OSPAR COMMISSION

Assessment of the environmental impact of offshore wind-farms

Biodiversity Series

2008

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. It has been ratified by Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland and the United Kingdom and approved by the European Community and Spain.

La Convention pour la protection du milieu marin de l'Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998. La Convention a été ratifiée par l'Allemagne, la Belgique, le Danemark, la Finlande, la France, l'Irlande, l'Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d'Irlande du Nord, la Suède et la Suisse et approuvée par la Communauté européenne et l'Espagne.

Assessment of the Environmental Impact of Offshore Wind-farms

Table of contents

Executive summary

Interest in renewable energy technologies is steadily increasing as international and national mechanisms are developed to reduce our reliance on fossil fuels and to address the effects of climate change. In recent years national authorities and developers have been exploring options for the potential development of offshore wind-farms. This assessment explores the status of offshore wind-farm development within the OSPAR area in terms of the current scale and planned potential schemes, and the environmental effects of this. Its conclusions relate to the effects that all offshore wind-farm developments under construction and operational within the OSPAR area have and how these affect the quality status of the OSPAR maritime area.

The pressure on the environment will increase if planned developments are realised

This assessment shows that the level of development within the OSPAR area in 2008 is relatively small. There are 12 operational offshore wind-farms in the OSPAR area and the total number of turbines is 467. There are 31 authorised offshore wind-farms (2324 turbines) where construction has yet to start, and 47 applications (3792 turbines) are being assessed by the regulatory authorities in the OSPAR area. If realised, these planned and future activities will exert greater pressures on the OSPAR maritime area.

At the scale of development in 2008, national and international controls are in place to ensure that the environmental impacts associated with offshore wind-farm developments are appropriately evaluated and managed. The main instruments are the Strategic Environmental Assessments and Environmental Impact Assessments.

More knowledge and experience are needed before definite conclusions on impacts can be drawn

Whilst research is ongoing on certain impacts, *e.g.* underwater noise, electro-magnetic fields, bird displacement, public perception, there are also several aspects of offshore wind-farm developments where the effects are fully understood (*e.g.* suspended sediment concentrations from monopile foundations installation and cable laying; scour pit development around monopiles; seabed morphological effects within arrays of monopile foundations and species composition and rates of organisms colonising the sub-sea structures). Only a relatively small number of developments are operational so the determination of definitive trends is not possible.

Further OSPAR actions may be needed in future as offshore wind-farm development increases

This assessment concludes that the OSPAR measures for offshore wind-farms leading up to 2010 have been adequate and that the ongoing work programme to monitor the scale of development in the annually updated offshore wind-farm database; the knowledge exchange via www.environmentalexchange.info; updates to the 2006 current state of knowledge paper and the guidance on location, construction, operation and removal of offshore wind-farms is adequate with no immediate priorities for further action. These conclusions should be regularly revisited after 2010 as the scale and rate of offshore wind-farm development within the OSPAR area increases. Of particular importance will be the assessment and management of cumulative impacts and transboundary effects.

Récapitulatif

L'intérêt que présentent les technologies d'énergie renouvelable grandit avec le développement de mécanismes internationaux et nationaux permettant de réduire notre dépendance envers les combustibles fossiles et d'aborder les effets du changement climatique. Au cours des dernières années, les autorités nationales et les promoteurs ont étudié des options pour l'aménagement potentiel de parcs d'éoliennes offshore. La présente évaluation étudie le statut de l'aménagement de parcs d'éoliennes offshore dans la zone OSPAR du point de vue de leur envergure actuelle et des programmes potentiels prévus. Ses conclusions portent sur les effets de tous les aménagements de parcs d'éoliennes offshore en cours de construction et exploitables dans la zone OSPAR et comment ils affectent l'état de santé de la zone maritime OSPAR.

La pression sur l'environnement va augmenter si les aménagements prévus sont effectués

Cette évaluation révèle que le niveau d'aménagement au sein de la zone OSPAR en 2008 est relativement faible. 12 parcs d'éoliennes offshore sont actuellement en fonctionnement dans la zone OSPAR avec un nombre total de turbines de 467. L'autorisation de construction a été donnée pour 31 parcs (2324 turbines) et 47 applications (3792 turbines) sont en cours d'évaluation par les autorités réglementaires dans la zone

OSPAR. Si ces activités planifiées et futures sont effectuées, les pressions exercées sur la zone maritime OSPAR seront plus élevées.

Les contrôles nationaux et internationaux sont en place pour s'assurer que les impacts environnementaux associés à l'aménagement de parcs d'éoliennes offshore sont évalués et gérés de manière appropriée, au titre de l'envergure de l'aménagement en 2008. Les principaux instruments sont les évaluations stratégiques de l'environnement et les évaluations de l'impact sur l'environnement.

Il est nécessaire d'obtenir plus de connaissances et d'expériences afin de tirer des conclusions définitives sur les impacts

Les recherches se poursuivent sur certains impacts (par exemple les bruits sous-marins, les champs électromagnétiques, le déplacement d'oiseaux, la perception du public). Toutefois on comprend pleinement les effets de plusieurs aspects de l'aménagement de parcs d'éoliennes offshore (par exemple : les teneurs des sédiments en suspension liées à l'installation de fondations à monopilot et à la pose de câbles, la formation de trous d'affouillement autour des monopilots, les effets sur la morphologie du fond de mer dans la zone des fondations à monopilot, la composition des espèces et la vitesse de colonisation des structures du sous-sol marin par les organismes). Un nombre relativement faible seulement d'aménagements sont opérationnels et il risque donc de ne pas être possible de déterminer des tendances précises.

Il sera peut-être nécessaire d'appliquer d'autres mesures OSPAR à l'avenir puisque les aménagements de parcs d'éoliennes deviennent plus nombreux

Cette évaluation conclut que les mesures OSPAR sur les parcs d'éoliennes offshore jusqu'en 2010 sont adéquates et que le programme de travail en cours, en matière de surveillance de l'envergure de l'aménagement dans la base de données sur les parcs d'éoliennes offshore qui est actualisée tous les ans, d'échange de connaissances grâce à www.environmentalexchange.info, d'actualisation du document de 2006 sur l'état actuel des connaissances et des orientations sur l'emplacement, la construction, l'exploitation et l'enlèvement de parcs d'éoliennes offshore est adéquat et qu'aucune action prioritaire supplémentaire n'est nécessaire. Ces conclusions seront révisées régulièrement après 2010 au fur et à mesure que l'envergure et la vitesse d'aménagement de parcs d'éoliennes offshore augmentent. L'évaluation et la gestion des impacts cumulatifs et des effets transfrontières est particulièrement importante.

1. Introduction

This assessment is a contribution to the assessment of human activities under the OSPAR Joint Assessment and Monitoring Programme (JAMP) and to the Quality Status Report 2010. Ways in which data for the JAMP should be collected are:

a. describing the spatial distribution of a range of environmental parameters;

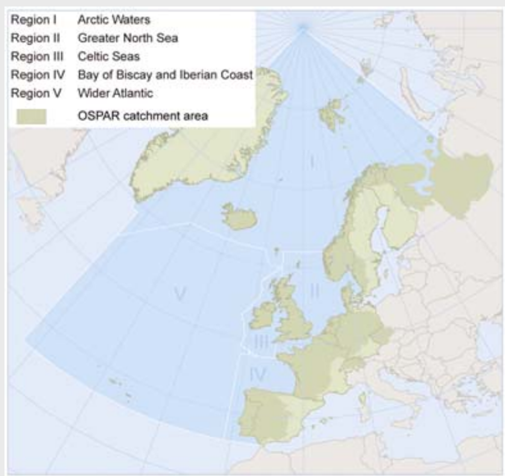
b. determining temporal trends and/or discrete changes; and

c. establishing links between anthropogenic pressures and observed impacts and other changes in the marine environment.

This paper is concerned with (a) above, with actions for (b) scheduled for 2008 and (c) the Quality Status Report scheduled for 2010 once all the assessments for the various human activities have been completed. The information related to effects of noise from wind-farms has been coordinated with the available information from the draft OSPAR assessment of impact of noise. The assessment of underwater noise which forms part of the QSR 2010 should be consulted for an update on assessment of impacts of noise from wind-farms. Ancillary activities to offshore wind-farms and their impacts are covered by complementary QSR assessments of the impact of human activities on the OSPAR maritime area and its Regions.

Electronic navigator to complementary QSR assessments and documentation

- Underwater noise (OSPAR, 2009a)
- Construction or placement of structures (OSPAR, 2008c)
- Cables (OSPAR, 2009b)
- Climate change mitigation and adaptation (OSPAR, 2009c)



Map: OSPAR maritime area and its five Regions

2. Status of offshore wind-farm development in the OSPAR Region

In March 2007 the European Council backed Commission proposals on energy and climate change, agreeing on an action plan to further develop energy policy by 2009 (EC, 2007). Key aspects of the agreement include a binding target to reduce EU emissions by 20% by the year 2020, (increased to 30% should other industrialised nations take similar steps). For renewable energies a binding target is set to have 20% of the EU's overall energy consumption coming from renewable sources by the year 2020. The 27 EU states will each agree how they contribute to meeting this 20% overall target in renewable energy use by 2020.

In order to meet the targets described above, based on currently available technologies, wind turbines are the most developed and readily available source for large scale exploitation of renewable energy. With increasing pressures for space on land, capturing offshore wind resources is gaining momentum by both national authorities and developers (see Table 1). Offshore wind provides a huge source of renewable energy. Proposals in the United Kingdom for a third round of offshore wind-farm development, information provided by the Netherlands, the figures presented in Tables 1 and 2 and aspirations discussed by other Contracting Parties at OSPAR meetings, provide an expectation that the scale of offshore wind-farm development beyond 2010 is set to increase. As such there is a need for OSPAR to continue with the current work on offshore wind-farms and explore options for further work streams beyond 2010.

The 2008 update of the OSPAR Database of Offshore Wind-farms (OWF) (OSPAR, 2008a) summarises planned and constructed OWF in the OSPAR area (see Table 2 and Figures 1a-f):

Operational OWF: there are 12 operational OWF in the OSPAR area and the total number of turbines is 467. All but one had an Environmental Impact Assessment (EIA) undertaken. The operational OWF are located in Denmark, Ireland, the Netherlands and the United Kingdom.

Authorised OWF: there are 31 authorised OWF in the OSPAR area where construction has yet to start. The total number of turbines authorised is 2324. All authorisations were given based on an EIA. The authorised OWF are to be located in Belgium, Denmark, Germany, Netherlands and the United Kingdom.

Applications: there are 47 applications for OWF currently being assessed by the regulatory authorities in the OSPAR area with a total number of 3792 turbines. 29 of these have an EIA but 18 do not (no reason is provided on whether an EIA was not required or is not yet completed). These applications are for OWF in Belgium, Denmark, Germany, Ireland Netherlands, Norway and the United Kingdom.

Refused OWF: 7 OWF have been refused in the OSPAR planned in Belgium, the Netherlands and Sweden totalling 261 turbines (all with EIA).

Table 1. Wind power installed in Europe by the end of 2007. Source: European Wind Energy Association (EWEA) – www.ewea.org

	Onshore and Offshore (MW)		**Offshore (MW)**	
	Total installed capacity (2006)	**Total installed capacity (2007)**	**Installed capacity (2007)**	**Capacity under construction**
Belgium	194	287	0	0
Denmark	3136	3125	426	400
Finland	86	110	0	0
France	1567	2454	0	0
Germany	20 622	22 247	0	0
Ireland	746	805	25	0
Luxembourg	35	35	0	0
Netherlands	1558	1746	108	120
Portugal	1716	2150	0	0
Spain	11 623	15 145	0	0
Sweden	571	788	133	30
United Kingdom	1962	2389	404	457
Total	43 816	51 281	1096	1007

Table 2. Status of offshore wind-farm development activities for all Contracting Parties in the OSPAR maritime area. Data source: OSPAR, 2008a.

	Application			**Authorised**			**Refused**			**Operational**		
	Number of wind-farms	**Number of turbines**	**Capacity (MW)**	**Number of wind-farms**	**Number of turbines**	**Capacity (MW)**	**Number of wind-farms**	**Number of turbines**	**Capacity (MW)**	**Number of wind-farms**	**Number of turbines**	**Capacity (MW)**
Belgium	1	36	216	2	180	630	3	114	228	0	0	0
Denmark	1	98	215	1	3	18	0	0	0	5	109	207
Finland	0	0	0	0	0	0	0	0	0	0	0	0
France	0	0	0	0	0	0	0	0	0	0	0	0
Germany	21	1528	7535	17	1129	5062	0	0	0	0	0	0
Iceland	0	0	0	0	0	0	0	0	0	0	0	0
Ireland	2	275	1430	0	0	0	0	0	0	1	200	520
Luxembourg	0	0	0	0	0	0	0	0	0	0	0	0
Netherlands	10	813	2748	1	60	120	3	87	261	1	36	108
Norway	3	334	1500	0	0	0	0	0	0	0	0	0
Portugal	0	0	0	0	0	0	0	0	0	0	0	0
Spain	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	0	0	0	0	0	0	1	60	300	0	0	0
Switzerland	0	0	0	0	0	0	0	0	0	0	0	0
United Kingdom	9	708	2743	10	952	3414	0	0	0	5	122	304
Total	47	3792	16387	31	2324	9244	7	261	789	12	467	1139

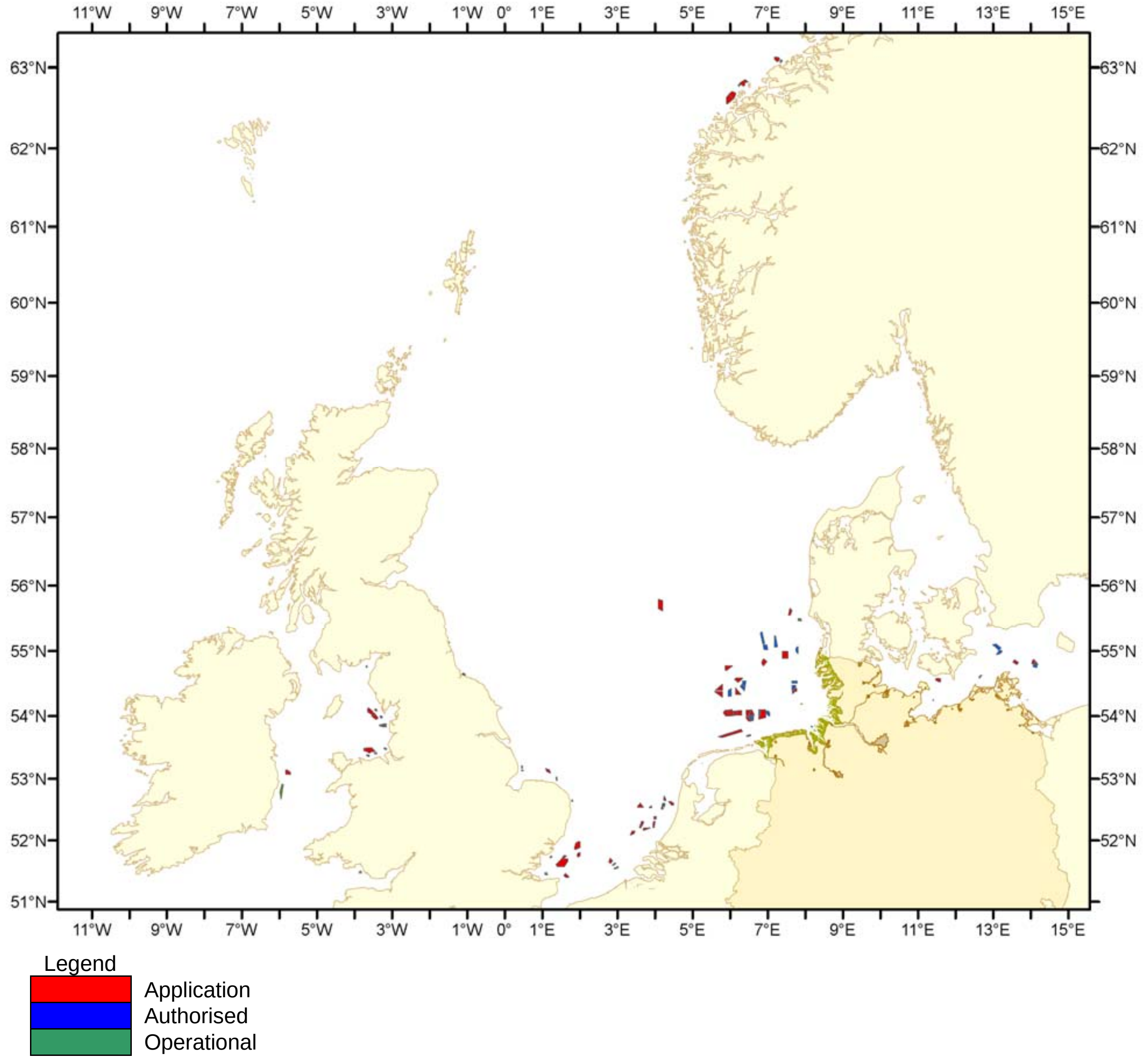


Figure 1a. Overview of location of authorised and planned wind-farms in the OSPAR maritime area. Data source: OSPAR database on offshore wind-farms in 2007.
(NB. Baltic areas shown are outside the OSPAR maritime area.)

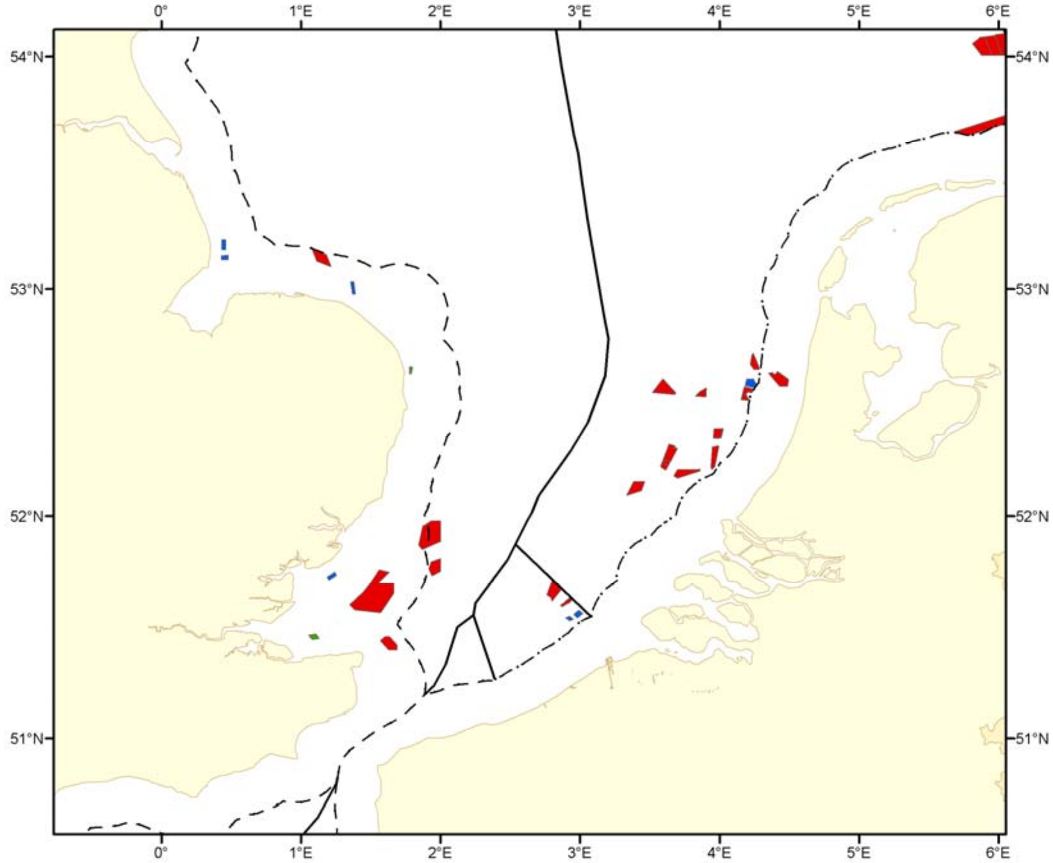


Figure 1b. Location of authorised and planned wind-farms in the Netherlands, Belgium, United Kingdom.

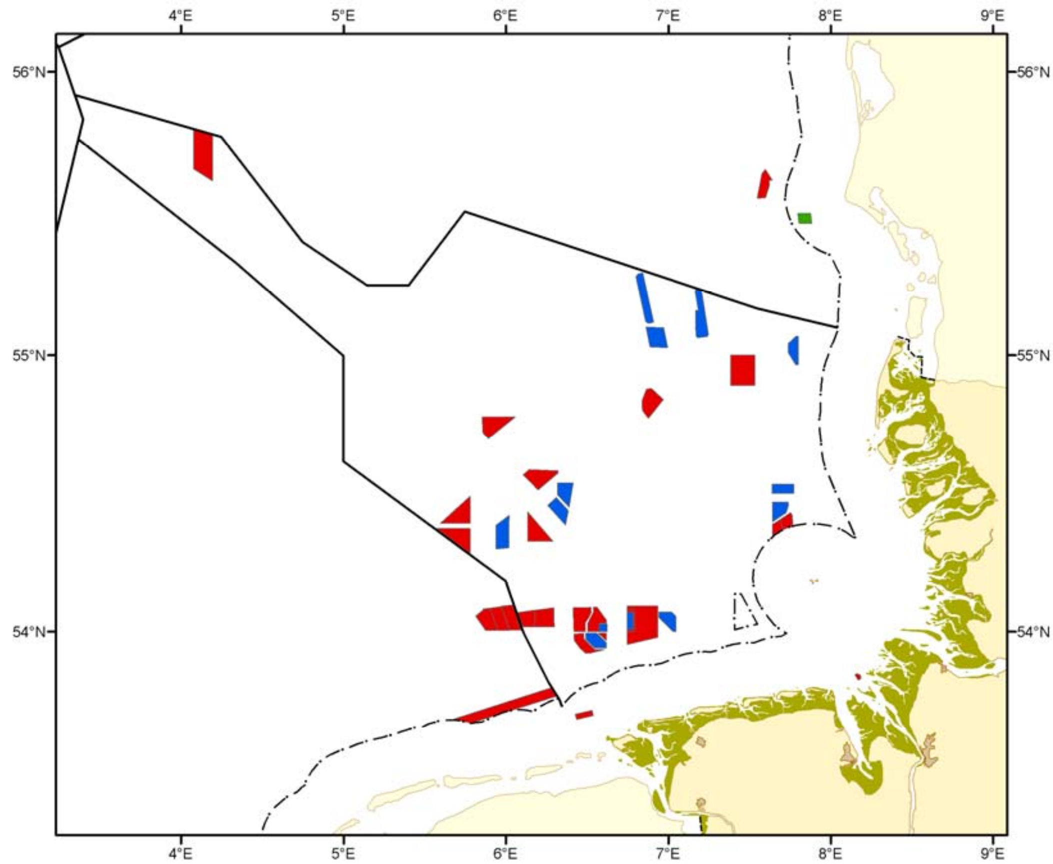


Figure 1c. Location of authorised and planned wind-farms in Germany, Denmark and the Netherlands.

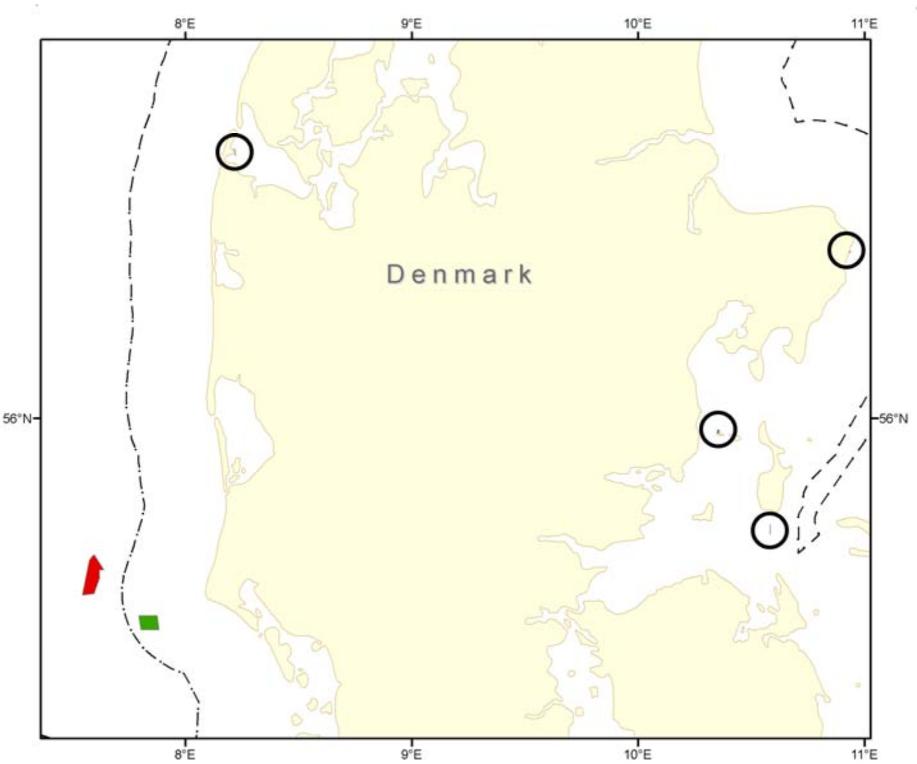


Figure 1d. Denmark

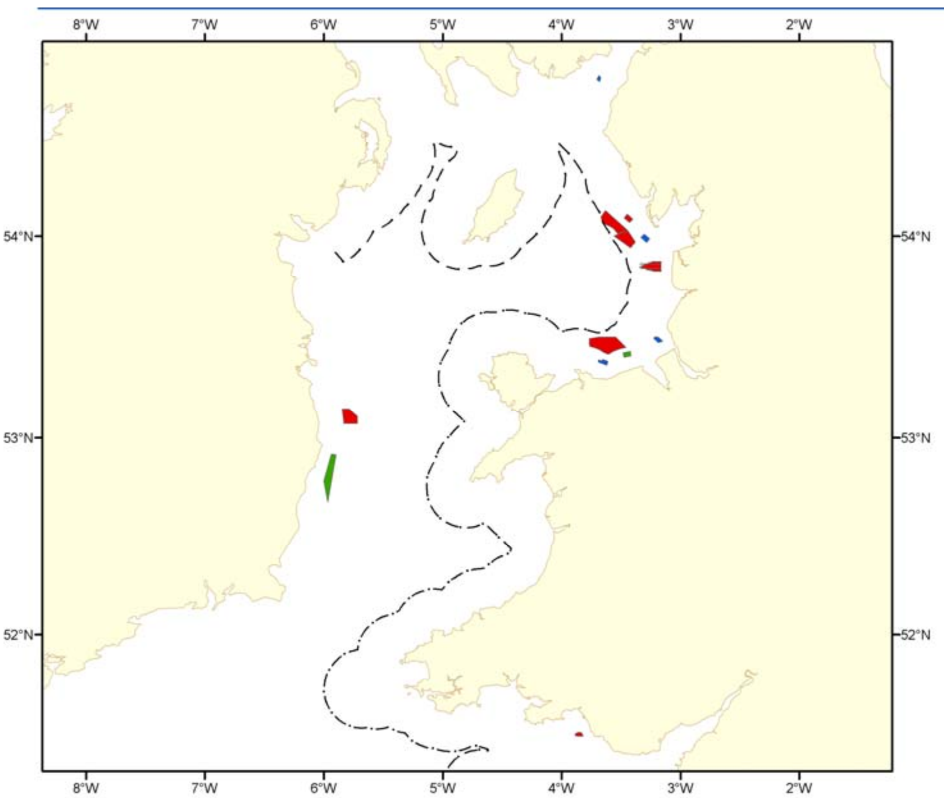


Figure 1e. Location of authorised and planned wind-farms in the Irish Sea.

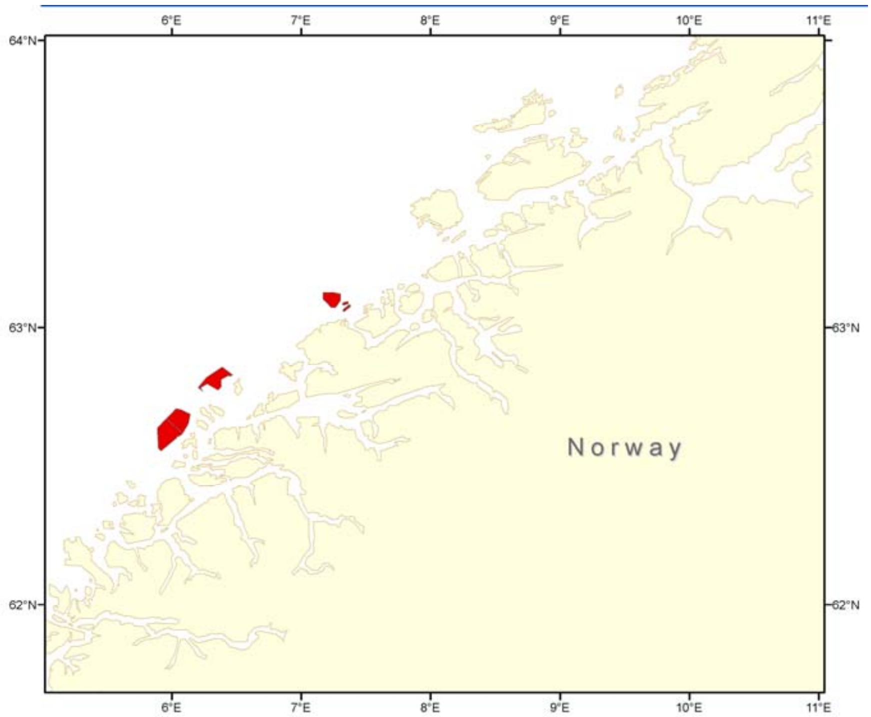


Figure 1f. Location of authorised and planned wind-farms in Norway.

The information in Table 2 and Figures 1a-f shows that the only OSPAR regions with current and planned offshore wind-farm development are Regions II (The Greater North Sea) and III (The Irish Sea). Both the United Kingdom and Ireland have current and planned developments in Region III (14 offshore wind-farms made up of 1346 turbines). Region II has 73 current and planned offshore wind-farms made up of 4930 turbines.

Figure 2 shows that there has been a rapid increase in offshore wind-farm development within Europe between 2000 and 2007. Whilst there is a clear trend in gross capacity the capacity installed annually is variable year on year.

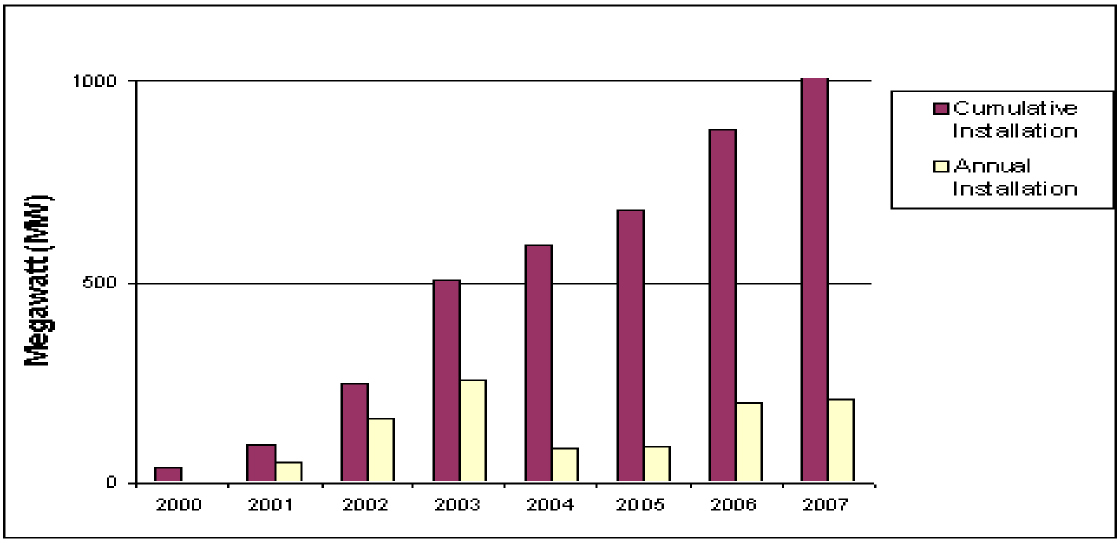


Figure 2. Installed offshore wind capacity in Europe (2000-2007). Source: European Wind Energy Association – www.ewea.org

3. The future

It is a possibility that drives for OWF will increase in order to meet national obligations under the EU targets (EC, 2007). In the United Kingdom in addition to the developments listed in Table 2 there are a further 6 proposals with a total capacity of approximately 3 GW progressing through the EIA process under the current second round of developments with applications expected in 2008. A third round of offshore wind-farm proposals was announced in the United Kingdom on 10 December 2007 and is to be based on a Strategic Environmental Assessment. Also, in addition to the data provided in Table 2, Norway has 2 proposals (for up to 200 turbines) and the Netherlands have 72 offshore wind-farm proposals (number of turbines not specified) at the pre-application stage and progressing through the EIA phase (see www.noorzeeloket.nl). 467 turbines are operational or under construction within the OSPAR maritime area. Current experience suggests that a single vessel can install up to 80 turbines in one year (RPS, 2005). Discussions with offshore wind-farm developers in the United Kingdom suggest that globally there are only a limited number of vessels capable of installing these large structures. .The assumption is therefore that there will be a moderate further development of offshore wind-farms up to 2010 due to supply chain constraints and that it is unlikely for the number of turbines to exceed 800 (based on 5 vessels working at full capacity for one year). This estimate is consistent with the EWEA (2007) prediction that based on current growth rates an estimated 3.5 GW of offshore wind capacity could be installed within Europe by 2010 (Table 1 shows that by end of 2007 2.0 GW were installed or under construction). Whilst the current level of development is relatively small, once those developments in Table 2 shown as authorised are realised, if those at the application stage are authorised and if the trends shown in Figure 2 continue, the pressures within the OSPAR area will increase.

4. What are the problems?

There are a number of potential problems and benefits associated with the location, construction, operation and removal phases of OWF. OSPAR derived knowledge on the design and construction of offshore wind-farms and the identification of potential environmental impacts from a number of Environmental Statements for offshore wind-farm developments (primarily from Denmark and the United Kingdom) (OSPAR, 2006). Included within all Environmental Statements for offshore wind-farms is site specific data on the biological environment (biological communities, population dynamics, distribution, abundance etc); habitat types and characteristics and physical and chemical features (morphology, waves, currents, temperature, salinity etc). This data provides the context against which the pressures and impacts associated with the construction and operation of the offshore wind-farm can be assessed. This analysis of the essential characteristics and current environmental status is consistent with the requirements under Article 8 of the EC Marine Strategy Framework Directive (2008/56/EC).

OSPAR (2004) provided an initial overview of the key issues and potential impacts, gaps in scientific knowledge and potential benefits of offshore wind-farms. Table 3 lists the key issues and source of potential impacts identified by OSPAR. The third column provides examples of potential impacts that might arise based on our current knowledge and understanding, it is not exhaustive. Impacts (when they occur) will vary in significance from location to location. Further work is needed to determine the generic significance and/or acceptability of some of these impacts. As our knowledge and understanding progresses the contents and prominence of any list of potential impacts will change with items added or removed as the evidence dictates.

Table 3. Potential impacts associated with the development of offshore wind-farms (not exhaustive). Source: OSPAR, 2004.

Issue	Source of Potential Impacts	Examples of Potential Impacts
Birds	- turbines, mainly rotor blades and wakes - light emission	- bird collision - attraction of birds due to illumination by navigational lights and subsequent increase in the risk of collision
	- wind-farm as a whole	- temporary or permanent habitat loss or change, including exclusion of habitat, *e.g.* sandbanks, water surface/water body due to disturbance - fragmentation of feeding, breeding and roosting areas, as well as migratory routes due to barrier effect - change of food species availability
	- boat traffic during construction and maintenance	- stress and reduction of biological fitness - temporary or permanent exclusion from habitat
	- electric cable to shore – increase of temperature in sediments during operation	- increased risk of botulism in coastal areas (eulittoral) resulting in an increased death rate for wading birds and water birds
Bats	- turbines mainly rotor blades and wakes	- collision and barrier effects
Marine Mammals	- shadow from rotor blades - emission of sound and vibration into the water body - construction noise (including pile driving)	- habitat loss due to avoidance - fragmentation of migratory routes and of sites for foraging and reproduction - induced permanent or temporary threshold shift in hearing (PTS/TTS), reduced perception of biologically significant sounds (masking)
	- boat traffic during construction and maintenance	- changed behaviour, stress
	- electric cables (see below)	- disturbance of small- and large-scale orientation
Fish	- electric cable within the wind-farm and to shore – artificial electromagnetic fields emitted during operation, in particular from monopolar direct current cables	- disturbance of small- and large-scale orientation (especially migratory species) - impediment of foraging activity - physical barrier
	- emission of sound and vibration into the water body	- habitat loss as fish may leave area - disturbance of behaviour and stress
	- clouding and sedimentation during construction	- damage to fish eggs - damage and or disturbance to spawning grounds
	- introduction of hard substrate - construction noise (including pile driving)	- alteration of food species availability and abundance, which in turn may alter community composition and abundance of fish - induced permanent or temporary threshold shift in hearing (PTS/TTS), reduced perception of biologically significant sounds (masking)

Issue	Source of Potential Impacts	Examples of Potential Impacts
Zoobenthos	- cable laying	- disturbance of intertidal habitats
	- local destruction and sediment plumes during the construction/removal of foundations - permanent covering of the sea floor	- temporary and permanent habitat loss
	- introduction of artificial hard substrate	- alteration in the benthic community composition
	- changes in hydrodynamics	- indirect habitat loss through small-scale changes in sediment structure around the turbine and changes of large-scale sediment dynamics
	- electric cable within the wind-farm and to shore – increase of temperature in sediments during operation	- alteration in the endobenthic community including colonisation by alien species - increased degradation of the organic content resulting in a release of heavy metals (depending on the total organic matter content and metal content of the sediment)
Macrophytes	- local destruction and sediment plumes during the construction of foundations - permanent covering of the seafloor	- temporary and permanent habitat loss
	- change of current dynamics and sediment conditions - introduction of artificial hard substrate	- habitat loss - alteration in the plant community composition
Hydrodynamics and MorphodynamicsHydrodynamics and Morphodynamics	- construction and presence of foundations and cables	- change of sediment dynamics, for example slowing down of natural erosion and sedimentation processes (at the site and adjacent coastlines) - reduction in wave energy (shadow effects) from different sized arrays and how/if this influences sediment inputs and exchanges - beach faces and flood defences
Landscape	- tall structures visible from afar - lighting	- intrusion on the typically flat and featureless sea and "industrialisation" of this natural landscape - alteration of the scenic landscape – especially at night
Navigation	- danger of collisions between vessels and wind turbines (including restriction/constriction of shipping routes)	- pollution through oil spills or chemical spills - impact on socio-economic operations
Emergency Operations	- obstacles due to the presence of static structures	- impact on emergency operations
Other Users	- exclusion of other users from the area - disturbance of the natural landscape	- socio-economic losses, *e.g.* for fisheries and tourism

The issues and potential impacts from Table 3 were critically reviewed in the OSPAR (2006) paper in order to rationalise the potential areas for concern and allow a more targeted approach to the assessment, monitoring and management of environmental impacts. The key source of information for the OSPAR 2006 review were the results of monitoring studies and research at offshore wind-farms in Denmark and the United Kingdom and from the research platforms in Germany. The other main source of information came from peer-reviewed reports of studies undertaken on analogous works on the construction and placement of large structures.

The potential problems are identified in the OSPAR (2006) review along with the measures taken to predict, measure, assess and mitigate the associated effects. Attempts have also been made to demonstrate which issues are of local importance and those that have wider implications. It is those activities that affect considerable spatial and temporal scales that have the greatest potential to affect the overall quality status, and this review along with its source documents is intended to identify these.

The OSPAR offshore wind-farm database describes the spatial extent of developments in the OSPAR area and the OSPAR 2004 and 2006 papers provide a generic description of the environmental parameters and the assessment of their impacts. The existing OSPAR work streams also provide an initial step in establishing a link between anthropogenic pressures and observed impacts. The OSPAR 2006 paper looked at providing a detailed assessment of the environmental effects of OWF, however, data on OWF have only been available over relatively short time-scales and, as can be seen from Table 2 and Figures 1a-f, only a relatively small number of developments are operational so the determination of definitive trends is not possible from this assessment.

OSPAR has identified the following significant gaps in understanding pertinent to the QSR 2010:

- Impacts of underwater noise from construction activities and operation;
- Bird displacement and collision risk;
- Seabed morphology (gravity base and multi-pile foundations);
- Public perceptions/acceptance;
- Cumulative impacts.

Gaps in understanding are discussed in more detail in the section of this report titled “Data gaps and sharing information”.

However, there were also a number of issues where understanding is sufficient for impacts to be confidently predicted, assessed and managed at the scale of development predicted up to 2010, *e.g.* disturbance/loss of seabed habitat from monopile foundations, which species colonise foundations and monopiles, pollution incidents, agreed construction vessel routes (OSPAR, 2006). Given the qualitative nature of some of the data for OWF and the relatively small data sets currently available where gaps exist, this report suggests options for the type of data and assessments necessary to prepare a trend analysis.

The three OSPAR reports (2004, 2006 and 2007) provide the basis for this JAMP assessment for a concise summary of contemporary knowledge, management techniques and identifying significant gaps in knowledge, the resolution of which will become increasingly important as the scale of OWF development increases beyond 2010 levels.

The next section draws heavily on the OSPAR 2004 and 2006 reports to elaborate on what has been done to date to improve our understanding of the main impacts identified within Environmental Statements under the headings: Sea bed habitat loss / disturbance; Fish; Marine mammals; Birds; Seascape public perception and Cumulative Impacts pertinent to the level of OWF development in the OSPAR maritime area up to 2010.

5. What has been done? Did it work?

There are international and national measures that guide the identification, assessment and mitigation of the potential impacts for marine works, including offshore wind-farms. If these measures are followed it is possible that many of the potential problems in Table 2 and discussed above can be resolved for a specific application. However, as already stated in this report as the rate and scale of OWF development increases beyond 2010 levels additional measures may become necessary.

The EU EIA Directive (85/337/EEC, as amended by 97/11/EC) requires Member States to adopt all measures necessary to ensure that, before consent is given, projects likely to have significant effects on the environment by virtue of their nature, size or location are made subject to a requirement for development consent and an assessment with regard to their effects. In line with the requirements of the Directive an EIA is to be carried out in support of applications to develop certain types of project as listed in the Directive at Annexes I and II. Offshore wind-farm developments are listed in Annex II as ‘installations for the harnessing of wind power for energy production (wind-farms)’. Projects listed in Annex II shall be made subject to an assessment where Member States consider that their characteristics so require. For the majority of offshore wind-farm developments in the OSPAR area contracting parties have decided that an EIA is necessary (OSPAR, 2008a).

EIA is essentially a predictive tool involving the systematic assessment of a project’s likely significant environmental effects. The purpose of the EIA process is to ensure that all the likely effects of a development are fully understood and taken into account before a development is permitted to go ahead. The approach to EIA should be:

- to provide a complete and objective description of the development;
- to provide as complete as is possible description of the existing environment;
- to provide as systematic and objective an account as is possible of the direct and indirect environmental effects to which the project is likely to give rise;
- to describe and present the data gathering and interpretation that underpins the assessment of the identified environmental impacts;
- to provide an overview of the available knowledge and identify what effect knowledge gaps may have on the certainty of predicting environmental effects;
- to formulate evidence based conclusions supported by the information gathered in the EIA process.

All these steps should be reported in an Environmental Statement to a level of detail sufficient to provide the public and competent authorities with a proper understanding of the importance of the predicted effects and the scope for reducing them.

By following the EIA process OSPAR Contracting Parties have been able to consent and construct OWF within their national waters (OSPAR 2007). In this context the existing measures at the international level for EIA are sufficient and have been shown to work. However, the importance of guidance in the identification and assessment of impacts at both the international and national level has been highlighted.

National guidance has been (and is being) developed to assist developers and regulators in the assessment and consenting process, examples include:

- Standards for Environmental Impact Assessments of Offshore Wind Turbines on the Marine Environment (StUK 3). Issued by Bundesamt für Seechiffahrt und Hydrographie, February 2007 (Germany);
- Offshore Wind-Farms – Guidance note for Environmental Impact Assessment In respect of FEPA and CPA requirements. Version 2 – June 2004 (United Kingdom);
- Nature Conservation Guidance on Offshore Wind farm Development – A guidance note on the implications of the EC Wild Birds and Habitats Directives for developers undertaking offshore wind-farm developments. March 2005. Defra (United Kingdom).

OSPAR is also developing guidance to assist contracting parties (in particular those that have yet to embark on the process of establishing offshore wind energy schemes) with the assessment and consenting of offshore wind-farm developments. Guidance on location, construction, operation and removal of offshore wind-farms has been produced and consolidated into a single guidance document to cover the whole life-cycle of an offshore wind-farm (OSPAR, 2008b).

This guidance (in parallel with the available generic EIA guidance) has proven invaluable in ensuring that the key marine environmental issues are identified and adequately assessed within the EIA and consents processes. It is important that such guidance is reviewed and updated in light of new and improved knowledge and understanding of the construction techniques and environmental effects.

All OWF developments in the United Kingdom and to the best of our knowledge in other OSPAR Contracting Parties require robust ship collision risk assessments to be undertaken. It is also an essential component of the licensing procedures that site-specific marine pollution contingency plans are developed and implemented. Employing such measures will assist in planning projects to minimise the risk of impacts.

The remainder of this section concentrates on the outputs of research and monitoring studies at offshore wind-farms and the assessment of peer-reviewed literature on analogous activities and how this information can be used in the assessment and consents process.

6. Sea bed habitat loss/disturbance

Based on information presented in the OSPAR (2006) paper we know that the typical pile diameter for OWF currently installed in the OSPAR area is between 4 and 5 m. A typical scour pit diameter of 100 m has been extrapolated from the Scroby Sands OWF as a worst case for monopile foundations and is discussed in the OSPAR (2006) paper. As a simple indication of the possible scale of effect based on the information presented in the OSPAR database of Offshore Wind-Farms, assuming all had monopile foundations

- for the 12 operational wind-farms the area of seabed affected by foundations and scouring/scour protection is 3.67 km^2.
- for the 31 authorised wind-farms the area of seabed affected by foundations and scouring/scour protection would be 18.25 km^2.
- for the 47 wind-farm applications the area of seabed affected by foundations and scouring/scour protection would be 29.78 km^2.

Therefore, OWF with monopile foundations have a relatively small area of impact in terms of direct impact on the seabed from the foundation pieces, scour pits and scour protection. This is of particular interest when compared to other activities: active marine minerals extraction in the United Kingdom covers 144 km^2 (data for 2003, from www.thecrownestate.co.uk); United Kingdom dredged material sea disposal sites cover 310 km^2 (Koen Vanstaen, Cefas pers comm.) and cuttings piles produced by the United Kingdom offshore hydrocarbon industry cover 1605 km^2 (www.ukooa.co.uk). The scouring effects on the seabed from other foundation types (gravity base or multi-pile) are less well understood and therefore it is not possible to provide estimates on the area of seabed affected. Studies in the United Kingdom have added greatly to knowledge and understanding of the effects of OWF on the seabed, *e.g.* Review of Round 1 sediment process monitoring data – lessons learned [in prep]; Dynamics of scour pits and scour protection [in prep] and the monitoring studies at the North Hoyle, Kentish Flats and Barrow offshore wind-farms.

Direct impacts on the seabed are limited to within one to two hundred metres of a wind-farm array and bed-forms between turbines are undisturbed (OSPAR, 2006). In addition to monopile foundations tripod or jacket foundations are under consideration for the use offshore and these foundation types are also assumed to have only local direct impacts on the seabed although further study is required to provide evidence of this.

Cables will also affect seabed and sediments. Cables are buried in trenches approximately 2 m wide and depths up to 3 m to create a circuit of each turbine in the array and to connect the OWF to the shore to export electricity. Impacts on the seabed are likely to be limited to the near proximity of the cable (OSPAR, 2006) but the scale of effect will be dependant on the grain size of the sediments, ambient turbidity, hydrodynamics and the sensitivity of the species and habitats at the site and will need to be quantified and assessed as part of the EIA. For the 5 operational OWFs in the United Kingdom the data presented in the Environmental Statements predicted impacts from resuspended sediments to be low for those sites and the environmental monitoring for these sites has proven these predictions. Fine grained sediments may be transported in suspension for longer and over greater distances. A United Kingdom study on the effects of cable laying is due to report soon and the Background Document on potential problems associated with power cables other than those for oil and gas activities to be published by OSPAR in 2009 should increase our knowledge in this respect.

An integral part of the EIA for every OWF should be a detailed assessment of the effects on sediment transport and seabed morphology. These are required to accurately predict impacts and it is essential that physical or numerical models, if used, are properly calibrated and appropriate validation measurements are taken. There are numerous national and international efforts to improve and develop appropriate sediment transport models, but their use varies between Contracting Parties and there is no requirement for these to be used. It is essential that best use is made of available data and if used improvements are required to existing models, in particular: bed shear stress exceedance curves to calibrate sediment transport models; sediment transport models for mixed sediments; use of realistic wave, tide and storms scenarios; check whether surge currents from tidal surges are significant in a particular area etc. Experience should also be drawn from other offshore installations (*e.g.* pipelines, cables) that can verify the assessments by means of inspections of scouring.

Once the spatial extent of the seabed affected by the placement of OWF infrastructure can be quantified, consideration can be given to the scale of this impact on the benthic organisms that inhabit the areas of seabed affected. Direct impact on the seabed is therefore local only and the identification, prediction and quantification of the impacts should be via a thorough EIA to assess significance at each potential OWF site.

A study at the Nysted OWF in Denmark showed temperature increases in the sediments around operational OWF power cables (Meißner *et al*., 2006). Measurements vertically above the cable compared to a reference station on the day the highest temperatures were recorded ranged from –0.2 ºC at the sea bed, 0.3 ºC at 10cm below the sea bed, 1.4 ºC at 20cm below the sea bed to 2.5 ºC at 50cm below the sea bed. Measurements taken at 30 cm distance from the cable ranged from –0.1 ºC at the sea bed, 0.2 ºC at 10cm below the sea bed, 0.5 ºC at 20cm below the sea bed to 1.3 ºC at 50cm below the sea bed. The majority of animals will inhabit the top 5-10 cm in open waters and the top 15 cm in intertidal areas (Eleftheriou and McIntyre, 2005) where the observed temperature increases are at their lowest, although some organisms will burrow deeper.

The above conclusion on the spatial extent of the direct effects of OWF on seabed morphology is based on datasets for monopiles (from the Scroby Sands, North Hoyle, Kentish Flats and Barrow OWFs in the United Kingdom), however, further work is needed on multi-piles, gravity base or hybrid structures to determine whether the scale and type of associated impacts are similar or different to those recorded for monopiles.

Monitoring of colonisation of OWF foundations and scour protection by marine organisms in Denmark and the United Kingdom has shown this to be as predicted and as analogous to observations at other offshore structures; however, the long-term consequences of biofouling and regular cleaning for biomass and biodiversity are not yet fully understood. The impact is therefore a local change in species composition. The cumulative impact of large numbers of foundations should be taken into consideration. The implications of such changes should be assessed as part of an EIA for each development to identify, predict and quantify the impacts to assess significance at each potential OWF site.

7. Fish

Noise is associated with many activities in the marine environment, *e.g.* construction works, seismic surveys, military activities, vessel movements, oil and gas activities etc. The pragmatic approach is to concentrate attention on those aspects of wind-farm development that generate noise at levels likely to disturb fish, *e.g.* pile driving, operational phase and breakdown. The approach in the United Kingdom is to concentrate on times when fish can be considered to be at their most vulnerable to noise disturbance, *e.g.* spawning seasons, migration, etc. for those species at risk on a case by case basis.

Whilst there is limited information available on the impacts of underwater noise (in particular from pile-driving) on fish there are a number of studies and reports available (Cefas, 2003; Coull *et al.*, 1998; Degn, 2003; Hastings and Popper, 2005; Nedwell *et al.,* 1998, 2003, 2004, 2005; ODS, 2000; Thomsen *et al.,* 2006; Wahlberg and Westerberg, 2005). The review of these documents reveals that the approaches to the measurement and assessment of noise differ and as such the results and predictions are not always directly comparable. Any assessments can only be based on an amalgam of the available data and the application of a precautionary approach in line with national and international obligations. The available information indicates an average figure for ambient noise in the marine environment of approximately 70 dB. The available information also indicates that pile driving noise (for 4 to 5 m diameter piles) can be as high as of 260 to 270 dB re 1 µPa at source (Nedwell *et al.,* 2003) at a range of 20 Hz to > 20 kHz with most energy around 100 to 200 Hz (Nedwell and Howell, 2004 and Madsen *et al.,* 2006). However, factors such as pile diameter, water depth, geology and sea bed topography can all influence noise generation and propagation so values are likely to vary from site to site.

The noise associated with the construction of offshore wind-farms could affect marine fish in several ways:

- Primary effects – immediate or delayed fatal injuries, often caused by “barotraumas” arising from gas embolisms in mammals or ruptures to swim bladders in fish.
- Secondary effects – injuries such as deafness that may impact upon survival, particularly among species that hunt by acoustic methods.
- Tertiary (behavioural) effects – these effects may be milder but experienced over a greater area. This may include avoidance that may arise from pain or discomfort (although these terms are of course subjective).

There are only a limited number of investigations on the effects of offshore wind-farm construction noise on fish. Relating the above possible effects to the sensitivity of fish is difficult as few fish species have been tested for hearing sensitivity. Four species whose hearing capabilities have been investigated are Dab (*Limanda limanda*), Atlantic salmon (*Salmo salar*), Atlantic Cod (*Gadus morhua*) and Atlantic herring (*Clupea harengus*).

Hastings and Popper (2005) provide a detailed overview of results from five recent experimental studies looking at the effects of **pile driving** on fish. Four of them took place off the west coast of the United States and one was undertaken in the United Kingdom. Species investigated included the shiner surfperch (*Cymatogaster aggregate*), Sacramento blackfish (*Orthodon microlepidotus*), brown trout (*Salmo trutta*), steelhead (*Oncorhynchus mykiss*), Chinook salmon (*Oncorhynchus tshawytscha*) and northern anchovy (*Engraulis mordax*). **Behavioural observations** were undertaken in one of the studies on caged fish held at different distances from piling (methods reviewed in Hastings and Popper 2005). However, as mentioned by Hastings and Popper (2005), experimental conditions were in most cases difficult to control and conclusions drawn from some of the studies might be viewed as being rather limited. [1]In the course of the San Francisco Oakland Bay Bridge Project, a variety of external and internal **injuries,** including reddening of the liver, rupture of the swim bladder, or internal bleedings were observed in one of the investigations (Caltrans, 2001). In another study, no physical injuries were observed in caged sea trout within a radius of 400 m from the piling (SL = 194 dB peak to peak re 1 µPa) in the harbour of Southampton during construction of the Red Funnel Terminal (Nedwell *et al*. 2003b). There is also evidence from reports in the

[1] For example, Nedwell *et al*. (2003a) placed brown trout in cages positioned at different distances from vibro and impact pile-driving operations in Southampton harbour and filmed them using close-circuit television monitoring. ‘Startle-reactions’ and ‘Fish activity level’ were investigated prior and during pile driving, with activity levels measured by counting the number of times a fish entered the camera’s field of view within a two-minute observation period. Controls were performed on the same animals as tested and control and event activity levels were compared with a Mann-Whitney U-test (Nedwell *et al*. 2003B). The observations revealed no evidence that trout reacted to impact piling at 400 m, nor to vibropiling at close ranges (<50 m; source level of impact pile-driving = 194 dB re µPa peak to peak). However, since control observations were performed on the same animals as tested, the results are difficult to interpret. It should also be noted that not all of the cage but only a part of it – the long diagonal - could be observed. How many animals were placed in the different cages was also not stated and it might be only speculated that this was the same number (n=10) than was examined later for injuries (for a detailed critical review of this and the four other studies see Hastings and Popper 2005).

grey literature that pile driving kills fish of several different species if they are sufficiently close to the source (review by Hastings and Popper 2005). For example, mortalities were observed after pile-driving in the course of the San Francisco-Oakland Bay Bridge Demonstration Project, USA. Sound levels at a distance of 100 and 200 m from the pile were between 160 and 196 dB re 1 µPa RMS (Caltrans, 2001). Fish were found dead primarily within a range of 50 m (n=13). The external and internal injuries, which were observed, gave reason to assume that there might have been further mortalities, especially of species with swim bladders. The zone of direct mortality was about 10 - 12 m from piling, the zone of delayed mortality was assumed to extend out at least to 150 m to approx.1,000 m from piling. Tests on caged fish revealed greater effects when using a larger hammer (1700 kJ, as compared with 500 kJ). The greatest effects were observed in a range of 30 m from piling. Preliminary results indicated increasing damage rates to the fish together with extended exposure times (Caltrans, 2001). However, reviewing these and other studies, Hastings and Popper (2005) point out that the results provided are yet highly equivocal[2]. To summarise, some reports in the grey literature indicate that severe damage due to pile-driving noise is possible. However, in light of the possible pitfalls of some of the analysis, it is clear that much more research is required to investigate the extent and dimension of physical effects on marine fish due to pile-driving.

For mitigation of impacts from **pile driving**, measures might focus on the source of noise as well as the receiver. Looking at the source, there are several mitigation options currently in discussion (see also Nehls *et al*., 2007)[3]:

- extending the duration of the impact during pile-driving (decrease of 10-15 dB in SL; mostly at higher frequencies > 2 kHz);
- mantling of the ramming pile with acoustically-isolated material (plastic etc.; decrease of 5 –25 dB in SL; higher frequencies better than lower ones);
- placing air-bubble curtains around the pile (maximum decrease of 10-20 dB, depending on frequency; Würsig *et al*. (2000) and Nehls *et al*. (2007) give an overview of different results with bubble curtains. Fig 3.18 (Nehls *et al*., 2007) shows that the best result of Würig *et al*. (2000) varies between 2-19 dB. Reduction in broadband noise varies only between 0-10 dB. Furthermore, Nehls *et al.* (2007) point out that 'The highest sound attenuation was obtained with the double-ring system, but at the expense of a very complex air supply. No bubble curtain operation known so far was made under offshore conditions or at noteworthy tide current'; and
- applying a soft-start / ramp-up procedure (slowly increasing the energy of the emitted sound (Richardson *et al*., 1995).

The methods mentioned above have benefits and costs that are discussed in detail by Thomsen *et al*. (2006) and Nehls *et al*. (2007). Precautionary mitigation measures would include not carrying out pile-driving in confined areas in close proximity to migrating fish. Times of special sensitivity (migration peaks, spawning time of fishes) might be avoided. Time frames should also be allowed for, with respect to the danger of masking during spawning of gadoid fishes.

The available evidence suggests that some fish are likely to aggregate within an OWF array (Bioconsult A/S, 2003; Ibrahim *et al.* 1996; Baine, 2001; Soldal *et al.,* 2002, Fabi *et al.,* 2004; Anderson and Gates, 1996). However, this will only be a local redistribution of fish so there will not be an increase in fish numbers, therefore this is of local interest but low ecological significance.

If fishing activities are restricted within OWF there may be impacts on fish stocks (an effectively closed area offering protection) but this depends on factors such as species behaviour and the area of wind-farm (carrying capacity), i.e. fish are likely to move outside OWF to feed, spawn etc when they will no longer be protected so any protection is only temporary.

The available evidence suggests that the only impacts from electromagnetic fields of concern are changes to the behaviour of electro-sensitive species and species sensitive to magnetic fields (Bioconsult A/S, 2004; Sisneros *et al.,* 2003; Kalmijn, 1982; Gill and Taylor, 2001; COWRIE, 2003 and COWRIE, 2004). The

[2] Hastings and Popper (2005) note, for example, that no clear correlation between the level of sound exposure and the degree of damage could be determined. They also criticise that in most of the studies, 'pathology was done on fish that did not receive appropriate pathological or histological preparation or analysis'. Finally, in some studies it could not be ensured that exposed and control animals were treated identically (for a more detailed review on the pathological methods used see Hastings and Popper 2005; pp 40).

[3] For example, extending the duration of the impact reduces the source and has biological implications since signals of longer duration would mask communication signals to a greater extent than shorter signals. The method is also limited technically, since shorter pulses are more effective in driving the pile into the bottom than longer ones. Mantling seems to be very promising but has so far only been tested in a relatively short pile. Air bubble curtains are very expensive and might only be effective in relatively shallow water. Soft-start procedures are theoretically promising but their effect has not been tested to a large degree. Ramping-up might also make it more difficult for cetaceans and seals localising the sound source (RICHARDSON *et al*. 1995).

significance of such behavioural changes are unknown but potentially high, the greater the area covered by OWF and their associated cables the greater the potential impact. Studies are ongoing in the United Kingdom to better understand these impacts.

The available evidence discussed above and from Environmental Statements and monitoring reports from the United Kingdom and Denmark suggests that the impacts on fish are low if appropriate mitigation measures are taken during the construction phase of the OWF, i.e. some local redistribution but no overall change in species composition or abundance, sensitive life-stages protected by intelligent scheduling of works. Impacts are likely to be limited to within a predictable distance from the OWF, however greater certainty in predictive tools on behavioural effects is required. In order to reach conclusions on impacts you need to know the distribution and abundance of fish in the OWF area and their status. EIA is therefore essential to assess the importance of impacts to populations, i.e. to identify, predict and quantify the impacts to assess significance at each potential OWF site. A better understanding of behavioural impacts is needed.

8. Marine mammals

The primary risk to marine mammals arises from underwater noise arising from construction activities, most notably pile-driving. The magnitude of such noise is likely to be great enough to cause disturbance, and in close proximity to the works even injury or death to individuals or populations of marine mammals. Temporary or permanent threshold shift (TTS / PTS) or masking of biologically significant sounds can occur. Resultant changes in behaviour may include separations of mother calf groups.

Such impacts can be mitigated through the application of various procedures during construction or by the adoption of engineering solutions. From the perspective of the comparatively low level of underwater noise associated with the installation of gravity based structures this foundation type may be the Best Environmental Option (BEO). However, the installation of such structures is limited to shallow water and they may impact adversely upon the environment in other ways (*e.g.* scouring and consequent effects upon benthic communities; increased turbidity; greater footprint on the sea bed), involve additional seabed preparation works and may create problems during removal (de-ballasting, suction effects may disturb lifting operations) and the disposal (recycling capacity on land).

Assessment of the impact of sub-sea construction noise on marine mammals (and other receptors) is problematic. As discussed above this is because knowledge of underwater noise, marine mammal behaviours and of distributions is in many cases limited. A seven stage approach, was adopted in the United Kingdom to support the EIAs for the United Kingdom Round 2 wind-farms in the Greater Thames area (detailed below), and this approach illustrates the main issues associated with the impact assessment.

8.1 Assessment of use of the site and regional population (baseline data)

Obtaining a detailed knowledge of the use of the proposed development site and the surrounding area by resident, seasonal or migrant marine mammals is an essential part of EIA and can be obtained by using existing data or commissioning new survey work .There are two broad types of data which can be used in EIA - the regional scale distribution or abundance of marine mammals such as information collected SCANS type surveys (Small Cetaceans in the European, Atlantic and North Sea - see http://biology.st-andrews.ac.uk/scans2/index.html) or in the Atlas of Cetacean Distribution in North-West European Waters (see http://www.jncc.gov.uk/default.aspx?page=2713). Site specific survey work may also be undertaken such as that described as part of MINOS project (Marine warm-blooded animals in the North and Baltic Seas: Foundations for assessment of offshore wind-farms - http://www.minos-info.org/). Deployment of passive acoustic monitoring (PAM) or T-Pods may assist with surveys. A full understanding of the use of the site and regional population dynamics is, however, unlikely to be technically attainable without a considerable budget and available time.

8.2 Prediction of source noise level

Such predictions may be model based, utilising data obtained from other piling operations or, alternatively, may be derived from test piles. The predicted level will be that likely to occur after all relevant mitigation techniques to reduce noise at source have been applied.

8.3 Assessment of geographical and temporal range of predicted noise levels

Central to this exercise will be the calculation of noise attenuation rates (the extent to which noise levels decrease at distance from the source). Modelled approaches may again be relevant here to allow for variation in water depth, sediment structure, topography, a key factor in attenuation. Temporal effects will be dependent on the construction programme. For the larger offshore wind-farms construction activities may be taking place across a number of seasons, or even years, and on a 24 hour a day basis. The potential arises that marine mammals could be denied access to a large area surrounding a site for a considerable period of time.

8.4 Application of thresholds to assess potential impacts on individuals

Our understanding of the potential impacts of underwater noise on individuals is extremely limited. Considerable variation is likely to occur between species and between individuals. One approach, applied in the United Kingdom, is the application of the dB(ht) species metric (see Nedwell *et al*., 2007 for details) which seeks to describe thresholds at which underwater noise may give rise to certain responses in an individual or impact upon it. By applying such thresholds to the geographical range of noise levels calculated in 8.3 above "zones of influence" on individuals around construction activities can be assessed. In many cases these zones are likely to extend for many kilometres around a proposed development site. Because of the uncertainties associated with any particular methodology it may be necessary to apply a precautionary approach to the delineation of zones of influence. In 2006, a report funded by Collaborative Offshore Wind farm research into the Environment (COWRIE) on effects of offshore wind-farm noise on marine mammals and fish has been published. The report provides the most recent review of studies undertaken in this area of research. For the auditory sensitive harbour porpoise hearing thresholds (dB_{rms} re 1 µPa) - as obtained by behavioural and evoked auditory potential trials - were considered in this study. This leads to the assumption that the zone of audibility of pile-driving for harbour porpoises and also for harbour seals will most certainly extend beyond 80 km, perhaps hundreds of kilometres, or even more from the sound source. Behavioural responses are expected to probably range up to 80 km. In the immediate vicinity of ramming activities severe injuries can not be excluded. Mitigation measures should include both the source and the receiver. Potential measures include a combination of acoustic isolation of the ramming pile, ramp-up procedures and acoustic deterrent devices (Thomsen *et al*., 2006). Currently, in German approvals for wind-farms the compliance is required with the threshold of 160. db (re 1 µPa) sound exposure level (SEL) outside a circle with a radius of 750 m around the area where ramming takes place. Seasonal restrictions on piling activity may also be relevant (*e.g.* during calving or pupping season).

8.5 Application of distribution data to assess potential impacts on populations

In the case of resident populations the zones of influences can also be used to assess the level of displacement, if any (behavioural responses to pile-driving noise could be up to 80 km, however, the nature and significance of such responses is not clearly understood). However, it may be less possible to assess impacts on seasonal use of the site (if indeed this is known) or on migration movements. Knock-on effects on regional populations may need to be made on a qualitative, rather than quantitative, basis. The assessment of cumulative / in-combination effects on marine mammal populations (including international and transboundary impacts) is poorly developed and requires further research.

8.6 Verification of predicted noise levels during construction

It is necessary to require verification of noise models applied during the impact assessment. This could be carried out by *in situ* measurements during construction, both in the near- and far- fields (thereby verifying attenuation calculations as well as source levels).

8.7 Monitoring of population during and post- construction

Monitoring of populations during and post- construction is likely to be problematic. Passive Acoustic Monitoring or the use of "T-Pods" have been applied in the case of construction activities at Horns Rev and Nysted, however, assumptions drawn from data from such sources may need to be treated with caution. Additionally, because of possible inadequacies with baseline data (see 8.1 above) it may not be possible to obtain statistically robust results from any monitoring programme, therefore the rationale and scope of any monitoring programme must be based on the data that can be collected (and any account for inherent limitations in data collection). The potential impact of the operational noise of the turbines and of maintenance activities should be assessed as part of an EIA and be monitored.

9. Birds

Risks to birds from offshore wind installations arise from four main potential impacts:

a. direct loss of habitat

b. displacement

c. collision risk

d. avoidance behaviour / barrier effect

Additionally cumulative impacts of a number of wind-farm projects (or in combination with other users of the marine environment) may also occur.

In respect of direct loss of habitat although the area of seabed impacted is relatively small (see above) the footprint of an OWF defined by its outer turbines is much larger, *e.g.* North Hoyle in United Kingdom 30 turbines in 10 km^2, Horns Rev in Denmark 80 turbines in 20 km^2 and the proposed London Array in the United Kingdom, 271 turbines in 245 km^2 and these larger areas may be more important when considering bird displacements. Some seabird species may be displaced from this area and its immediate vicinity within a 2 to 4 km buffer zone giving rise to a potential significant loss of feeding grounds. In the Horns Rev monitoring programme, density surveys were only carried out up to 4 km. However, displacement effects beyond 4 km cannot be ruled out. Although concerns over collision risk have to some extent been addressed for some species (*e.g.* common eider) in certain conditions (daylight, good visibility) by radar-based and other studies in Denmark and Sweden it remains a potentially significant impact, particularly in respect of a number of species (for example terns) or during poor visibility or at night.

Issues of avoidance during flight, or potential barriers to bird movements arising from wind-farm development have also been addressed by Danish and Swedish radar studies (on mainly migratory birds) which suggest that large waterfowl species have successfully avoided wind-farms without adverse effects on populations (Desholm and Kahlert, 2005)). Notwithstanding this issue there may be considerable variations between species (*e.g.* on daily foraging flights or to roosting sites) and the larger size of more recently proposed developments (for example United Kingdom Round 2 projects) may create more formidable barriers as the scale of development increases beyond 2010 levels.

The greatest challenge associated with assessing impact of OWF on birds is the establishment of robust baseline data. Ideally decision-makers would be presented with complete baseline information including an assessment of the species present there, their use of the site, flight heights, presence of prey species and other factors affecting site use, the location of migratory routes and the relationship of the site and its species to regional, national and international populations. However, while a number of extremely useful tools have been deployed recently to provide this baseline data – including radar, aerial surveys and agreed approaches to boat-based surveys (see Maclean *et al*., 2007a, Maclean *et al*., 2007b and Maclean *et al.*, 2006) – to obtain a full understanding of any particular site may never be available. In the framework of EIA, all applicants for approvals for OWF in the German EEZ are obliged to submit baseline data, ascertained in accordance with the relevant Standards for Investigation of the Impacts of Offshore Wind Turbines on the Marine Environment (BSH, 2007).

It is not possible to generalise about how to assess potential bird impacts, this will be dependent upon the species present at any site and the relative importance of the site in its regional or supra-regional context. Furthermore, large scale investigations (*e.g.* MINOS – Marine warm-blooded animals in the North and Baltic Seas. Foundations for assessment of offshore wind-farms; (see http://www.minos-info.org) should be considered.

Collision risk with any part of the OWF structure may be assessed by the application of collision risk models (*e.g.* see http://www.snh.org.uk/strategy/renewable/sr-we00.asp) based on appropriate site and species specific data. Modifications to such models may provide the decision maker with a more robust assessment of potential impact although any underlying assumptions need to be carefully considered. It is also necessary to consider the potential for birds to be injured from turbulence behind the turbine or if birds migrating at higher levels are forced to fly at levels equivalent to the wind-farm due to bad weather etc. The use of flight height data in such assessments should be approached with caution as the accurate estimation of seabird flight heights from boat, shore or aeroplane based observers can be problematic. Application of collision risk data (*e.g.* a mortality of x individuals per month) may only be meaningful if considered in conjunction with population viability analysis. It is important to agree which reference populations should be used given that these could cross national boundaries. The use of collision risk models also requires post-construction studies to validate predictions and verify that the approach and chosen species are appropriate.

In respect of avoidance or barrier effects it may be necessary to rely on radar studies to understand how populations or migratory flocks use a site or move around it. The deployment of suitable radar in the marine environment, however, is problematic as many systems are dependent upon a stable base and the lack of species-specific data that is gathered with radar. Ongoing studies are increasing our knowledge of how birds approach and avoid turbines.

Approaches to the assessment of displacement in United Kingdom wind-farm areas have applied a buffer zone around a wind-farm site to calculate how many individuals in a population may be displaced (such an approach is based on evidence from Denmark suggesting that displacement may occur beyond 2 km and up to 4 km). However, the Horns Rev monitoring programme only carried out density surveys up to 4 km, so it cannot be ruled out that displacement effects occur beyond 4 km. The ecological significance of displacement should it occur will clearly depend upon available habitat and interactions with other individuals and species. Many of these issues are not well understood. The detection of displacement is also difficult due to the inherent variation in numbers and distributions of seabirds (and the statistical power of the available data is often low).

The assessment of cumulative / in-combination effects on bird populations (including international and transboundary impacts) is notably poorly developed and requires further research. However, the lack of already completed large wind-farms located adjacent to each other, or within the ecological range of key species/populations means that at this stage attempts can only be made to predict effects rather than based on measured data.

10. Seascape/public perception

Public perceptions of wind-farm proposals are specific to that development on that site, and are swayed by local sensitivities, thus the same proposal in two different places may produce very different public perceptions (*e.g.* North Hoyle versus Scarweather Sands in United Kingdom). So specific proposals require local consideration, however, there are more general patterns of perception of both place and of wind-farms that tend to be consistent across wider areas. For example, 42 surveys across Europe up to the end of 2002 showed 71% 'in favour' of wind-farm developments. It should be noted that some national cultural perceptions may be potentially different.

The missing connection is to consider public perceptions of places (such connections are not usually made with such general studies). Specifically what characteristics and qualities do people consider are important or value highly about a place? Where we have tourists, why do they go there, what do they expect to see there and what do they do there? It is only with that kind of knowledge that we start to understand why some wind-farm proposals receive a lot of opposition when general surveys say there is general support. This should be an essential requirement of EIA but a better focus to studies is required to better gauge opinions (*i.e*. remove potential bias from questions). Without this type of approach there will be insufficient and inappropriate data for any assessment of impact.

11. Cumulative impacts

Developing assessment tools for cumulative impacts is not just needed for OWF, but for all marine works. Assessment of cumulative impacts is notoriously difficult. Marine Spatial Planning initiatives should greatly assist by addressing this issue at source. Within OSPAR, Workshops on Marine Spatial Management have facilitated the sharing of experience and knowledge providing the foundations for collaboration. The development of approaches and guidance on cumulative impacts and trans-boundary effects is now an integral part of the OSPAR Work Programme and it is essential that any outputs from this are robust enough to cope with the growing pace of offshore wind-farm development in the OSPAR maritime area. Strategic Environmental Assessment is also a useful tool for generating high-level data to assist cumulative impact assessments. Concepts for cumulative impact assessment should be developed.

12. How does this work affect the overall quality status?

The information in the August 2008 update of the OSPAR database shows that to date there are 12 operational offshore wind-farms within the OSPAR region, that is a total of 467 turbines. These are located in Denmark (109 turbines), Ireland (200 turbines), the Netherlands (36 turbines) and the United Kingdom (122 turbines). This equates to a relatively small area of seabed coverage and as such the effects on the physical environment, biota and habitats at the OSPAR region level are insignificant. There are impacts at the local level and these have been predicted, assessed and monitored as part of the national EIA and consents procedures. However, it is also clear from the OSPAR database and the developing energy policy within the EU that a significantly increased rate of developments and area of coverage is to be expected in the coming years.

This report provides a preliminary assessment of the main impacts of OWF on the marine environment for the JAMP based on the current level of development. The assessment of temporal trends and discrete changes in the variability of the quality of the marine environment for the JAMP may require additional baseline datasets to those developed for individual OWF developments in each OSPAR country. In particular larger scale investigations (such as MINOS) would be necessary. Change is unlikely to be detected from short runs of data, where population levels are variable or where receptors have large spatial ranges. Given the current low level of development further assessment may be necessary once more post construction monitoring data is available for OWF as to date only a small data set is available and further discussion by OSPAR is required to determine what data is required to complete the Quality Status Report.

Based on the available evidence the current level of operational offshore wind-farm developments described in section 2 and the predicted scale of development in 2010 is not detrimental to the overall quality status of the OSPAR region (but as for other human activities the long-term and cumulative effects are not yet fully understood). However, as the level of development increases then the potential effects and pressures on populations, habitats, seabed features, etc. could have the potential to affect the overall quality status. This highlights the need for robust assessment, consenting and management procedures for the location, construction and operation (and ultimate removal) of offshore wind-farms to ensure that such effects are avoided, or at worst kept to the absolute minimum.

13. What do we do next? / Lessons learnt

There are a series of marine environmental impacts associated with the development of offshore wind-farms but site selection and robust EIA and consenting procedures all contribute to reducing and mitigating these. However, some of the available mitigation measures can add to the costs of development and as such it is important that developers are aware of the potential issues and that developments are planned and costed in accordance with the environmental constraints. Alternatively regulators could make judgements balancing the marine environmental effects with the global environmental benefits.

At the level of development in 2010 careful site selection can prevent (some) impacts on the marine environment. However, as the rate and scale of development beyond 2010 increases, careful site selection, robust EIA and consenting procedure do not on their own guarantee that (significant) environmental impacts do not occur.

14. Data gaps and sharing information

In general terms for the assessment of effects from all human activities in the marine environment (including OWF, oil and gas, aggregate extraction, navigation dredging, sea disposal, land reclamation, coast protection, tourism, shipping, fishing etc) and for marine conservation initiatives, there is a need for more and better data on marine species, including benthos, fish, marine mammals and birds. This includes data on the distribution and abundance, migration routes, behaviour, life-history traits, food and habitat requirements and population dynamics of sensitive species including temporal and spatial variation. Also, as the rate and scale of development increases beyond 2010 levels, the identification of suitable reference populations and the assessment of cumulative and trans-boundary effects will require more robust methodologies. A detailed approach to determining the physical and ecological footprint at several scales is important, i.e. a single turbine, a wind-farm, several wind-farms close together, several well spaced wind-farms, wind-farms with other activities (listed above), these other activities with themselves, etc. and up to a north-east Atlantic scale and beyond. Whilst such data are an integral part of the environmental impact assessment process for any marine development, given the large and often transboundary distribution of many of the key species (birds, fish and marine mammals) a collaborative approach to its collection, analysis and interpretation might assist regulators and developers by providing a consistent and accepted baseline. However, it must be recognised that the scale and logistics of such investigations may be prohibitively expensive and it may never be possible to gather appropriate data to prove / disprove certain impacts. There are already initiatives working at the international scale, *e.g.* MESH and SCANS to provide better knowledge and understanding of discrete areas of the marine environment, and a proportion of this data has relevance to the OSPAR maritime area. However, there are ways in which the coverage, accessibility to and comparability of data can be improved and shared within the OSPAR maritime area to ensure that national and collaborative studies are appropriately targeted to the key national issues and are also relevant to tackling the fundamental questions applicable to all OSPAR Contracting Parties.

To better understand the effects of noise and electromagnetic fields on fish and marine mammals better information on hearing and electric sensitivities is required. A study is under development in the United Kingdom to investigate the behavioural effects of pile-driving noise on marine fish and also in the United Kingdom a study into the behavioural effects of electromagnetic fields on electro-sensitive fish is due to report shortly. Further development of models to predict levels of underwater noise relative to site-specific differences in biota, morphology and background noise would benefit the EIA process. Also, further generic studies on behavioural responses of different species with regard to construction, operation and removal activities to develop species-specific sensitivities (based on life-history traits, population dynamics, ecology and abundance) would benefit the assessment of impacts for all human activities. Further development of modelling tools that extrapolate local to population level effects (*e.g.* density dependant effects, carry-over effects, individual based models (see Kaiser *et al.*, 2002) would assist the process.

Development and testing of measures to minimise and mitigate the environmental impact of human activities, in particular for OWFs, on the marine environment require further development, such as bird collisions (*e.g.* through layout design, lighting and appearance of the OWFs) or sound emissions during the construction phase (*e.g.* methods to dampen the noise, methods to reduce noise propagation, novel installation techniques). Improved approaches to comparing physical and biotic data sets are important, hydrodynamic models to predict local and large-scale changes in current and sediment dynamics, as well as verification of these models by adequate *in situ* assessment of these changes and how these relate to marine habitats is essential.

A condition on all Round 2 offshore wind-farm developments in the United Kingdom is a requirement to submit environmental data and information to a central repository. COWRIE will manage and make available this data and information through a programme of data management and coordination to collate, manage and make available the data and information from offshore wind-farm projects. A similar system at the international level (or preferably national systems working to agreed data standards) may be a more realistic and achievable means of improving the requisite data sets listed above and making them more accessible. Aligned to this could be the development of cost-effective monitoring procedures, including survey design and methods (*e.g.* radar tracking of birds) and novel methods for measuring the impacts of human activities in remote marine locations (*e.g.* bird collision rates) particularly in times of poor visibility.

The OSPAR www.environmentalexchange.info website aims to promote the sharing of information and discussions are also underway at the European level to better coordinate and facilitate the exchange of data and information for offshore wind-farms to avoid duplication of effort wherever possible. Such an initiative is wholly consistent with the objectives of the JAMP so it is recommended that a work stream be developed in close cooperation/collaboration with the EC and existing national/international proposals to ensure that this is achieved.

15. Conclusions

In 2008 the scale of offshore wind-farm development in the OSPAR maritime area is relatively small. 467 turbines are operational or under construction. Based on availability of construction vessels, equipment and materials and the current rate of development, the number of turbines is predicted to increase to nearly 800 turbines by 2010, although the planned areas are much larger and these will be developed over the next 5-10 years. Data on OWF have only been available over relatively short time-scales and, as can be seen from Table 2 and Figure 1 a-f, only a relatively small number of developments are operational so the determination of definitive trends is not possible from the initial assessment provided in this report. The annually updated OSPAR database is keeping track of the location and scale of these developments in the OSPAR area. The OSPAR guidance on wind-farms will ensure that future developments adequately assess environmental, social and economic effects during site selection, construction, operation and decommissioning; however, it is important that this guidance be regularly updated as new information becomes available. National mechanisms are in place that target priority research and development issues for offshore wind-farms. The ongoing review programme of the environmental effects of wind-farms (along with the www.environmentalexchange.info website) ensures that up to date knowledge and information is readily available to all OSPAR Contracting Parties; however, to be fully effective this will need to be supported and proactively used by all OSPAR Contracting Parties to ensure that all new data are posted on the site.

The conclusion of this assessment is that, based on the current level of development, the existing OSPAR work programme associated with offshore wind-farms is appropriate and working effectively and that at present there is no need for OSPAR to take further action. However, as the rate and scale of development increases beyond 2010 OSPAR will need to further develop measures to address cumulative and trans-boundary effects and identifying appropriate reference populations. Consequently, the quality status of the OSPAR maritime area is not compromised by the current level of offshore wind-farm development. However, OSPAR should maintain activities to ensure that appropriate measures are implemented developed to ensure that the effects of the increasing levels of development beyond 2010 are appropriately assessed and the conclusions of this assessment revisited.

16. References

Anderson, J. and Gates, P.D., 1996. South Pacific Commission Fish Aggregating Device (FAD) Manual, Volume 1. Planning FAD Programmes. South Pacific Commission.

Baine, M., 2001. Artificial reefs: a review of their design, application, management and performance. Ocean and Coastal Management 44. 241-259

Bioconsult A/S, 2003. Hard Bottom Substrate – Sea Bottom and Marine Biology Horns Rev Offshore Wind Farm. Annual Status Report 2003.

Bioconsult A/S, 2004. Monitoring programme status report 2003: fish at the cable trace Nysted offshore wind-farm at Rodsand. Document Number: 2352-03-002-rev2.doc. March 2004.

BSH, 2007. Standard: Investigation of the Impacts of Offshore Wind Turbines on the Marine Environment (StUK3), Status February 2007. BSH-Nr.7003

Caltrans, 2001. Fisheries Impact Assessment – San Francisco – Oakland Bay Bridge East Span Seismic Safety Project. PIPD EA 012081, Caltrans Contract 04A0148, Task Order 205.10.90, PIPD 04-ALA-800.0/0.5: 57 pp 51.

Cefas, Preliminary investigation of the sensitivity of fish to sound generated by aggregate dredging and marine construction, Defra Project Code AE0914, March 2003.

Coull, K.A., Johnstone, R. and Rogers, S.I., 1998. Fisheries Sensitivity Maps in British Waters. Published and distributed by UKOOA Ltd.

EC, 2007. Council of the European Union, Presidency Conclusions from the Brussels European Council, 8/9 March 2007, CONCL 1, 7224/1/07 Rev 1, Brussels, 2 May 2007.

http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/ec/93135.pdf

COWRIE, 2003. A baseline assessment of electromagnetic fields generated by offshore wind-farm cables. Final Report. Prepared by Centre for Marine and Coastal Studies, Centre for Intelligent Monitoring Systems, Applied Ecology Research Group and Econnect Ltd, July 2003

COWRIE, 2004. The potential effects of electromagnetic fields generated by subsea power cables associated with offshore wind-farm developments on electrically and magnetically sensitive marine organisms – a review. Prepared by Centre for Marine and Coastal Studies and Cranfield University.

Degn U., 2003. Measurements of noise induced from offshore wind turbines and ambient noise in the sea water. Presented at GIGAWIND 2. Symposium 9/9/02 Hannover, Germany. Ødegaard & Danneskiold-Samsøe A/S.

Desholm, M. and Kahlert, J., 2005. Avian Collision Risk at an Offshore Wind Farm. Biology Letters 1(3) 296-298.

Eleftheriou, A. and McIntyre, A., 2005. Methods for the Study of Marine Benthos. Third Edition. Blackwell Publishing, 2005. ISBN 0-632-05488-3.

EWEA, 2007. Delivering Offshore Wind Power in Europe – Policy Recommendations for Large-Scale Deployment of Offshore Wind Power in Europe by 2020. www.ewea.org.

Fabi, G., Fabio, G., Puletti, M. and Scarcella, G., 2004. Effects on fish community induced by installation of two gas platforms in the Adriatic Sea. Marine Ecology Progress Series. Vol. 273: 187-197, 2004.

Gill, A.B. and Taylor, H., 2001. The potential effects of electromagnetic fields generated by cabling between offshore wind turbines upon elasmobranch fishes. CCW Contract Science Report No 488.

Hastings, M.C. and Popper, A.N., 2005. Effects of Sound on Fish. California Department of Transportation Contract No. 43A0139, Task Order 1. 28 January 2005 (Appendix B Revised 23 August 2005).

Ibrahim, S., Ambak, M. A., Shamsudin, L. and Samsudin, M.Z., 1996. Importance of fish aggregating devices (FADs) as substrates for food organisms of fish. Fisheries Research 27. 265-273.

Kaiser, M.J., Elliot, A., Galanidi, M., Rees, E.I.S., Caldow, R., Stillman, R., Sutherland, W. and Showler, D., 2002. Predicting the displacement of common scoter *Melanitta nigra* from benthic feeding areas due to offshore wind-farms – Final Report, COWRIE-BEN-03-2002.

Kalmijn, A.J. (1982) Electric and Magnetic field detection in elasmobranch fishes. Science, 218. 916-918.

Maclean, I.M.D., Skov, H., Rehfisch, M.M. and Piper, W. 2006. Use of aerial surveys to detect bird displacement by offshore wind farms. COWRIE DISP-03-2006

Maclean, I.M.D., Frederikson, M. and Rehfisch, M.M., 2007a. Potential use of population viability analysis to assess the impact of offshore windfarms on bird populations. COWRIE ISBN: 978-0-9554279-7-8

Maclean, I.M.D., Skov, H. and Rehfisch, M.M. 2007b. Further use of aerial surveys to detect bird displacement by offshore windfarms. COWRIE EXT-DISP-06-07 ISBN: 978-0-9557501-1-3

Madsen, P.T., Wahlberg, M., Tougard, J., Lucke, K. and Tyack, P., 2006. Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs. Mar. Ecol. Progr. Ser. 309, 279-295.

Meißner, K., Bockhold, J. and Sordyl, S., 2006. Heat emission from subsea power cables – a problem? Seabed temperature measurements near submarine power cables in the offshore wind-farm Nysted Havmøllepark (Denmark), reported in Meeresumwelt-Symposium 2006 http://www.bsh.de/de/Das%20BSH/Veranstaltungen/MUS/2007/Symposium_2006_Internet.pdf

Nedwell, J. and Turnpenny, A.W.H., 1998. The use of a generic weighted frequency scale in estimating environmental effect. Proceedings of the Workshop on Seismics and Marine Mammals, 23rd-25th June 1998, London. UK.

Nedwell, J., Langworthy, J. and Howell, D., 2003a. Assessment of sub-sea acoustic noise and vibration from offshore wind turbines and its impact on marine wildlife; initial measurements of underwater noise during construction of offshore wind-farms, and comparison with background noise. Report No. 544 R 0424. COWRIE.

Nedwell, J., Turnpenny, A., Langworthy, J. and Edwards, B., 2003b. Measurements of underwater noise during pile driving at the Red Funnel Terminal, Southampton, and conservations of its effect on caged fish. Subacoustech Ltd. Report 558 R 0207.

Nedwell, J. and Howell, D., 2004. A Review of Offshore fwind-farm related underwater noise sources. Report No. 544 R 0308. COWRIE.

Nedwell, J.R., Lovell, J and Turnpenny, A.W.H., 2005. Experimental validation of a species-specific behavioural impact metric for underwater noise. Acoustical Society of America Journal, Volume 118, Issue 3.

Nedwell, J.R., Turnpenny, A.W.H, Lovell, J., Parvin, S.J., Workman, R, Spinks, J.A.L. and Howell, D (2007) A validation of the dBht as a measure of the behavioural and auditory effects of underwater noise. Subacoustech Report No. 534R1231

Nehls, G., Betke, K., Eckelmann, S. and Ros, M., 2007. Assessment and costs of potential engineering solutions for the mitigation of the impacts of underwater noise arising from the construction of offshore wind-farms. COWRIE Ltd, Newbury, UK.

OSPAR, 2004. Problems and Benefits Associated with the Development of Offshore Wind-farms, Biodiversity Series, OSPAR Commission. Publication Number 212/2004.

OSPAR, 2006. Current State of Knowledge on the Environmental Impacts of the Location, Operation and Removal/Disposal of Offshore Wind-farms – Status Report April 2006, OSPAR Commission. Publication Number 278/2006.

OSPAR, 2008a. OSPAR Database on Offshore Wind-farms 2008 Update, OSPAR Commission. Publication Number 364/2008.

OSPAR, 2008b. OSPAR Guidance on Environmental Considerations for Offshore Wind-Farm Development. Reference Number 2008-3.

OSPAR, 2008c. Environmental impact of the construction or placement of structures (other than oil and gas and wind-farms). OSPAR Commission, London. Publication Number 367.

OSPAR, 2009a. Environmental impact of underwater noise. OSPAR Commission, London. Publication 441/2009.

OSPAR, 2009b. Environmental impact of cables, OSPAR Commission, London. Publication 437/2009.

OSPAR, 2009c. Climate change mitigation and adaptation. OSPAR Commission, London. Publication 464/2009.

ØDS[1], 2000. Offshore Wind-Turbine Construction – Offshore Pile-Driving Underwater and Above-water Noise Measurements and Analysis. Report No. 00.877. Ødegaard & Danneskiold-Samsøe A/S.

ØDS[2], 2000. Offshore Wind-Turbines - VVM – Underwater Noise Measurements, Analysis and Predictions. Report No. 00.792. Ødegaard & Danneskiold-Samsøe A/S.

Richardson, W.J., Malme, C.I., Green, C.R. jr and Thomson, D.H., 1995. Marine Mammals and Noise. Academic Press, San Diego, CA 576pp.

RPS, 2005. London Array Limited, Environmental Statement.

Sisneros, J.A. and Tricas, T.C., 2003. Neuroethology and life history adaptions of the elasmobranch electric sense, Journal of Physiology – Paris 96 (2002) 379-389.

Soldal, A.V., Svellingen, I., Jorgensen, T. and Lokkeborg, S., 2002. Rigs-to-reefs in the North Sea: hydroacoustic quantification of fish in the vicinity of a “semi-cold” platform. ICES Journal of Marine Science, 59:281-287.

Thomsen, F., Lüdemann, K., Kafemann, R. and Piper, W., 2006. Effects of offshore wind-farm noise on marine mammals and fish, Biola, Hamburg, Germany on behalf of COWRIE Ltd.

Wahlberg, M. and Westerberg, H., 2005. Hearing in fish and their reactions to sound from offshore wind-farms. Marine Ecology Progress Series. Vol. 288: 295-309.

Würsig, B., Green, C.R. jr and Jefferson, T.A., 2000. Development of an air bubble curtain to reduce underwater noise of percussive piling. Mar. Environ. Res. 49, 79-93.

17. Glossary and acronyms

Barrow	- a 90 MW operational OWF off the north-west coast of England
BDC	- OSPAR's Biodiversity Committee
BEO	- Best Environmental Option
Biofouling	- the undesirable accumulation of microorganisms, plants, algae, and animals on submerged structures
BSH	- Bundesamt für Seechiffahrt und Hydrographie (agency responsible for shipping, environmental protection and spatial planning in German territorial waters)
°C	- degree Celsius
Cefas	- Centre for Environment, Fisheries and Aquaculture Science (agency with responsibilities to conserve and enhance the aquatic environment, promote sustainable management of its natural resources, and protect the public from aquatic contaminants)
cm	- centimetre
COWRIE	- Collaborative Offshore Wind Research into the Environment (an independent company set up to raise awareness and understanding of the potential environmental impacts of the UK offshore wind-farm programme)
CPA	- Coast Protection Act 1949 (As Amended) (UK)
dB	- decibel (a unit of measurement for noise level)
$dBht_{(species)}$	- a pan-specific metric incorporating the concept of "loudness" by using a frequency-weighted curve based on the species hearing threshold (extrapolated from audiogram data) as the reference unit for a dB scale (http://www.subacoustech.com/index.shtml)
Defra	- Department for Environment, Food and Rural Affairs (UK)
EEZ	- Exclusive Economic Zone
EIA	- Environmental Impact Assessment
EIHA	- OSPAR's Working Group on Environmental Impacts of Human Activities
ES	- Environmental Statement
FEPA	- Food and End Environment Protection Act 1985 (As Amended) (UK)
foundation	- the part of an OWF that sits in or on the sea bed
GBS	- gravity base structure (a type of OWF foundation that sits flat on the sea bed)
GW	- Gigawatt
Horns Rev	- a 160 MW operational OWF off the west coast of Denmark
Hz	- Hertz (a unit of measurement for frequency of sound waves)
jacket	- a form of OWF foundation
JAMP	- OSPAR's Joint Assessment and Monitoring Programme
JNCC	- Joint Nature Conservation Committee (nature conservation advisor to the UK Government)
Kentish Flats	- a 90 MW operational OWF in the Thames Estuary (UK)
kHz	- kiloHertz (a unit of measurement for frequency of sound waves)
km	- kilometre (a unit of measurement for distance)
km^2	- square kilometre (a unit of measurement for area)
London Array	- a 1000 MW authorised OWF in the Thames Estuary (UK)

m	- metre (a unit of measurement for distance)
MESH	- Mapping European Seabed Habitats (a partnership drawing together scientific and technical habitat-mapping skills, expertise in data collation and its management, and proven practical experience in the use of seabed-habitat maps for environmental management within national regulatory frameworks)
MINOS	- Marine warm-blooded animals in the North and Baltic Seas: Foundations for assessment of offshore wind-farms (project examining whether large scale offshore wind-farms within the German parts of North and Baltic Seas affect or endanger harbour porpoises, common seals and sea birds)
monopile	- a singular OWF foundation piece that is drilled or driven into the sea bed.
multipile	- a multiple OWF foundation piece that is drilled or driven into the sea bed.
MW	- Megawatt
North Hoyle	- a 60 MW operational OWF off the north coast of Wales
Nysted	- a 166 MW operational OWF off the south-east coast of Denmark
OWF	- offshore wind-farm
µPa	- micropascals (a unit of measurement for sound pressure)
PAM	- Passive Acoustic Monitoring (a technique for detecting marine mammals)
QSR	- OSPAR's Quality Status Report
Round 1	- the first phase of OWF development in the UK, sites limited to 30 turbines in 10 km^2
Round 2	- the second round of OWF development in the UK based in 3 strategic areas (Greater Wash, Outer Thames and North West) following an SEA
Round 3	- the latest round in the UK announced on 10 December 2007 (no sites currently identified), the SEA is underway
SCANS	- Small Cetaceans in the European, Atlantic and North Sea (a study investigating the abundance of small cetacean populations)
Scarweather Sands	- a 60 MW OWF off the south coast of Wales still at the application phase
scour/scouring	- the movement of sediment from the base of OWF structures by changes in hydrodynamics
Scroby Sands	- a 60 MW operational OWF off the east coast of England
SEA	- Strategic Environmental Assessment
SL	- Sound level
SNH	- Scottish Natural Heritage (an agency with responsibility to care for the natural heritage: the wildlife, habitats, rocks, landscapes and natural beauty of Scotland)
T-Pod	- a passive acoustic monitoring device
tripod	- a multiple OWF foundation piece that is drilled or driven into the sea bed.
turbine	- the power generation component of an OWF, comprising the nacelle, blades and tower
UKOOA	- United Kingdom Offshore Operators Association (the leading representative trade organisation for the UK offshore oil and gas industry)

Annex. Case Study – North Hoyle Offshore Wind Farm

The North Hoyle offshore wind-farm (OWF) consists of 30 turbines covering an area of approximately 10 km^2 and is located 4 miles off the North Wales coast, between the towns of Rhyl and Prestatyn.

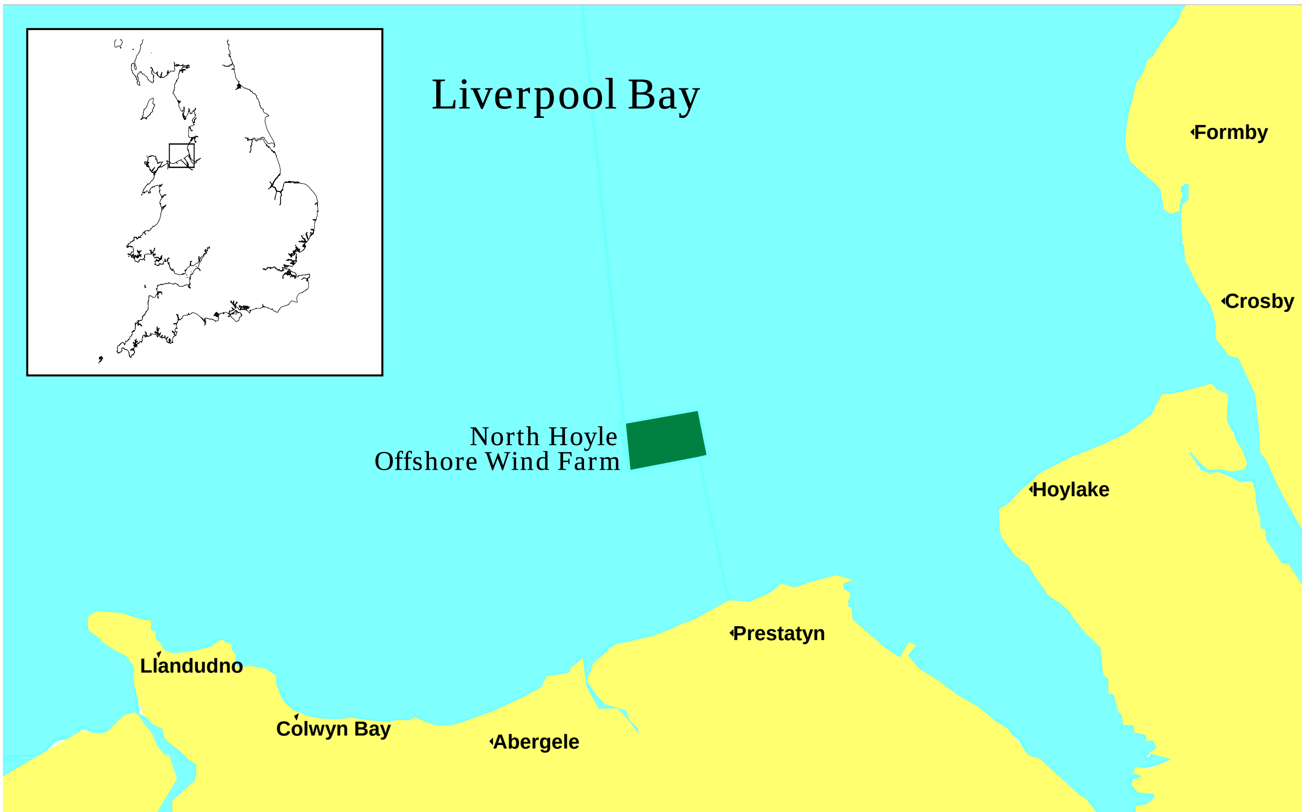


Figure 1. Location of the North Hoyle offshore wind-farm

In an initial site selection process the developer considered options to minimise any potential impacts on the physical, biological and human environments, to identify an area with an appropriate combination of relatively shallow waters, good strong winds and proximity to the national electricity network. Initial site investigations were undertaken in the summer of 1999 with options for the potential development of the North Hoyle site awarded in April 2001.

The United Kingdom has a regulatory regime in place whereby all construction works in the marine environment have to be consented by the United Kingdom's regulators. Wherever necessary an appropriate level of environmental assessment has to be undertaken to support applications to construct and operate offshore developments sufficient for the regulators to reach an informed decision on whether or not to give consent.

The developer, npower Renewables Ltd, sought formal Environmental Impact Assessment (EIA) screening and scoping opinions from the United Kingdom regulators in 2001. Based on the response from the United Kingdom regulators, a stakeholder consultation and the available guidance for the conduct of EIA at offshore wind-farms[1] an EIA was commissioned and undertaken and the developer submitted an Environmental Statement (ES) to the United Kingdom regulators along with the requisite applications for construction and operation consents in February 2002. This ES was based on a combination of historic data sourced for the proposed development area, new environmental surveys and predictive numerical models.

Following a formal consultation on the ES and a dialogue between the regulators, their statutory advisors and the developer to address uncertainties and omissions in the ES, the United Kingdom's regulators decided, that if certain conditions were applied, the potential for this development to have an adverse impact on the local environment was low, and as such they issued the consents for npower Renewables Ltd to construct and operate the North Hoyle OWF in October 2002.

Construction started in April 2003 and was completed in December 2003:

	Start	Finish
- Wind turbine foundations:	April 2003	July 2003
- Transition pieces:	July 2003	August 2003
- Export cables:	August 2003	October 2003
- Wind turbines:	August 2003	March 2004
- Intra array cabling:	September 2003	December 2003
- First power generation:	November 2003	

The consents to construct the North Hoyle OWF included a number of conditions to reduce the potential for the construction and operation of the offshore wind-farm to have an adverse environmental impact. The review of the ES by the UK regulators, their advisors and the output from the consultation also identified specific areas where environmental monitoring should be undertaken. The main premise of the environmental monitoring was to test the predictions made in the ES. All of the licence conditions and monitoring requirements are legally binding and non-compliance by the developer would result in legal action and penalties.

Licence conditions – examples of monitoring

Suspended sediments

Movement of suspended sediments through the North Hoyle site is in a south-easterly direction. Predictions in the ES were that the release of suspended sediments from the construction of the North Hoyle OWF would be at concentrations of up to 10-15 mg^{-3} the measured background levels of suspended concentrations to the south-east of the development of 200 mg (a maximum increase of 7.5%). In order to test this prediction a condition of the licence was to the measurement of suspended sediment concentrations before, during and after construction. The results of these measurements showed comparable baseline measurements within and to the south-east of the OWF. Whilst a few measurements exceeded the typical background levels, the majority of measurements at the North Hoyle site during construction were within the tolerances identified in the ES. From these results it was concluded that there was no overall detectable increase in suspended sediment load due to construction works at the North Hoyle OWF. It was also recommended that the need and scope of any monitoring at other offshore wind-farms should be on a site-specific basis and only needs to address the construction phase (and potentially any maintenance works that could disturb seabed sediments).

Seabed morphology and scour

Predictions in the ES were that scour pits could form around the bases of monopile foundations of up to 6 m depth, with side slopes of 25-30º and scour hole diameters of 24-40 m. The available evidence suggested that changes to ambient bed conditions would occur within 6 to10 diameters around the support structure to a depth of 1.4 diameters. As such it was predicted that there would be no interaction between the foundations as they were at a spacing of more than 40 m between foundations. The construction licence required the developer to investigate scouring via a sequence of bathymetric surveys to be undertaken around a subset of adjacent foundation pieces (minimum of 4) to assess the changes in bathymetry within the array. These surveys were undertaken at 6 monthly intervals for 3 years after construction was completed. The need and extent for any scour protection should be assessed on the basis of the outputs from these studies. Swathe bathymetry surveys in one hundred metre square boxes were undertaken around all 30 foundations between 2004 and 2007 at the site. The results showed that due to the local sedimentary conditions at this location the maximum scour depth recorded was 0.5 m although the overall dimensions of the scour holes were unclear. Rock scour protection was placed around the exposed cables at the J-tubes between July and October 2004. To date, no long-term scour is developing at the North Hoyle Offshore Wind Farm. It is possible to conclude from these investigations that the environmental implications of the regional sediment transport regime at the North Hoyle site are negligible, as no distinct scour pits have developed. Placement of rock around the J-tubes has generally remained *in situ* with potential movement occurring at only 3 locations.

Benthic organisms

The ES predicted that loss of seabed habitat would be small at 0.02 km^2 (based on thirty, 4 m diameter piles each with 30 m of scour protection). As such a minor and localised impact on benthos was predicted. The faunal assemblage observed at the North Hoyle site is widespread and common throughout Liverpool Bay with the recovery of benthic communities from disturbance predicted to be rapid. Conditions attached to the construction licence required monitoring of the local seabed habitats before, during and after construction. These investigations identified a total of 13 326 individuals from 190 taxa. The surveys between 2002 and 2004 indicated a general decline in invertebrate numbers and abundance across the development area, but this trend was observed both within the array and at several control sites outside. The 2005 survey revealed an increase in invertebrate numbers, both within the wind-farm array and in the surrounding area. Invertebrate numbers were in some cases the highest recorded in the monitoring campaign. In general, it appears that the samples from 2002 (pre-development) and 2005 are actually more similar than other paired samples in many cases. Video surveys of 6 of the foundations and the meteorological mast were undertaken in 2004 and showed that pioneering / 'fouling' organisms predominated (*Jassa falcata,* barnacles, mussels).

It was concluded from these investigations that there was no evidence to suggest that the biotopes previously identified in the 2001 and subsequent surveys have changed following construction of the North Hoyle offshore wind-farm. Some reduction has been observed in the number of species and individuals but there is no uniform pattern for this reduction. The observed changes have occurred at sites across the entire area, including those within the OWF and the controls. Sites within the OWF continued to have the highest number of taxa. The absence of any identifiable trend in sediment particle size characteristics associated with construction of the offshore wind-farm suggests that North Hoyle has not, to date, affected benthic invertebrate communities through this mechanism other than at a very localised scale due to the physical presence of the monopile foundations or, potentially, very localised effects of scour or scour protection within 50 m of turbines in areas that are not routinely sampled.

Fish aggregation device

The ES included the prediction that fish tend to aggregate around objects placed in the sea, but that such attractions to 'artificial reefs' were poorly understood. Different species have different affinities to submarine structures. The ES stated that it was not possible to predict the extent to which local distribution and abundance of fish would be affected but the balance of probability was that more fish would seek shelter than would be present outside the wind-farm. To investigate this assertion the construction licence required surveys of fish abundance and distribution in the vicinity of the North Hoyle OWF. During construction (spring 2004) and into summer/autumn 2004 poor catches in the vicinity of the OWF indicated that fish distribution and behaviour were affected in some way. From spring 2005 the general impression was that fish distribution and abundance and fishing activities were not significantly different from how it was immediately before construction work began. Data from 2005 indicated that although the catch rates of most fishes in the North Hoyle area decreased slightly from 2004 values, the data were broadly comparable to previous years for most species, and were within the range observed in preceding years.

[1] Offshore Wind-farms – Guidance note for Environmental Impact Assessment in respect of FEPA/CPA requirements, Version 2 – June 2004

Sources of information:

- North Hoyle Offshore Wind Farm - Baseline Monitoring Report (June 2003)
- North Hoyle Offshore Wind Farm - Annual FEPA Monitoring Report (June 2005)
- North Hoyle Offshore Wind Farm - Annual FEPA Monitoring Report (February 2006)
- North Hoyle Offshore Wind Farm - Annual FEPA Monitoring Report (March 2007)

OSPAR COMMISSION

New Court
48 Carey Street
London WC2A 2JQ
United Kingdom

t: +44 (0)20 7430 5200
f: +44 (0)20 7430 5225
e: secretariat@ospar.org
www.ospar.org

OSPAR's vision is of a clean, healthy and biologically diverse North-East Atlantic used sustainably

ISBN 978-1-906840-07-5
Publication Number: 385/2008