level of control with regard to the location of activities.	As for alternative 2. The SEA has highlighted, in addition to IMO routeing, a range of indicative navigation routes – suitable shipping traffic surveys would need to be undertaken at the project level to assess the risk to shipping. Spatial restrictions may reduce the overall impact on navigation from plan activities.
Properties and quantities of waste and litter resulting from plan activities do not cause harm to the coastal and marine environment.	Neutral effect – no plan activities take place.	Through existing regulatory controls, offshore waste is returned to shore and disposed of appropriately.	Through existing regulatory controls, offshore waste is returned to shore and disposed of appropriately.
Conclusion	Neutral effect – no plan activities take place.	Plan activities have the potential to negatively impact existing users of the sea. There is the potential for colocation of activities where it is appropriate. Activities will not generate waste related impacts at sea or at the coast, nor will they impact upon present or potential marine resources.	Plan activities have the potential to negatively impact existing users of the sea. There is the potential for colocation of activities where it is appropriate. Activities will not generate waste related impacts at sea or at the coast, nor will they impact upon present or potential marine resources.

5.17.10 Cultural heritage

Consideration of sources of potentially significant effect

Potentially significant effect	Alternatives 1	2	3	Narrative
Physical damage to submerged heritage/archaeological contexts from infrastructure construction, vessel/rig anchoring etc and impacts on the setting of coastal historic environmental assets and loss of access.				The risk of damage associated with the footprint of oil and gas, gas storage (including CO_2), OWF and other marine renewables anchoring is mitigated through appropriate preparatory survey work. Such survey work has the potential to make positive contributions to identification and interpretation of archaeological remains.
				Given their coastal nature and large scale, tidal range schemes have the potential to significantly impact the setting of historic environmental assets.

Consideration of OESEA3 objectives and guide phrases

- Protects the historic environment and cultural heritage of the United Kingdom, including its setting.
- Contributes to archaeological knowledge.

Guide phrases	Alternatives 1	2	3
Activities avoid adverse effects on the character, quality and integrity of the historic and/or cultural landscape, including those sites which are designated or registered, and areas of potential importance.	Neutral effect – no plan activities take place.	The impact of plan activities on the archaeological resource is largely mitigated through statutory controls and project level assessment and reporting in keeping with industry guidelines, though in the absence of the same level of protection offshore as afforded onshore, site specific surveys would be required to prevent any loss to the marine archaeological resource. The Marine Policy Statement notes that the lack of designation for some sites does not necessarily indicate a level of lower significance.	The outcome is the same as for alternative 2, though certain areas would be avoided though primarily for environmental or socio-economic reasons, though these may confer indirect protection to certain areas of interest, for instance intertidal areas.

Guide phrases	Alternatives		
	1	2	3
Plan activities contribute to the archaeological and cultural knowledge of the marine and coastal environment through survey and discovery.	No plan activities and associated surveys take place.	Site surveys associated with plan activities may identify new archaeological material and further knowledge in this area, provided that reporting is undertaken in keeping with established codes of practice.	Site surveys associated with plan activities may identify new archaeological material and further knowledge in this area, albeit on a more restricted basis than for alternative 2.
Conclusion	Neutral effect, though the potential for industry led research from plan activities is reduced.	Preparatory survey work will both help to minimise potential damage to marine archaeological sites, and further knowledge in the area.	Preparatory survey work will both help to minimise potential damage to marine archaeological sites, and further knowledge in the area.

6 Recommendations & Monitoring

6.1 Recommendations

The conclusion of OESEA3 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 together with a number of mitigation measures to prevent, reduce and offset significant adverse impacts on the environment and other users of the sea. This conclusion has been reached through a consideration of the agreed reasonable 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.

Substantial progress has been made in implementing the recommendations made in earlier UK Offshore Energy SEAs which, together with a wide range of other initiatives (reflected in this document, particularly Section 5 and Appendix 1) have served to improve understanding of receptors and effects. However, a number of important areas of uncertainty remain and these are summarised below.

A number of recommendations are made arising from the OESEA3 process, for detail see the topic specific assessments in Section 5. Many recommendations apply to all the different elements of the draft plan/programme as there is a large degree of commonality in the potential sources of effect from the different industrial activities. The introduction of marine spatial planning across UK waters, with some marine plans in place and those for the remaining areas in preparation, is recognised and reflected in the recommendations made in respect of the current draft plan/programme.

The recommendations are listed below under the four categories of: spatial considerations, managing environmental risk, improving the information base, and best practice/mitigation. No implied priority is given to the ordering of the recommendations. Where appropriate, these recommendations reflect the recommendations made in previous DECC SEAs including any elaboration made in the Post Consultation Reports.

6.1.1 Spatial considerations

1. It is recommended that leasing/licensing and any subsequent consenting of activities should ensure the minimisation of disruption, economic loss and safety risks to other users of the sea and the UK as a whole. It is recognised that individual projects will be assessed on a case by case basis through the relevant planning process. However, in advance of formal and spatially explicit marine planning for most UK seas, and recognising the overarching policy of the UK Marine Policy Statement, developments (individually or cumulatively) should aim to:

- avoid impingement on major commercial navigation routes where this could significantly increase collision risk or lead to appreciably longer transit times;
- avoid causing alteration to the ease and safety of navigation in port approaches or reduce the commercial attractiveness of the ports e.g. through increases in vessel insurance premiums;

- avoid occupying recognised important fishing grounds in coastal or offshore areas (where this would prevent or significantly impede sustainable fisheries);
- avoid potential disruption of existing and potential future aggregate supplies;
- avoid interference with civilian aviation operations necessary to ensure aviation safety, efficiency and capacity, including radar systems, unless the impacts can be mitigated, are deemed acceptable, are temporary or can be reversed;
- avoid jeopardising national security for example through interference with radar systems or unacceptable impact on training areas unless the impacts can be appropriately mitigated or are deemed acceptable in consultation with MoD;
- avoid causing significant detriment to tourism, recreation, amenity and wellbeing as a consequence of deterioration in valued attributes such as landscape, tranquillity, biodiversity and hydrographic features;
- explore opportunities for co-location which could mitigate potential spatial conflicts with existing users.

2. As part of the Natura 2000 and linked initiatives, further offshore SACs, SPAs, MCZs and MPAs (and extensions to them) are being identified. Although in line with the UK Marine Policy Statement, existing and future Natura 2000 and MCZ/MPA sites are not intended or treated as strict no-go areas for other activities, competent authorities have a responsibility to secure compliance with the requirements of the Habitats and the Wild Birds Directives. It is recommended that developers are made aware at the licensing/leasing stage that SAC/SPA or MCZ/MPA designation may, subject to the conclusions of any Habitats Regulations or MCZ/MPA Assessment, preclude development or necessitate suitable mitigation measures so as to avoid adverse effects on a designated site or species.

3. The importance of territorial waters and adjacent coasts is reflected in numerous, often overlapping designations to protect their scenic, geological, ecological and cultural features, and designations or use for recreational, shellfishery, fishery, navigational, commercial and other activities. The environmental sensitivity of coastal areas is not uniform and the intensity of designations and uses typically declines further offshore away from the coast. All activities and developments covered by the draft plan/programme require site-specific information gathering and stakeholder consultation to inform consenting decisions. In addition to marine spatial plan requirements, the particular sensitivity of the coastal zone and must be taken into account during site selection for proposed developments within territorial waters. Some developments may not be compatible with a particular nearshore location.

4. In view of the above, extensions to existing wind farm lease areas during the currency of the SEA requires careful site-specific evaluation since significant new information on sensitivities and uses of these areas is now available.

5. Important navigation routes were identified as part of the first marine plans in England, primarily in territorial waters. In view of the projected construction of major offshore of wind farms resulting from Round 3 leasing, and that further wind farms may be proposed in these and other areas (for fixed and tethered turbines), it is considered that a wider set of offshore routes be considered and documented. This would help to ensure continuity of efficient and safe shipping traffic between UK national and international ports. Where necessary, important navigation routes could be treated as “Clearways” in the siting and

consenting of marine developments. These would require agreement for all waters of the British Isles as well as international coordination for transboundary routes since there are wind farm and other development proposals in the waters of adjacent states.

6. For the area to the west of the Hebrides 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 deeper parts of the Southwest Approaches, beyond the shelf break, in waters >200m deep. 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 in these areas can be revisited. The potential for collaborative investigations in the areas is recognised reflecting the cost and difficulty of studies in distant, deep waters.

6.1.2 Managing environmental risk

7. The offshore wind and marine renewable industry remains relatively young, with appreciable technological development expected in for example, turbine size, rotation speed, foundation structure, spacing and potentially rotational axis. A firm base of information is required to inform risk assessments and adaptive management, and consequently in respect of ecological receptors a precautionary approach to facility siting in areas known to be of key importance to bird and marine mammal populations is recommended unless evidence indicates that impacts can be appropriately mitigated.

8. For areas which contain habitats/species listed in the Habitats Directive Annexes or those for which MCZs and MPAs have been designated, developers should be made aware that a precautionary approach will be taken and some areas may either not be leased/licensed until adequate information is available, or be subject to strict controls on potential activities.

9. Previous SEAs have recommended consideration of the establishment of criteria in relation to underwater noise for determining limits of acceptable cumulative impact and for subsequent regulation of cumulative impact. The advances made in this respect through the establishment of the indicator on low- and mid- frequency impulsive sounds under the Marine Strategy Framework Directive are recognised. While criteria have not yet been defined, the establishment of the Marine Noise Registry database to collate occurrences of ‘noisy activities’ represents the necessary precursor. It is recommended that these efforts are prioritised to allow effective consideration of the cumulative impacts of underwater noise.

10. Beaked whales are very sensitive to anthropogenic noise (particularly to powerful sonar but potentially also to seismic survey) and their behaviour makes them difficult to observe visually or acoustically as part of implementation of standard seismic survey mitigation procedures. In recognition of this, it is recommended that opportunities to enhance mitigation measures for beaked whales beyond those in the JNCC guidelines for minimising the risk of injury and disturbance to marine mammals from seismic surveys should be considered during deep water seismic survey planning and implemented during operations.

11. A range of chemicals are used in marine renewables developments and during operations, a proportion of which are discharged to sea. On the UKCS all chemicals used in the exploration and production of offshore hydrocarbons (and de facto CCS) are controlled through the Offshore Chemical Notification Scheme, reflecting the OSPAR Harmonised Mandatory Control Scheme. Since most of the chemicals used by the renewables industry are similar to those used in the oil and gas industry there seems a

logic to standardise their control and reporting (including those chemicals listed by OSPAR for priority action or candidates for substitution).

12. The nature and uses of the range of estuaries and embayments in which tidal range developments have been and may be proposed vary widely. Similarly there is a wide diversity in the type and location of installations proposed to exploit tidal range. Consequently it is recommended that site specific assessments are undertaken before decisions can be taken on potential leasing and the desirability and acceptability of individual projects, and that successive tidal range proposals should consider the potential for local, regional and wider far-field effects to be generated cumulatively. Such assessments will require a broad subject, spatial and temporal consideration e.g. coastal defence trends and plans, local and regional nutrient flows and siltation patterns, feasibility of compensatory measures for effects on Natura 2000 sites, effects on endangered diadromous fish, and the importance for waterbirds the UK assumes during extreme cold winters.

13. The subject of cumulative effects assessment (CEA) is challenging at project, industry and strategic levels, and is frequently raised by stakeholders as an issue. The establishment of a Cross-Government Cumulative Effects Assessment Working Group is welcomed as, is its aim to develop guidance for regulators, advisors and applicants to help increase consistency in application of CEA. At all levels of assessment, guidance on the spectrum of certainty and the point beyond which CEA is considered conjectural would be useful.

6.1.3 Improving the marine management information base

Although the information base continues to improve, there remain a number of subject areas for which information is limited and should be enhanced to support appropriate development site selection and 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.

14. Although there has recently been significant boat based and aerial survey effort in coastal waters, there is a general lack of modern survey data on waterbirds in offshore areas. Adequate data on waterbird distribution and abundance is a prerequisite to effective environmental management of activities, for example, in timing of operations to avoid periods of particular sensitivity. A comprehensive analysis of the European Seabirds at Sea (ESAS) database was undertaken to identify possible marine SPAs but gaps in spatial coverage necessitated the use of interpolation to estimate values for un-surveyed areas. The development of high-precision tracking devices has led to a recent upsurge in bird tracking studies, and for some species several hundreds of individuals have been tracked from numerous colonies around the UK, allowing the marine distribution of some species to be predicted from tracking data. It is recommended that the results of cross-validations of models of marine distribution derived from tracking individual birds with those from at-sea survey are assessed to inform decisions on the nature and location of waterbird distributional research.

15. In view of the potential interest in deepwater hydrocarbon exploration to the west of the Hebrides, improved understanding of the ecology and location of important areas for beaked whales should be obtained to underpin assessments of effects and identification of mitigation measures. The forthcoming SCANS III survey is noted but specific research on beaked whales in deepwater areas of the UK is also required.

16. A number of conservation sites have been recently proposed for harbour porpoise in parts of the UK. To support the assessment of potential effects of proposed activities (in

sites and beyond), improved understanding of their ecology is needed, along with that of their prey and interspecific interactions (such information will assist in the management of the population(s) in UK waters). The forthcoming SCANS III survey is noted, the data from which will inform efforts to understand the underlying causes of temporal variability in harbour porpoise distribution evident from the results of the SCANS I and II surveys.

17. Whilst the information base has improved in recent years, further data are required on the spatial scale at which marine mammals and their prey respond to well characterised noise sources, and whether this varies according to individual characteristics, behavioural state or other environmental variables, and whether the scale of effects is sufficient to cause significant adverse effects at an individual or population scale.

18. There is a need for enhanced, strategic level understanding of biodiversity and its patterns in UK waters, in particular for the species (e.g. the bivalve *Arctica*) and features (e.g. habitats characterised as seapens and burrowing megafauna communities or burrowed mud) used as the bases for MCZ/MPA identification and designation, to inform considerations of site integrity and the assessment of proposed activities impinging on sites.

19. There is little information available on the interaction of birds, marine mammals and fish with surface and submerged wave and tidal stream and range generation devices. It is recommended that for the deployment of single devices and small arrays, appropriately focussed surveys of animal activity and behaviour should be undertaken to inform commercial scale deployment risk assessments and consenting. A strategic and coordinated approach to such research is recommended since the results will be of wider application; research results should be made publicly available where ever possible.

20. For some areas there is excellent data on seabed topography and texture from multibeam mapping undertaken under various auspices including by the MCA, BGS and the SEA programme. The NERC Marine Environmental Mapping Programme (MAREMAP) and the scoping study for a UK National Seabed Mapping Programme are noted. However, significant gaps in coverage remain, and continued effort should be focussed on developing comprehensive coverage of the UKCS, prioritising areas of industrial and conservation interest.

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 UKOilandGasData, Marine Data Exchange 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.

6.1.4 Best practice/mitigation

22. The volumes of rock used for example in cable armouring, foundation scour protection and pipeline protection and upheaval buckling prevention must be the minimum required to provide the necessary protection in order to minimise permanent habitat change and to ensure areas developed as a result of the current draft plan/programme are left fit for other uses after decommissioning. Alternative methods of protection/control should be considered to minimise the potential for permanent habitat change.

23. In areas with vulnerable habitats and species such as maerl beds and cold water coral reefs mitigation may be required for physically damaging activities such as rig/vessel anchoring, discharges of drilling wastes and cable, pipeline or umbilical installation (from

hydrocarbon, gas storage or renewable energy related activities). Prior to decisions on activity consenting in such areas, developers should provide a detailed assessment and seabed information so that appropriate site specific mitigation can be defined.

24. Whilst it is recognised that most developers in the marine environment have Health, Safety & Environmental management systems in place, it is recommended that companies involved in the planning, undertaking and control of marine activities resulting from the current draft plan/programme operate Environmental Management Systems which are consistent with an international standard.

25. Site surveys for marine developments can identify unexploded ordnance (UXO), which is either left in situ or rendered harmless through attachment and detonation of an explosive charge. Human safety is paramount in such decisions, but the potential to minimise the cumulative effects of the percussive noise on marine mammals should be explored, in particular in relation to conservation sites established or proposed for seals or cetaceans in areas of relatively high UXO occurrence e.g. the southern North Sea.

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 three types:

- Emissions monitoring
- Effects monitoring
- SEA objectives monitoring

Each of these is summarised below.

6.2.1 Emissions monitoring

As required by the various environmental permits and other environmental legislative requirements (see Appendix 3), developers must monitor and report the quantities of solid, liquid and atmospheric emissions, discharges and wastes generated. For the marine renewable energy industry this is required as part of a combined marine licence; for the oil industry, including gas storage, this is reported 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 enforce statutory instruments in support of this, offshore installations are inspected and operators are encouraged to use Best Environmental Practice (BEP) and Best Available Technique (BAT) in all activities. This also applies to carbon dioxide storage facilities, except those in Scottish Territorial Waters where the Scottish Government have responsibility.

6.2.2 Effects monitoring

There has been extensive monitoring of the effects of UK offshore oil and gas activities since 1975, and several regional surveys have been undertaken in recent years under the auspices of DECC/OGUK Monitoring Committee, Marine Scotland, 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 marine licence 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 periodically reviewed as part of the DECC SEA process and to date is considered adequate to understand the evolution of baseline conditions in respect of sediment contamination and biological effects across the SEA areas. For other marine renewable energy generation types, monitoring of effects is in its infancy although the body of information is expected to grow through monitoring required by marine licence and other permit conditions. With the exception of loss of integrity of the geological store, the effects of carbon dioxide transport and storage developments are anticipated to be largely similar to those of offshore hydrocarbon exploration, production and storage. Research studies into the likely effects of large release of carbon dioxide have helped define the scale of potential impacts as well as suitable monitoring methods. Developer initiated and permit required monitoring is expected to provide the basis for effects monitoring of demonstrator and commercial scale developments and their operation. In view of the ongoing regional marine planning processes for UK seas, and their related sustainability appraisals (SA), there is the potential for future synergies in the monitoring of marine plans/marine plan SAs and the OESEA programme.

6.2.3 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 4). The agreed objectives and indicators are given in Section 3.5. 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 the UK Charting Progress 2 Report was published in 2010. Similarly the last OSPAR Quality Status Report was published in 2010, with an intermediate assessment planned for 2017 and the next QSR scheduled for 2021. Data from the monitoring of the effects of the implementation of this draft plan/programme would be included in future such reports as well as those reporting on the achievement of good environmental status as required by the Marine Strategy Framework Directive. The conservation status of UK Natura 2000 (and MCZ/MPA) sites is monitored by the statutory nature conservation agencies and progress with Habitats & Birds Directives implementation, including marine Natura 2000 sites is reported to the European Commission by Defra.

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 advises Government on the level of carbon budgets and submits annual reports to Parliament on the UK's progress towards targets and budgets to which the Government must respond. The 5th Carbon Budget is scheduled for publication in June 2016.

7 Next steps

The Offshore Energy SEA 3 Environmental Report and supporting documents are available for review and public comment for a period of 8 weeks from the date of publication. The documents are being made available from the SEA webpages of the gov.uk website and https://www.gov.uk/government/consultations/. Comments[152] and feedback should be marked "OESEA3 Consultation" and may be made via the website or by letter or e-mail addressed to:

Email: oesea3@decc.gsi.gov.uk

Postal address:

Offshore Energy SEA 3 Consultation
The Department of Energy and Climate Change
4th Floor Atholl House
86-88 Guild Street
Aberdeen AB11 6AR

The Department will consider comments received from the public consultation in their decision making regarding the draft plan/programme. Following public consultation a Post Consultation Report will be prepared and placed on the SEA webpages collating the comments, DECC responses to them. On adoption of the plan/programme a Statement will be published detailing:

- how environmental considerations have been integrated into the plan/programme
- how the Environmental Report has been taken into account
- how opinions expressed by the consultation bodies and public consultees on the relevant documents have been taken into account
- how the results of any consultations entered into with other Member States have been taken into account (if required)
- the reasons for choosing the plan/programme as adopted, in the light of the other reasonable alternatives dealt with; and
- the measures that are to be taken to monitor for potential significant environmental effects of the implementation of the plan/programme.

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[152] **Confidentiality and data protection:** We will summarise all responses and place this summary on the OESEA3 section of the GOV.UK website. This summary will include a list of organisations that responded, but not people's personal names, addresses or other contact details. Information provided in response to this consultation, including personal information, may be subject to publication or disclosure in accordance with the access to information legislation (primarily the Freedom of Information Act 2000, the Data Protection Act 1998 and the Environmental Information Regulations 2004). If you want information that you provide to be treated as confidential please say so clearly in writing when you send your response to the consultation. It would be helpful if you could explain to us why you regard the information you have provided as confidential. If we receive a request for disclosure of the information we will take full account of your explanation, but we cannot give an assurance that confidentiality can be maintained in all circumstances. An automatic confidentiality disclaimer generated by your IT system will not, of itself, be regarded by us as a confidentiality request.

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Glossary and Abbreviations

Term	Definition
µatm	Microatmospheres
µg	Microgram(s)
µPa	Micropascal(s) (unit of pressure)
µS	Micro second
2D seismic	A two dimensional (2D) seismic survey involves a survey vessel towing a single airgun array and a single streamer, containing several hydrophones along its length.
3D seismic	In a three dimensional (3D) seismic survey, a vessel tows two or more airgun arrays and several streamers. Because the streamers are close to each other, data density is much improved with respect to 2D.
4D seismic	A series of 3D seismic surveys acquired at the same place at different times
AA	Appropriate Assessment
Abiotic	Refers to non-living objects, substances or processes e.g. climate
Abyssal	Relating to the great depths of the ocean, typically in water depths of 2000-6000m
AC	Alternating current where the movement of electric charge periodically reverses direction
Acceptable EE%	For tidal stream devices, the limit of percentage energy extraction before any significant environmental effects occur.
Accretion	An increase resulting from depositional processes
Actinaria	Sea anemones
ADCP	Acoustic Doppler Current Profiler
Aeolian	Wind-borne source
AFBI	Agri-Food and Biosciences Institute
AFEN	Atlantic Frontier Environmental Network
AGLV	Areas of Great Landscape Value
AHD	Acoustic Harassment Device
AIFMCL	Aviation Investment Fund Company Limited
AIP	Aeronautical Information Package
AIS	Automatic Identification System (related to navigation)
AIS	Air Insulated Switchgear (related to cables)
ALARP	As Low As is Reasonably Practical
AMD	Acoustic Mitigation Device
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*
AMO	Atlantic Multidecadal Oscillation
AMOC	Atlantic Meridional Overturning Circulation
Amphipods	Small crustaceans e.g. “sandhoppers”
AN	Aerodynamic Noise
Anadromous	Fish (e.g salmon) that migrate 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	Area of Search
AOS	Apparently Occupied Sites (birds)
AoSP	Area of Special Protection
AOT	Apparently Occupied Territories (birds)
APS	Annual Population Survey
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
Array	For this SEA, a number of renewable devices deployed at a commercial scale
ARU	Automated Recording Unit
ASACS	Air Surveillance and Control Systems
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 (Northern Ireland)
ATBA	Areas To Be Avoided
ATC	Air Traffic Control (aviation)
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
B field	Magnetic field component of a cable
BACI	Before-After Control-Impact, experiment design often used to monitor for potential environmental impacts
Bacterioplankton	The bacterial component of plankton
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 $0.4ms^{-1}$
Barrage	An artificial obstruction, such as a dam, built in a watercourse to increase its depth or to divert its flow, referring in this case to enclosure of estuaries for the extraction of tidal range energy
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
BE-AWARE	Bonn Agreement: Area-Wide Assessment of Risk Evaluations (spill modelling)
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
BERR	Department for Business, Enterprise and Regulatory Reform (former name for DECC and BIS)

BGS	British Geological Survey
BIIS	British-Irish Ice Sheet
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 2009/147/EC on the conservation of wild birds
BIS	Department for Business, Innovation & Skills
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
BMAPA	The British Marine Aggregate Producers Association
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
BOWL	Beatrice Offshore Windfarm Limited
BP	Before Present (years)
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
BRES	Business Register and Employment Survey
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
Byssus	A tough, thread-like structure by which mussels attach themselves to the substratum
CAA	The UK Civil Aviation Authority
Caisson	A watertight chamber open at the bottom and containing air under pressure
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
Catadromous	Fish (e.g eel) that migrate from freshwater rivers to the sea to spawn
Catenary	An inextensible cord hanging freely from two fixed points with a curved shape
CBD	Convention on Biological Diversity
CCA	Climate Change Agreement

CCC	Committee on Climate Change
CCL	Climate Change Levy
CCRA	UK Climate Change Risk Assessment
CCS	Carbon capture and storage
CCTS	Scottish carbon capture, transport and storage development study
CCW	Countryside Council for Wales (now NRW)
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
Cephalopods	Marine molluscs including squid, octopus and cuttlefish
CEA	Cumulative Effects Assessment
CET	Central England Temperature dataset
Cetaceans	Aquatic mammals including whales, dolphins and porpoises
CFCs	Chlorofluorocarbons
CfD	Contracts for Difference
CFP	Common Fisheries Policy
CGNS	Celtic & Greater North Seas
CH_4	Methane
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
CHP	Combined Heat and Power plant
CIA	Cumulative Impact Assessment
CITES	Convention on International Trade in Endangered Species
CLRTAP	The UNECE Convention on Long-Range Transboundary Air Pollution
Clupeids	Fish of the family Clupeidae including herring, sprat and anchovy
CMA	Centre for Maritime Archaeology
CMACS	Centre for Marine And Coastal Studies
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
CO	Carbon monoxide
CO_2	Carbon dioxide
Coastal lagoon	Small, shallow basin which has very low (or negligible) freshwater input
Coccolithophorids	Exclusively marine phytoplankton characterised by calcium carbonate plates
CODA	Cetaceans Offshore Distribution and Abundance in the European Atlantic
Coelenterates	Invertebrate animals of the phylum Cnidaria including the jellyfishes, hydras, sea anemones, and corals
COLREG	Convention on the International Regulations for Preventing Collisions at Sea
COMEAP	Committee on the Medical Effects of Air Pollutants
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	Marine sediment deposited by fast flowing ocean-bottom currents along contours.
Copepods	Small crustaceans, usually planktonic
COWRIE	Collaborative offshore wind research into the environment
CPA	Coast Protection Act
C-POD	Passive acoustic monitoring device
CPR	See *Continuous Plankton Recorder*
CRC	CRC Energy Efficiency Scheme (the CRC, formerly the Carbon Reduction Commitment)

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
CRM	Collision Risk Modelling
CRoW	*Countryside and Rights of Way Act 2000*
Crustaceans	Arthropods (mostly aquatic) usually having a segmented body and chitinous exoskeleton e.g. crabs, lobsters, copepods
CSA	Council for Scottish Archaeology
cSAC	See *Candidate Special Area of Conservation*
CSEMP	Clean Seas Environmental Monitoring Programme
CSIP	UK Cetacean Strandings Investigation Programme
CSON	Continental Shelf Operations Notice
CTD	Conductivity + Temperature + Depth sensor
Ctenophores	Any of various marine animals of the phylum Ctenophora, having transparent, gelatinous bodies bearing eight rows of comb-like cilia used for swimming
CZCS	Coastal Zone Colour Scanner
DAC	Data Archive Centre
DAF	Displacement Assessment Framework
DARDNI	Department for Agriculture and Rural Development, Northern Ireland
dB	Decibel(s)
DC	Direct current, where the flow of electric charge is only in one direction
DCS	Decompression sickness
DCS	Dutch Continental Shelf
DDT	Dichloro-Diphenyl-Trichloroethane
Decalcified fixed dunes	Mature stages of sand dune succession
Decapods	Crustaceans characterised by ten legs, such as lobsters, crabs, shrimps and prawns
DECC	Department of Energy and Climate Change (formerly BERR, DTI)
Defra	Department for Environment, Food and Rural Affairs
Delphinids	Dolphins and porpoises
DEM	Digital Elevation Model
Demersal	Living at or near the bottom of the sea
DEPCON	Deposit Consent (included in Pipeline Works Authorisation)
DETI	Department of Energy, Trade and Industry
Development well	Well drilled in order to produce hydrocarbons from a proven field
DFOWDC	Dounreay Floating Offshore Wind Development Centre
DHSV	Down Hole Safety Valve
Diadromous	Fish that migrate between freshwater and saltwater. May be either anadromous or catadromous
Diamicton	Thick unconsolidated muddy and gravelly unsorted sediments
Diapir	An intrusion caused by buoyancy and pressure differentials, especially in non–igneous materials, examples being salt domes and mud diapers
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*
Diatoms	Microscopic algae, with cell walls of silica consisting of two interlocking symmetrical valves
DIN	Dissolved Inorganic Nitrogen
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
DIP	Dissolved inorganic phosphorus
DOE	See *DOENI*

DOENI	Department of the Environment (Northern Ireland)
DP	Dynamic Positioning, a computer-controlled system to automatically maintain a vessel's position and heading by using its own propellers and thrusters.
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
DSM	Density Surface Modelling
DSP	See *Diarrhetic Shellfish Poisoning*
dSPA	Draft Special Protection Areas
DTI	Department of Trade and Industry (replaced by BERR and BIS)
Duel operation mode	Power generation at tidal barrage occurs on both ebb and flood tides
Dune slacks	Low-lying areas within dune systems that are seasonally flooded and where nutrient levels are low
E&A	Exploration and Appraisal (drilling)
E&P	Exploration and Production (drilling)
EAC	Ecotoxicological Assessment Criteria
Ebb Tide	The receding or outgoing tide
EC	European Community
Echinoderms	Radially symmetrical marine invertebrates e.g. starfish, sea urchins
Echiurans	Non-segmented worms, usually burrowing
Echolocation	Determining the location of something by measuring the time it takes for an echo to return from it
EcoQO	Ecological Quality Objective, *set by OSPAR*
Ecosystem	An ecological community together with its environment, functioning as a unit
ECWC	East Coast War Channels
Eddy	A current of water or air, moving contrary to the direction of the main current, especially in a circular motion
EEC	European Economic Community
EEDI	Energy Efficiency Design Index
EEMS	Environmental emissions monitoring system
EEZ	Exclusive Economic Zone
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
ELC	European Landscape Convention
EMEC	European Marine Energy Centre
EMECO	European Marine Ecosystem Observatory
EMF	Electromagnetic Field
EMODnet	European Marine Observation and Data Network
EN	English Nature, *now Natural England*
ENAW	Eastern North Atlantic Water
Endocrine disruption	Disruption of the hormonal systems of organisms
ENSO	El Niño Southern Oscillation
ENTSO-E	European Network of Transmission System Operators for Electricity

Environmental Impact Assessment	Systematic assessment of the environmental effects a proposed project may have on its surrounding environment
Environmental Statement	Formal document presenting the findings of an EIA for a proposed project issued for public consultation
EOR	Enhanced Oil Recovery
Epifauna	Benthic organisms that live upon the surface of seabed sediments or soils
EPS	European Protected Species
EPT	Energy Payback Time
ERCoP	Emergency Response Co-operation Plan
ERD	Enteric Redmouth Disease (fish)
EROD	Ethoxyresorufin-O-deethylase
ERS	European Remote-Sensing Satellite
ES	See *Environmental Statement*
ESA	Environmentally Sensitive Area
ESAS	European Seabirds at Sea
ESC	The European Slope Current
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
ETV	Emergency Towing Vessel
ETYS	Electricity Ten Year Statement
EU	European Union
EU ETS	European Union Emission Trading Scheme
EU TSG	EU Marine Strategy Framework Directive Technical Sub-Group
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
EUROBATS	The Agreement on the Conservation of Populations of European Bats
Eustatic	A uniform worldwide change in sea level
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
FAD	Fish Aggregating Device
FAECE	Framework for Assessing Ecological and Cumulative Effects
FAME	Future of the Atlantic Marine Environment
FAO	Food and Agriculture Organization of the United Nations
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
Faunal	The animals of a particular region or time period
FEED	Front End Engineering and Design
FEPA	Food and Environment Protection Act
FES	Future Energy Scenarios
Fetch	The un-interrupted distance over which wind acts to produce waves
Fjard	Similar to a fjord but tend to be wider and shallower, often with larger numbers of low lying islands.
Fjord	A long, narrow, deep inlet of the sea between steep slopes

Flaring	The process of disposal by ignition of hydrocarbons during clean-up, emergency shut downs or disposal of small volume waste streams of mixed gasses that cannot easily or safely be separated.
Flood tide	The incoming tide
FLOWBEC	Flow and Benthic Ecology 4D – a project jointly funded by NERC and DEFRA
FLOWW	The Fishing Liaison with Offshore Wind and Wet Renewables Group
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
FPA	Final Project Assessment
FPSO	Floating production storage and offloading vessel.
FRMP	Flood Risk Management Plans
Fronts	The interface between water masses of different characteristics, usually temperature and/or salinity
FRS	Fisheries Research Services
FSA	Formal Safety Assessment
FTE	Full-Time Equivalent (employment)
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
GB	Great Britain
GCR	Geological Conservation Review site
Geomorphology	The study of the underlying form, and weathering processes, of rocks and land surfaces
GEP	Good Ecological Potential
GES	Good Environmental Status *as described in the MSFD*
GGOWL	Greater Gabbard Offshore Winds Limited
GHG	Greenhouse gas
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
GIS	Geographical Information System. A system of hardware and software used for storage, retrieval, mapping, and analysis of geographic data
GIS	Gas Insulated Switchgear (related to cables)
GISZ	Gas Importation and Storage Zone
Glacigenic	Relating to glacial activity
GMES	Global Monitoring for Environmental Security
GPS	Global Positioning System
Gravity based foundation	Foundation type comprising a concrete slab stiffened with ribs or a cellular box-like structure, with a central cylindrical or tapered column. Once the structure is in position, sand or rock *ballast* is added to the cellular base and/or the central column in order to increase the total weight.
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
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
Gt	Gross tonnage
GVA	Gross Value Added
GW	Gigawatt
GWh	Gigawatt-hour
GWP	Global Warming Potential
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 / Halite	Salty or regarding salt content
HALTAFALL	A computer program for calculating the composition of equilibrium mixtures (spill modelling)
HC	See *Heritage Coast*
HER	Historic Environment Record
Heritage Coast	Sections of coast that are of exceptionally fine scenic quality, substantially undeveloped and containing features of special significance and interest
Heterogeneity	The quality of being diverse
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 siliceous spicules, often referred to as glass sponges
HFC	Hydrofluorocarbon
HLC	Historic Landscape Characterisation
HMR	Helicopter Main Routes
HMR	Historic Monument Record
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
HPHT	High Pressure High Temperature
HRA	Habitats Regulations Assessment
HSC	Historic Seascape Characterisation
HSE	Health and Safety Executive
HVDC	High Voltage, Direct Current electric power transmission system.
HWDT	Hebridean Whale and Dolphin Trust
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
IAIP	Integrated Aeronautical Information Package
IALA	International Association of Marine Aids to Navigation and Lighthouse Authority
IAMMWG	The Inter-Agency Marine Mammal Working Group
IBA	Important Bird Area
Iceberg ploughmarks	Ridge/trough features on the seabed created by icebergs
ICES	International Council for the Exploration of the Sea
ICG-C	The OSPAR Intercessional Correspondence Group on Cumulative Effects
ICOMOS	International Council on Monuments and Sites
ICTHR	International Centre for Tourism and Hospitality Research
ICZM	Integrated Coastal Zone Management
IDBR	Inter Departmental Business Register
iE	Electrical field component of a cable
IEC	International Electrotechnical Commission
IERP	Internal Emergency Response Plan

IFCA	International Fisheries Conservation Authorities
IFG	Inshore Fisheries Group
Igneous	Rocks formed when molten rock cools and solidifies
IMARES	Institute for Marine Resources & Ecosystem Studies
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 living within sediments or soil
INIS Hydro	Ireland, Northern Ireland and Scotland Hydrographic Survey
INSPIRE Directive	European Directive 2007/2/EC, establishes an infrastructure for spatial information in the European Union
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
IOTP	Integrated Offshore Transmission Project
IPA	Initial Project Assessment
IPCC	International Panel on Climate Change
IPPC	Integrated Pollution Prevention and Control
IR	Infrared
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 International Union for Conservation of Nature
I-VMS	Inshore Vessel Monitoring Systems
Jacket foundation	A tubular steel lattice structure, typically with four legs. The legs are inclined at a shallow angle to the vertical and then braced with smaller diameter horizontal and diagonal members
JESS	Joint Energy Security of Supply Working Group
JIBS	Joint Irish Bathymetric Survey
JMCs	Joint Maritime Courses
JNCC	Joint Nature Conservation Committee
JOMOPAN	A monitoring strategy for the North Sea set up to develop a structure for a joint monitoring programme for ambient noise in the North Sea.
Jurassic	A major unit of the geologic timescale, extending from approximately 200-146 Ma
Ka	Thousand years ago
KDE	Kernel Density Estimation
Kelp	Any of often very large brown seaweeds of the order Laminariales
Km	Kilometre(s)
kV	Kilovolt, unit of electric potential
kya	Thousand years ago
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
LANR	Local Authority Nature Reserves (Northern Ireland)
LBAP	Local Biodiversity Action Plans

LCA	Life Cycle Assessment
LCA	Landscape Character Assessment
Lewisian gneiss	Metamorphic rocks which have been modified by heat and pressure several times. Up to approximately 3,000 million years old
LFS	Low Flying Systems
LGM	Last Glacial Maximum
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	The World's first commercial wave power station located on the shoreline of Islay
Littoral	The edge of the sea, but particularly the intertidal zone
LLD	Local Landscape Designation
LNG	Liquefied Natural Gas
LNR	Local Nature Reserve
LOIS	The NERC Land Ocean Interaction Study
Loliginid	Squids of the family Loliginidae, mostly neritic and ranging in size from approximately 3-100cm mantle length
Long-crested wave	Ocean surface waves that are nearly two-dimensional, in that the crests appear very long in comparison with the wavelength, and the energy propagation is concentrated in a narrow band around the mean wave direction.
Lough	A lake, or bay/inlet of the sea (Ireland)
Ma	Million years ago
MAB	Man and the Biosphere, UNESCO programme
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
MAFF	Ministry of Agriculture, Fisheries and Food
MALSF	Marine Aggregate Levy Sustainability Fund
MaREE	Marine Renewable Energy and the Environment – SAMS research project: 2010-2013
MAREMAP	Maritime Environment Mapping Programme
MARG	Marine Assessment and Reporting Group
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
MarLIN	The Marine Life Information Network
MARPOL	The 1973/1978 International Convention for the prevention of pollution from ships
MASH	Marine Protected Areas and Species Habitats, OSPAR working group
MAT	Master Application Template, used in DECC's Portal Environmental Tracking System
MBES	Multi-Beam Echosounder System
MCA	Maritime and Coastguard Agency
MCA	Marine Consultation Area
MCA	Marine Character Area
MCCIP	Marine Climate Change Impacts Partnership
Mcm	Million cubic metres
MCS	Marine Conservation Society
MCZ	Marine Conservation Zone
MDAC	Methane Derived Authigenic Carbonate
MDIP	Marine Data and Information Partnership

MEDAG	Marine Environmental Data Action Group
MEDIN	Marine Environmental Data and Information Network
Medusae	Standard body form of adult 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
MEPC	The Marine Environment Protection Committee
MER	Maximising Economic Recovery
MER UK	Maximising Economic Recovery Strategy for the UK
Meroplankton	Plankton that spend only part of their life cycle (usually the larval stage) in the water column
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
MGN	Marine Guidance Note
MI	Marine Institute
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
MIS	Marine Isotope Stage
MITS	Main Interconnected Transmission System
MMCG	Marine Monitoring Coordination Group
MMO	Marine Management Organisation
MMPA	US Marine Mammal Protection Act
MNCR	Marine Nature Conservation Review
MNR	Marine Nature Reserve
MOC	Meridional Overturning Circulation
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
Monopile foundation	A single, often cylindrical, steel pile driven vertically into the sea bed
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
MPS	Marine Policy Statement
MROG	Marine Renewables Ornithology Group
ms	Millisecond
MSC	Marine Stewardship Council
MSCC	Marine Science Coordination Committee
MSFD	Marine Strategy Framework Directive 2008/56/EC
MSPP	Marine Spatial Planning Pilot
MSS	Marine Scotland Science
Mt	Million tonnes
MTTS	Masked temporary threshold shifts

MU	Management unit (cetaceans)
Mudstones	Dark clay rock
Multibeam data	Multi beam is a type of sonar that produces multiple acoustic beams in a fan shape across the ocean floor, providing a detailed acoustic image of the sea floor, roughly equal to an underwater topographic map.
MV	Morbilliviruses
MW	Megawatt
MWe	Megawatt electrical
N_2O	Nitrous oxide
NAC	See *North Atlantic Current*
NAEI	National Atmospheric Emissions Inventory
NAIZ	Non-Auto Initiation Zone
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
NATS	National Air Traffic Services
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
NCA	National Character Area
NCMPA	See *MPA*
NCR	Nature Conservation Review sites
NE	Natural England
NEAFC	North East Atlantic Fisheries Commission
Necropsy	Examination of a body to determine or confirm the cause of death
NEF	New Economics Foundation
Nekton	Free swimming organisms the water column
Nematode	Roundworms (free-living or parasitic in plants and animals)
Nemertea	Soft unsegmented marine worms
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, langoustine or "scampi". A small, commercially fished lobster found in the north-east Atlantic and Mediterranean Sea.
NERC	Natural Environment Research Council
Neritic	Relating to the ocean waters between low tide and a depth of approximately 200m
NERL	NATS En-Route PLC, see *NATS*
NETS	National Electricity Transmission System
NETSO	National Electricity Transmission System Operator
NFFO	National Federation of Fishermen's Organisations
NGET	National Grid Electricity Transmission plc
NGO	Non-Government Organisation
NH_3	Ammonia
NI	Northern Ireland
NIEA	Northern Ireland Environment Agency
Nioz	Netherlands Institute for Sea Research
NISRA	Northern Ireland Statistics and Research Agency
NMFS	National Marine Fisheries Service
NMMP	National Marine Monitoring Programme
NMR	See *National Monuments Record*
NMVOCs	Non-Methane Volatile Organic Compounds

NNIS	Non-Native Invasive Species
NNR	National Nature Reserve
NO_2	Nitrogen dioxide
NOA	Network Options Assessment (electricity network)
NOAA	The US National Oceanographic and Atmospheric Administration
NOC	National Oceanography Centre
NOEC	No Observed Effect Concentrations
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
NOTAM	Notices to Airmen
NO_x	Nitrogen oxide
NPOA	National Plans for Action
NPPF	National Planning Policy Framework
NPPG	National Planning Policy Guidelines
NPS	National Policy Statement
NPS EN-1	Overarching National Policy Statement for Energy
NRMSD	National Research and Monitoring Strategy for Diadromous Fish
NRW	Natural Resources Wales
NS	North Sea
NSA	National Scenic Area
NSCOGI	North Seas Countries' Offshore Grid Initiative
NSIP	Nationally Significant Infrastructure Projects
Nursery	A subset of all habitats where juveniles of a species occur
OBC	An assembly of vertically oriented geophones and hydrophones connected by electrical wires and deployed on the seafloor to record and relay data to a seismic recording vessel.
OBIS-SEAMAP	Ocean Biogeographic Information System – Spatial Ecological Analysis of Megavertebrate Populations
OBM	Oil Based Mud (drilling)
OBS	Ocean Bottom Seismometers
OCCS	The Office of Carbon Capture and Storage
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
OD	Ordnance Datum
ODIS	Offshore Development Information Statement
Odontocetes	Toothed cetaceans
ODPM	Committee on the Office of the Deputy Prime Minister
OESEA	Offshore energy strategic environmental assessment
OESEA2	Offshore energy strategic environmental assessment 2
OESEA3	Offshore energy strategic environmental assessment 3
Ofgem	The government regulator for gas and electricity markets in Great Britain
OGA	Oil and Gas Authority
OGUK	Oil and Gas UK
Oligotrophic	Lacking in plant nutrients and having a large amount of dissolved oxygen throughout
Ommastrephid squid	Short-finned squid
OMR	Offshore Marine Regulations
OMZ	Oxygen Minimum Zone

ONS	Office of National Statistics
OP	On Passage (birds)
OPEP	Oil Pollution Emergency Plan
OPERA	Operational Programme for the Exchange of weather RAdar information
OPF	Organic-Phase Drilling Fluids
Ophiuroids	Brittle stars, Echinoderms of the class Ophiuroidea
OPOL	Offshore Pollution Liability Association Limited
OPRC	The International Convention on Oil Pollution Preparedness, Response and Cooperation (1990)
OREI	Offshore Renewable Energy Installations
ORJIP	Offshore Renewable Joint Industry Programme
OSCR	Ocean Surface Current Radar
OSD	Offshore Safety Directive
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
OW	Over-winter (birds)
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.
PAM	Passive Acoustic Monitoring
PAP	Porcupine Abyssal Plain
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
PBR	Potential Biological Removal
PCAD	Population Consequences of Acoustic Disturbance model
PCB	Polychlorinated biphenyl
PCI	Phytoplankton Colour Index
PCI	Projects of Common Interest (electricity network)
PCoD	Population Consequences of Disturbance
PCZ	Preferred Conservation Zone
PDV	Phocine Distemper Virus
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
PERF	Petroleum Environmental Research Forum
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
PETS	DECC’s Portal Environmental Tracking System
PEXA	Practice and Exercise Area
PFC	Perfluorocarbon
PFR	Organophosphorus Flame Retardant
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
PIG	Pipeline Inspection Gauge
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
PINS	Planning Inspectorate
Pipe dope	Chemical used as a sealant between threads when joining sections of drill pipe
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 with a mean aerodynamic diameter of 10 µm
$PM_{2.5}$	Particulate matter of less than 2.5 micrometres in diameter
pMCZ	Proposed Marine Conservation Zone
pMPA	Proposed Marine Protected Area
PMSU	Prime Minister's Strategy Unit
PNR	Primary Navigation Route
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
POLCOMS	Proudman Oceanographic Laboratory Coastal Ocean Modelling System
POLREP	Pollution Reports
Polychaetes	Annelid worms, chiefly marine
Polychlorinated biphenyls	Persistent, toxic organic compounds once widely used in industry
PON	Petroleum Operations Notice
POP	Persistent Organic Pollutants
Possible Special Area of Conservation	Conservation site which has been formally advised to UK Government, but not yet submitted to the EC.
Potential Special Protection Area	Conservation site that has been approved by UK government and are currently in the process of being classified
ppt	Parts per thousand
Progradation	General term for a coastline which is advancing into the sea
Propagation	The process of spreading to a larger area or greater number.
Protozoan	Single-celled organisms with a nucleus
pSAC	See *Possible Special Area of Conservation*
PSC	Pacific Salmon Commission
PSP	See *Paralytic Shellfish Poisoning*
pSPA	See *Potential Special Protection Area*
PSR	Primary Surveillance Radars (aviation)
Pteropods	Small marine gastropod molluscs of the subclass Opisthobranchia with wing-like lobes on the feet
PTS	Permanent Threshold Shift (injury threshold from noise exposure)
Purse seines	A deep curtain of netting that is shot in a circle to form an enclosing cylinder around shoals of pelagic fish
PVA	Population Viability Analysis
PWA	Pipeline Works Authorisation

Pycnocline	Water column layer separating mixed surface and bottom layers during thermal stratification
QICS	A NERC funded project with the aim of quantifying and monitoring potential ecosystem impacts of geological carbon storage
QSR	The Quality Status Report by OSPAR Commission
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
R3	Round 3 offshore wind licensing round.
RACS	Regional Advisory Councils (fisheries)
Radionuclide	Natural or artificial radioactive isotope
RAF	Royal Air Force
RAG	Research advisory group on marine renewable energy and the environment
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
RBD	River Basin Districts
RBD	See *Red Book Data*
RBMP	River Basin Management Plans
RCAHMS	Royal Commission on the Ancient and Historical Monuments of Scotland.
RCP	Representative Concentration Pathway (emissions)
RCZAS	Rapid Coastal Zone Assessment Surveys
REC	Regional Environment Characterisations
Red Data Book	Documents the current status of globally threatened biodiversity
Refraction	The process by which a wave is bent or turned from its original direction
REZ	Renewable Energy Zone
RF	Radiative Forcing
Richter local magnitude	A logarithmic scale which assigns a single number to quantify the size of an earthquake based on measurements of seismic waves
RIGS	Regionally Important Geological and Geomorphological Sites
Riverine	Relating to or resembling a river
RLD	Regional Landscape Designation
rMCZ	Recommended Marine Conservation Zones
RMNC	Review of Marine Nature Conservation
RMS	Root Mean Squared, a measure of the average sound pressure over a given length of time
ROC	Renewables Obligation Certificate
Roche moutonée	Small bare outcrop of rock shaped by glacial erosion
ROI	Republic of Ireland
Ro-ro	Roll on-roll off
ROV	Remotely Operated Vehicle
ROW	Receiver of Wreck
RRH	Remote Radar Head
RS	Regional Sea
RSPB	Royal Society for the Protection of Birds
RUK	RenewableUK, formerly known as the British Wind Energy Association
RWE	Rheinisch-Westfälisches Elektrizitätswerk AG, a German electric utilities company
RYA	The Royal Yachting Association
SAC	Special Area of Conservation
SAHFOS	Sir Alister Hardy Foundation for Ocean Science
Salicornia	Glassworts: salt-tolerant plants growing on beaches, saltmarshes
Salmonids	Fishes of the family Salmonidae which includes salmon and trout

Salps	Any of various free-swimming tunicates
Salt Cavern	An artificial cavern constructed in a salt deposit by solution mining
Saltmarsh	Low coastal grassland normally overflowed by the tide
SAM	Static Acoustic Monitoring
SAMS	The Scottish Association for Marine Science
SAR	Synthetic Aperture Radar. A form of radar whose defining characteristic is its use of relative motion between an antenna and its target region to provide distinctive long-term coherent-signal variations that are exploited to obtain finer spatial resolution than is possible with conventional beam-scanning means
SAR	Search and Rescue
Sarn	Relict glacial outwash features composed of ridges of boulder to pebble-size rocky material
SAS	Surfers Against Sewage (environmental charity)
SAST	The JNCC Seabirds at Sea Team
SAT	Subsidiary Application Template, in DECC's Portal Environmental Tracking System
SCANS	Small Cetacean Abundance in the European Atlantic and North Seas (survey)
SCAPE	The Scottish Coastal Archaeology and the Problem of Erosion
SCC	See *Scottish Coastal Current*
SCI	See *Site of Community Importance*
SCNB	Statutory Nature Conservation Bodies
SCOPAC	Standing Conference on Problems Associated with the Coastline
SCOS	Special Committee on Seals
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
SDC	Sustainable Development Commission
SEA	See *Strategic Environmental Assessment*
Sea urchin	Spiny, hard-shelled animal that lives on the rocky seafloor or burrows into soft sediments
SeaMaST	Seabird Mapping and Sensitivity Tool
Seamount	Permanently submerged mountains rising from the seafloor, typically formed from extinct volcanoes
SEC	See *Shelf edge current*
SEEMP	Ship Energy Efficiency Plan
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 2D, 3D or 4D
SEL	Sound Exposure Level
SEPA	Scottish Environment Protection Agency
SES	Shelf Edge Study
Sessile	Permanently attached or fixed; not free-moving
SF_6	Sulphur hexafluoride
SFC	Sea Fisheries Committee
SFG	Scope for Growth
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
Short-crested wave	A wave that has a small extent in the direction perpendicular to the direction of propagation. Most waves in the ocean are short-crested.
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
Sinusoid	A mathematical function that describes a smooth repetitive oscillation
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
Slack tide	The period during which no appreciable tidal current flows in a body of water, It usually happens near high tide and low tide, when the direction of the tidal current reverses.
SL_E	Energy source level (noise)
SLVIA	Seascape and Landscape Visibility Impact Assessment
SMA	Sensitive Marine Areas
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
SMP	Seabird Monitoring Programme
SMP	Shoreline Management Plan
SMR	Sites and Monuments Record
SMRU	Sea Mammal Research Unit
SNCB	UK Statutory Nature Conservation Bodies
SNH	Scottish Natural Heritage
SO_2	Sulphur dioxide
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
SPL	Sound Pressure Level
Spotting fluids	Chemicals used to free stuck pipe in a wellbore.
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
SR	Scoping report
SSI	Spatial sensitivity index. The combined assessment of spatial distribution of "priority" species with the assessment of sensitivity
SSMR	Scottish Sites and Monuments Record
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
STAR	The RSPB Seabird Tracking and Research project
Statutory	Prescribed, authorised or punishable under a statute
Stochastic	A random variable
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
STPFS	The DECC Severn Tidal Power Feasibility Study
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
STW	Scottish Territorial Waters
Sublittoral	Below intertidal, permanently submerged by seawater
SVIA	Seascape and Visual Impact Assessment
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
SYS	Seven Year Statement
TAC	Total Allowable Catch
Taxa	Taxonomic category or group
TBT	Tributyltin
TCE	The Crown Estate
TDGVA	Tourism Direct Gross Value Added
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
THC	Thermohaline Circulation
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
TLP	Tension Leg Platform
TNORM	Technologically-enhanced Naturally Occurring Radioactive Material
TNT	Trinitrotoluene (explosive)
Tombolo	A sand or gravel bar connecting an island with another land mass
TOPEX/Poseidon	A joint satellite mission between NASA, the U.S. space agency, and CNES, the French space agency, to map ocean surface topography.
Topography	Surface features of an area
T-POD	Passive acoustic monitoring device
TPS77	Long-Range Radar System
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
Tripod foundation	A simpler version of the *jacket foundation* with larger member sizes
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
TSO	Transmission System Operators (electricity network)
TSS	Traffic Separation Scheme

TTS	Temporary Threshold Shift (injury threshold from noise exposure)
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
Turbidity	Having sediment or foreign particles stirred up or suspended
TWh	Terawatt-hour
TWT	The Wildlife Trusts
TYNDP	Ten Year Network Development Plan (electricity network)
UK	United Kingdom
UKBAP	The UK Biodiversity Action Plan
UKCP09	The UK Climate Projections, see http://ukclimateprojections.metoffice.gov.uk/
UKCP18	Forthcoming UK Climate Projections (building upon UKCP09)
UKCS	United Kingdom Continental Shelf
UKHO	United Kingdom Hydrographic Office
UK-IMON	UK Integrated Marine Observing Group
UKMMAS	UK Marine Monitoring and Assessment Strategy
UKOOA	United Kingdom Offshore Operators Association
UKOPP	United Kingdom Oil Pollution Prevention
UME	Unusual Mortality Rate
UNCLOS	The United Nations Convention on the Law of the Sea
UNECE	United Nations Economic Commission for Europe
UNESCO	United Nations Organisation for Education, Science, Culture and Communications
UNFCCC	United Nations Framework Convention on Climate Change
UXO	Unexploded Ordnance
Vitellogenesis	Formation of the yolk of an egg
VMCA	Voluntary Marine Conservation Areas
VMS	Vessel Monitoring System
VOC	Volatile Organic Compound
VPS	Vertical Seismic Profiling
VSC	Voltage Source Converter
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)
Wake effect	The region of turbulence immediately to the rear of a solid body in motion relative to a fluid. Under certain conditions a series of vortices may form in the wake and extend downstream.
WAM	Wales Activity Mapping (tourism)
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 (drilling)
WCA	Wildlife and Countryside Act 1981
WDC	Whale and Dolphin Conservation (charity)
WeBS	Wetland Bird Survey
WFD	Water Framework Directive (Directive 2000/60/EC)
WGBYC	Working Group on Bycatch of Protected Species
WGHAME	Holistic Assessments of Regional Marine Ecosystems (ICES working group)
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
Winnowing	The separation of sediment by grain size

WNAW	Western North Atlantic Water
Wrasse	Fishes of the family Labridae
WS	West Scotland
WWT	Wildfowl & Wetlands Trust
Xenophyophores	Large, single celled organisms of up to 10cm diameter, usually epifaunal benthic deposit feeders
YAC	Young Archaeologists' Club
ZAP	Zone Appraisal and Planning
Zoanthid	A soft coral
Zooplankton	Free floating animals (often microscopic)
ZTVI	Zone of Theoretical Visual Influence

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