Strategic review of Offshore Wind Farm Monitoring Data

Associated with FEPA Licence Conditions

Marine Mammals

Project Name:	Strategic review of Offshore Wind Farm Monitoring Data associated with FEPA Licence Conditions -Marine Mammals
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Version 1.2:	28th August 2009	

Contents

1. EXECUTIVE SUMMARY

Two rounds of offshore wind farm development have been licensed in UK waters. Each wind farm has to meet certain monitoring requirements, as detailed in its specific FEPA licence. In this review, FEPA monitoring protocols and subsequent data associated with marine mammals collected to date at operational wind farms were assessed, with a key aim to inform future monitoring programmes for Offshore Wind Farm developments.

There are currently 5 operational offshore wind farms in UK waters. The FEPA marine mammal monitoring conditions for these Round 1 wind farms were minimal or absent. In some wind farms no monitoring was required and in others monitoring was only required during the construction phase and specifically for impact mitigation purposes. In one wind farm (Scroby Sands), a long term monitoring plan was required under FEPA licence conditions to cover pre-construction (baseline), construction and operational phases of development, specifically because it was recognised that this wind farm was being developed near a known sizeable seal haul out.

The lack of dedicated monitoring across operational sites makes it difficult to compare data collected so far. This is further complicated by generally poor reporting of monitoring protocols and data collected. FEPA licence conditions for Round 2 wind farms were strengthened and became more consistent and consequently many of the issues raised by this review have already been addressed in the more recent licences.

International case studies such as the Danish wind farms at Horns Rev and Nysted were examined to review the marine mammal monitoring data collected at those sites. Long term and wide-scale dedicated marine mammal surveys were carried out at these wind farms during all project phases (including baseline). The overall conclusions of these studies suggested that noise during construction (the major issue) led to clear avoidance reactions at considerable distances, with abundances appearing to return to close to normal post-construction. Notably, different reactions by marine mammals were recorded at these sites, so it is important to note that reactions may be both site and species specific.

This review highlights that FEPA licences are concerned mainly with the construction phase of a development and consequently monitoring is often limited to that phase. Recommendations on how recent licences might be further improved have been made in this report. Recent licences put the onus onto the regulators such as Natural England or Countryside Council for Wales to determine if longer term monitoring is required. This may lead to lack of consistency in data collection and reporting.

The need for more intensive baseline data collection is considered important in assessing the potential impacts of future developments. The impacts caused by direct injury due to anthropogenic noise can likely be significantly reduced with appropriate mitigation without the need for a detailed baseline. However, appropriate mitigation to reduce potential indirect impacts (e.g., due to disturbance) will vary by species, time period and by location. Clearly, Round 3 wind farm development areas, being further offshore, are potentially areas where information on marine mammal abundance is sparse or lacking. Consequently, it is considered that baseline data is required not only to appropriately adapt mitigation measures, but also to assess the success of mitigation

practices and the overall impact of each project phase. It is important to standardise survey methodology and reporting. It may also be required to carry out more intensive surveys using telemetry or photo identification for example to investigate whether certain habitats are important foraging areas for marine mammals. It is also useful to incorporate noise measurements made during development into marine mammal data analysis and future mitigation.

Recommendations for future Round 3 wind farm development are made. It is considered the primary concerns are the far larger scale of these developments and their locations even further offshore. Offshore construction has the potential to impact on a wider variety of marine species, many of which have been poorly studied. For example, offshore developments may impact on the migratory routes of baleen whales. Large scale development may cause large scale displacement of species from important habitats, especially given that construction activities will likely take place over an extended period of time compared with smaller Round 1&2 wind farms. Larger scale projects increase general concern over ship interactions, pollution and EMF, in addition to ever present anthropogenic noise issues.

2. INTRODUCTION

This review examined in detail the marine mammal monitoring associated with FEPA licensing conditions assigned to the development of offshore wind farms. The key findings were used to highlight the lessons learned and to make recommendations for future monitoring. The new Renewables Obligation came into force in April 2002 as part of the Utilities Act (2000). It requires power suppliers to produce a specified proportion of the electricity from renewable sources and is planned to reach 10.4% by 2010. Offshore wind farms will play a major role in attaining this goal. The British Wind Energy Association (BWEA) predicts that offshore wind will contribute 4% to the government's target. The UK coastline has been estimated to have over 33% of the total European potential offshore wind resource with shallow coastal waters and strong winds (BWEA website).

The Crown Estate which officially owns much of the UK coastline out to 12 nautical miles decided to lease allocated sites for offshore wind development in 2001. This was termed Round 1, the first round of offshore wind development in the UK, consisting of 18 sites of up to 30 turbines around the UK coast (BWEA website). The second round of offshore wind development sites was announced in December 2003 and 15 projects, with a combined capacity of up to 7.2 GW (gigawatts), were allowed to apply for leases to operate offshore wind farms. The allocated sites are in three strategic areas of shallow sea: the Thames Estuary, Greater Wash, and North Wales/ Liverpool Bay (Figures 1 & 2). Round 2 sites are larger than Round 1 sites and will utilise more powerful machines, at greater distances from shore (BWEA website). In June 2008 the Crown Estate announced its Round 3 leasing programme for the next allocation of wind farm sites, aiming for the delivery of up to 25 GW capacity from new offshore wind farm sites by 2020. The final determination of the location and size of the allocated zones are subject to the conclusions of the Strategic Environmental Assessment (SEA) for UK Offshore Energy. Awards are likely to be made in 2009 with construction beginning in 2014.

Offshore wind farms undergo a strenuous planning procedure and consents from the Department of the Environment, Food and Rural Affairs (Defra) are required under Section 5 of the Food and

Environment Protection Act (FEPA 1985). A licence is required from the Secretary of State for Environment, Food & Rural Affairs (or the National Assembly for Wales) for deposits at sea:

- in UK controlled waters around England and Wales as defined by reference to Section 1(7) of the Continental Shelf Act 1961
- anywhere at sea from a British registered vessel, aircraft, or hovercraft, or the loading of materials in England, Wales or in UK controlled waters intended for deposit anywhere at sea.
- All applications are processed and licences issued by the Marine Consents & Environment Unit (MCEU) on behalf of the licensing authority.

A FEPA licence contains a series of conditions and monitoring requirements, which developers are required to meet. FEPA licence requirements are variable between sites and between leasing rounds. Monitoring is required so that predictions made in the Environmental Statement can be validated. A FEPA licence generally requires monitoring of sedimentary and hydrological processes, benthic ecology, electromagnetic fields, noise and vibration, fish, birds and marine mammals.

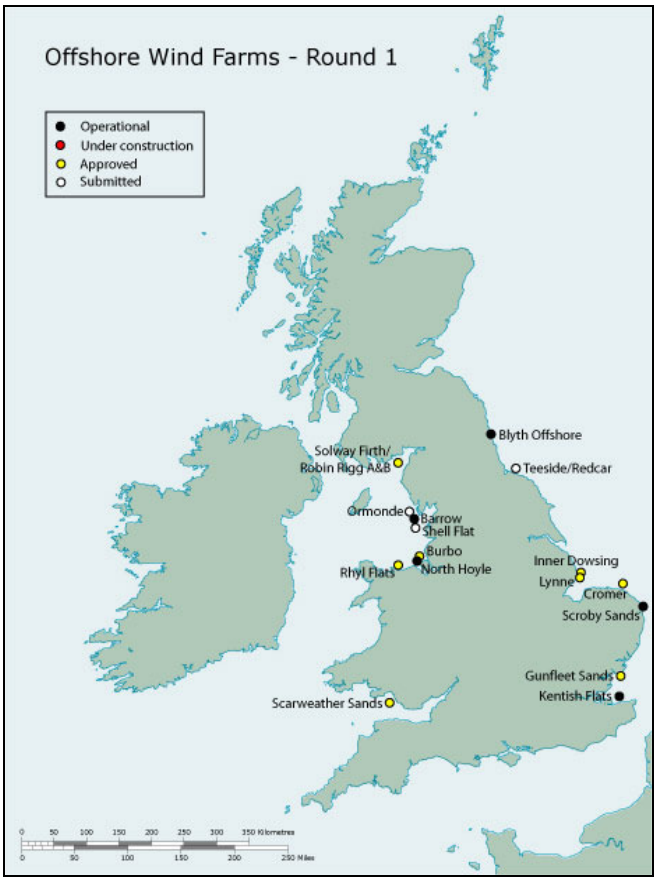

Figure 1: Round 1 offshore wind farms (BWEA website).

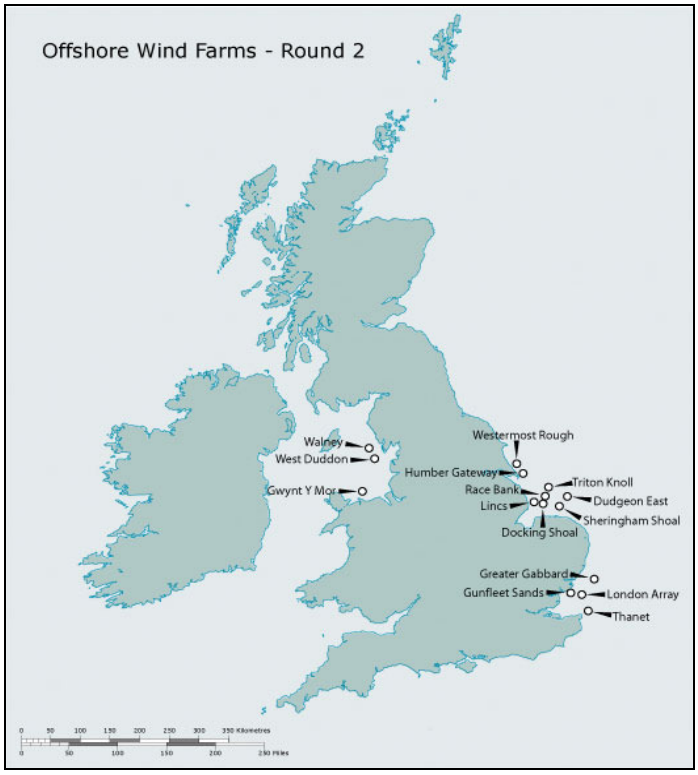

Figure 2: Round 2 offshore wind farms (BWEA website)

2.1CONSERVATION CONSIDERATIONS

Marine mammals are protected under a wide range of legislation in the UK.

2.1.1 Cetaceans

Cetaceans are protected under the European Commission's Habitats Directive and are listed in Annex IV (species of community interest in need of strict protection) and as a result it is illegal to deliberately kill, capture or disturb these species. Harbour porpoise and bottlenose dolphin are also in Annex II, which lists species of community interest whose conservation requires the designation of Special Areas of Conservation (SAC). In the UK two SACs have been designated for the bottlenose dolphin; Moray Firth, Scotland and Cardigan Bay, Wales. There are currently no SACs designated for harbour porpoise however work continues on the possible identification of offshore SACs. In the UK, all species of cetaceans are also protected under Schedule 5 of the Wildlife and Countryside Act 1981. Under WCA 1981, it is an offence (subject to exceptions) to intentionally kill, injure, or take, possess, or trade in any wild animal listed under Schedule 5, and prohibits interference with places used for shelter or protection, or intentionally disturbing animals occupying such places.

2.1.2 Seals

Harbour seals and grey seals are also Annex II species. Seals are protected by the Conservation of Seals Act 1970 which prohibits the killing or taking of seals by certain methods and during specified closed seasons. The Conservation of Seals (England) Order 1999 extends this protection to any time of year for the counties of England bordering the North Sea, from Northumberland to East Sussex, and adjacent territorial waters. There are a number of SACs designated for both seal species around the UK.

3 POTENTIAL IMPACTS OF WIND FARM DEVELOPMENT ON MARINE MAMMALS

The future expansion of offshore wind farms has led to increasing concerns about the impact these developments may have on the marine environment. These impacts may be short term or long term. In the case of marine mammals there are numerous potential impacts ranging from habitat loss to physical injury or death. The following is a list of the most important potential effects of offshore wind farm development on marine mammals.

3.1 Anthropogenic noise

The process of offshore wind farm construction has many activities which are noisy and are of particular concern for marine mammals which have very sensitive underwater hearing (Koschinski *et al.,* 2003, Thomson *et al*., 2006, Madsen *et al.,* 2006). Cetaceans are heavily reliant on sound to navigate, feed and interact socially. Different species have different hearing sensitivities and audiograms for the majority of species are unknown. Studies suggest that baleen whales communicate and hear sounds in low to medium frequencies (20 Hz to >3 kHz) and lack the high frequency echolocation systems (20-150 kHz) found in toothed whales (Richardson *et al.*, 1995). Seals communicate below and above water, and are believed to hear best at frequencies of 1-30 kHz (Richardson *et al.*, 1995).

Wind farm construction noise

During wind farm construction piles are often used to support the turbines. Pile driving generates noise with a high source level and broad bandwidth (Richardson *et al.,* 1995), potentially similar to levels experienced during seismic surveys. Monopiles are hammered into the sea bed using an impulse pile driving technique at 1 second intervals and it can take 1-3 hours to drive one into the bottom depending on the seabed. It can produce loud impulsive sounds which have the potential to be harmful to marine mammals. The levels of noise emissions are dependent on many factors including pile size and type, seabed characteristics, water depth, as well as impact strengths and duration (Diederichs *et al.*, 2008). The noise from pile driving activities may cause auditory damage such as temporary or permanent threshold shift. The sounds emitted during pile driving are generally low frequency and most energy is emitted below 1000Hz, but some components from ramming impulses are up to 100kHz (Evans, 2008). Noise measurements carried out during piling operations at 5 UK wind farms indicate that the source levels of these pile driving operations varied between 243 and 257dB re 1 µPa at 1m, having an average value of 250dB re 1 µPa at 1m (Nedwell *et al.,* 2007). Thomsen *et al.*, (2006) quoted peak broadband source levels of 228 dB re 1µPa at 1m,

with 1/3 octave levels highest at 315 Hz (peak 218dB re 1µPa at 1m) at the FINO -1 research platform in Germany. They calculated theoretical radii of various zones and for harbour porpoise and harbour seals, the zone of masking extended well beyond 80 km, a zone of behavioural responsiveness of several km, perhaps up to at least 15-20 km. These predictions are supported by studies of wind farms in the North and Baltic seas (Tougaard *et al*., 2003a, b, 2005). Thomsen *et al,* (2006) estimate animals close to the source exposed to sudden pile driving noise might be injured (echoed by Madsen *et al*., 2006), while fish may also be severely injured. Pile driving noise can be audible to some marine mammals over 100km away from the source and may cause behavioural reactions at ranges of many kilometres (Madsen *et al.,* 2006). Tougaard *et al.,* 2009 found the zone of responsiveness for harbour porpoises to pile driving extended beyond 20km. An alternative to using piles to support the turbine is the use of gravitational concrete platforms but this is more suitable in sheltered waters (Madsen *et al.,* 2006).

Seismic exploration of the site during geotechnical surveys will introduce an additional noise source in the form of active sonar into the habitat and may displace animals. Rock dumping for scour protection will also introduce additional noise. Increased boat traffic associated with any marine development raises the ambient noise levels in an area. Most construction of offshore wind farms involves a relatively high amount of ship-traffic for transporting piles and turbines, and maintenance. Sound levels and frequency characteristics are depending on ship size and speed with variation among vessels of similar classes. Medium sized support and supply ships generate frequencies mainly between 20 Hz and 10 kHz with source levels between 130 and 160dB re 1µPa at 1m (Richardson *et al*., 1995). Continuous noise from boat traffic can cause smaller cetaceans like harbour porpoises to avoid boats (e.g. Polacheck & Thorpe, 1990). They are known to react to vessels by moving away from them at distances as great as 1km (Palka & Hammond, 2001). This suggests that in areas of high shipping traffic, harbour porpoises may be excluded from that habitat. However acclimatization to boat noises has also been noted. There may also be avoidance issues where marine mammals may be displaced from a feeding or breeding ground due to such increased activity. Wind farms developed further offshore may potentially interrupt migratory routes for baleen whales.

Wind farm operation noise

During operation the turbine can produce low frequency noise and vibrations that can pass into the water column and there may be additive effects when many turbines are operating together (Ingemansson Technology 2003). Betke *et al*., (2004) concluded that operating 1.5 MW turbines will not cause hearing damage, but might affect behaviour in the vicinity. Thomsen *et al.* (2006) used data from Betke *et al*., (2004) to calculate a maximum sound pressure level of 142dB re 1µPa at 1m. Koschinski *et al*., 2003 showed that responses of harbour porpoises and seals, if any, to noise from a 2MW turbine, are restricted to 60-200m. Tougaard *et al*., 2009 examined underwater noise from operating wind turbines and found total sound pressure levels of 109-127dB re 1µPa rms at distances between 14-20m. This study concluded that harbour porpoises would not display behavioural responses unless they were very close to the turbine (Tougaard *et al.,* 2009). Due to their increased hearing sensitivities at low frequencies; harbour seals would be expected to hear the turbine noise at further distances than porpoises.

Decommissioning

Decommissioning offshore structures often involves using open water explosives which is the strongest point source of anthropogenic noise in the marine environment (Richardson *et al.,* 1995). Loud intense noise levels can potentially kill or injure marine mammals at certain distances and can cause behavioural effects at wide ranges.

3.2 Pollution

Another potential threat is pollution. Any offshore marine development requires the use of diesel and oil lubricants, hydraulic fluids and antifouling compounds. A large scale chemical spill has the potential to contaminate marine mammals in an area. Offshore wind farms could present a collision risk to shipping. A collision between ships or a ship and a turbine could result in an oil spill which could have serious environmental consequences. Lipophilic chemical substances biomagnify up the food chain and when accumulated in the blubber of marine mammals can have a negative consequence on health and breeding success (Ross *et al.*, 1996, Simms & Ross 2000, Ross, 2002).

3.3 Ship strikes

Increased boat traffic associated with wind farm development increases the risk of boat strikes. Most lethal strikes occur with ships 80 m or longer travelling at speeds of 14 kts or greater. No severe or lethal injuries are known to have been sustained at ship speeds below 10 kts (Laist *et al.*, 2001). The majority of collisions occur over or near the continental shelf and collisions may have a significant effect on small populations (Laist *et al.*, 2001).

3.4 Cabling

Cable-laying typically requires one or two vessels and will result in a short term increase in ambient noise levels. Electromagnetic impacts from the cabling using to connect the turbines may also have a potential impact on marine mammals and affect navigation. Wind farm development has led to considerable interest in electromagnetic effects on marine species, especially elasmobranchs, but also other fish and marine mammals. This is a relatively unstudied field of research, but direct magnetic effects on baleen whales and toothed whales appear possible at close range. A review of EMF effects was undertaken by the Collaborative Offshore Wind farm research into the Environment group (Gill *et al.*, 2005). Cable burial was found to be ineffective in 'dampening' the B-field, but burial to a depth of at least 1m is likely to provide some mitigation for the possible impacts of the strongest B-field and iE-fields on sensitive fish species. More data is clearly required.

3.5 Other effects

Construction work such as dredging and blasting may affect the local fish populations and so have an indirect effect on marine mammal populations who feed on them. On the other hand the development of offshore wind farms may also have a positive effect on local marine mammal populations. For example, fishing may be restricted in the site of an offshore development which may increase fish stocks in that area and have a knock on effect on their marine mammal predators. The creation of artificial reefs may encourage fish aggregations and thereby enhance marine

mammal foraging in the area. Alternatively, they may increase sedimentation or restrict water and prey movements in a detrimental way.

4. UK WIND FARM CASE STUDIES

There are 5 UK offshore wind farms currently operating (see Table 1), plus 5 in construction and 9 under licence. All available marine mammal monitoring data associated with the FEPA licence conditions for these wind farms were reviewed and compared across sites (Tables 2 & 3). In general, it is considered available datasets at this time are both sparse and inconsistent, preventing any vigorous assessment. Nevertheless, site specific and generic monitoring issues were discussed where possible and key conclusions drawn.

4.1 Operational wind farms

4.1.1 Barrow

Barrow offshore wind farm is situated in the east Irish Sea, 7km south west of Walney Island, near Barrow-in-Furness. It consists of 30 turbines each capable of producing 3MW of electricity. Construction started in 2005 and was completed in September 2006.

Licence conditions

"9.10 During construction the Licence Holder must ensure that disturbance to cetaceans is minimised, including temporary suspension of piling operations if cetaceans are sighted in the area. During the Geotechnical Survey the sighting of cetaceans in the area will be carried out in accordance with 'Method statement for the sighting of whales, dolphins and porpoises (cetaceans), seals (pinnipeds), and basking sharks, Seascore.' as supplied to the Department 23 February 2004."

Marine Mammal Monitoring and Mitigation

No pre or post-construction monitoring for marine mammals was carried out. The planned construction monitoring was as follows: Observation logs were kept during piling activities to record numbers and behaviour of animals. A crew member on the construction vessel was responsible for co-ordinating the marine mammal observations. Sightings were to be reported to the co-ordinator, reviewed and the potential for the cetaceans to be affected by construction assessed. Species, group numbers and locations were to be recorded and exchanged with JNCC and Seawatch. A pinger was used during construction as mitigation. No marine mammals were observed during construction.

Monitoring and Other Site Specific Issues

- The cetacean co-ordinator was one of the construction vessel crew so was unlikely to be an unbiased observer.

- The level of MMO training (or number of MMOs) and the methods used to observe marine mammals was not defined. It is uncertain whether monitoring continued in all weather conditions. It is not clear if there was piling activity at night and if so how the area was monitored for cetaceans.

- It is unclear how the co-ordinator planned to assess the potential for cetaceans to be affected by construction.
- It is unclear whether dedicated observers monitored for marine mammals during piling or were incidental sightings logged only.
- The post construction monitoring report mentions the use of a pinger as a mitigation measure however there is no information on the type of pinger used or how or when it was deployed.

4.1.2 Burbo Bank

Burbo Bank offshore wind farm is situated on the Burbo Flats in Liverpool Bay at the mouth of the river Mersey. It comprises 25 turbines which combine to generate 90MW of electricity. It is just over 6km from the Sefton coast and 7km from North Wirral.

Licence conditions

"9.10 During construction the Licence Holder must ensure that disturbance to cetaceans, seals and basking sharks is minimised by operating a soft start procedure for all drilling and/or piling operations."

Marine Mammal Monitoring and Mitigation

Marine mammal sightings were recorded during ornithological surveys and both harbour porpoise and grey seals were observed. Soft starts were implemented during piling operations.

Monitoring and Other Site Specific Issues

- The level of MMO training and the methods used to observe marine mammals were not defined.
- There is no record on how soft starts were carried out
- There is no information on marine mammal sightings during construction.
- Concurrent bird and marine mammal sighting surveys may not be ideal (although there may be site specific situations where concurrent surveys are acceptable).

4.1.3 North Hoyle

The North Hoyle wind farm is situated 4-5 miles off the North Wales coast between Rhyl and Prestatyn. The 30 turbines combine to generate 60MW of electricity. North Hoyle was the UK's first offshore wind farm and was built in 2003.

There is a grey seal haulout (non-breeding) on the West Hoyle Bank about 10km from the wind farm.

Licence conditions

There was no formal requirement for marine mammal monitoring under FEPA licence conditions.

Marine Mammal Monitoring

Marine mammal information was gathered coincidentally with other surveys carried out during the course of other environmental monitoring at the site. Anecdotal marine mammal sightings were recorded during ornithological surveys throughout pre, during and post construction phases. A total

of 79 marine mammals were recorded during these surveys from 2003-2007 with harbour porpoises and seals being the most commonly observed species. Grey seal counts are undertaken monthly at the West Hoyle Bank. Data has been gathered here since 1964. Similar numbers of seals were recorded at this site by the Hilbre Island Observatory during the pre-construction, construction and post-construction phases of development, and they concluded that there appeared to be no direct effect of the wind farm construction on numbers of seals hauling out in the area (nPower Renewables NHOWF 2008).

Table 1: Wind farm name, location, region, capacity, round, operation and monitoring data.

Windfarm	Location	Region	Capacity	Round	Development phase	Marine mammal monitoring data
North Hoyle	Rhyl	North Wales	60 MW	1	Operating (Dec 2003)	No monitoring required but some data collected on bird surveys
Scroby Sands	Great Yarmouth	Greater Wash	60 MW	1	Operating (Dec 2004)	Monitoring data for seals (pre-, during and post construction)
Kentish Flats	Whitstable	Greater Thames	90 MW	1	Operating (Sept 2005)	No monitoring required
Barrow	Barrow-in-Furness	East Irish Sea	90 MW	1	Operating (Sept 2006)	Monitoring during piling
Burbo Bank	Liverpool Bay	East Irish Sea	90 MW	1	Operating	No monitoring required
Lyn & Inner Dowsing	Lincolnshire	Greater Wash	90 MW	1	Under Construction	No monitoring required but some data collected on bird surveys
Rhyl Flats	Rhyl	North Wales	25 turbines	1	Under Construction	Monitoring data not available to date
Robin Rigg	Solway Firth	Solway Firth	180MW	1	Under Construction	Monitoring raw data available only
Gunfleet Sands 1&2	Essex	Greater Thames	172 MW	1 & 2	Under Construction	Monitoring data not available to date
Thanet	Margate	Greater Thames	300 MW	2	Under construction	Monitoring data not available to date
Ormonde	Barrow-in-Furness	East Irish Sea	150 MW	1	Licensed	N/A
Teeside	Redcar	Tees Estuary	30 turbines	1	Licensed	N/A
Gwynt Y Mor	Rhyl	North Wales	750MW	2	Licensed	N/A
West of Duddon	Walney Island	East Irish Sea	500 MW	2	Licensed	N/A
Walney	Walney Island	East Irish Sea	450 MW	2	Licensed	N/A
Sheringham Shoal	Blakeney	Greater Wash	315 MW	2	Licensed	N/A
Lincs	Skegness	Greater Wash	250 MW	2	Licensed	N/A
London Array	Essex	Greater Thames	1000 MW	2	Licensed	N/A
Greater Gabbard	Suffolk	Greater Thames	500 MW	2	Licensed	N/A

Table 2: Precis of FEPA licence relating to marine mammal monitoring requirements.

Round	Windfarm	FEPA Licence monitoring requirements
1	North Hoyle Kentish Flats	• No requirement for marine mammal monitoring
	Scroby Sands	• Monitoring plan for seals, pre, during and post-construction
	Barrow Robin Rigg	• Ensure that disturbance to cetaceans is minimised including temporary suspension of piling operations if cetaceans are sighted in the area
	Burbo Bank Lyn & Inner Dowsing	• Ensure that disturbance to cetaceans, seals and basking sharks is minimised by operating a 'soft-start' procedure for all drilling and/or piling operations
1 & 2	Rhyl Flats Gunfleet Sands 1&2 Thanet Ormonde Teeside Gwynt Y Mor West of Duddon Walney Sheringham Shoal Lincs London Array Greater Gabbard	• A Marine Mammal Mitigation Programme (MMMP) for the mitigation of potential impacts on marine mammals must be submitted to the Licensing Authority. • Suitably qualified and experienced Marine Mammal Observers (MMO) are appointed and the Licensing Authority and Natural England notified of their identity and credentials. • The MMO must maintain a record of any sightings of marine mammals, basking sharks and turtle within the Marine Mammal Monitoring Zone and action taken to avoid any disturbance being caused to them. • Ensure that piling activities do not commence until half an hour has elapsed during which marine mammals have not been detected in or around the site. • The detection should be undertaken both visually (by MMO) and acoustically using appropriate Passive Acoustic Monitoring equipment. Both the observers and equipment must be deployed at a reasonable time (to be identified in the MMMP) before piling is due to commence. • At times of poor visibility e.g. night-time, foggy conditions and sea state greater than that associated with force 4 winds, enhanced acoustic monitoring of the zone is carried out prior to commencement of relevant construction activity. • Piling commences using an agreed soft start procedure. The duration and nature of this procedure must be discussed and agreed with the Licensing Authority and Natural England prior to commencement of operations and submitted in the MMMP. • Ensure that a reporting methodology is included in the MMMP to enable efficient communication between the MMOs and the skipper of the piling vessel. • The need for additional post-construction marine mammal monitoring, over an initial three year period and on-going during the lifetime of the wind farm's operation, will be determined, in consultation with Natural England/Country Council for Wales and the Licensing Authority.

Table 3: A review of monitoring and mitigation information at UK wind farms in operation or currently under construction.

Windfarm	Monitoring	Mitigation	Main Issues
Barrow	• Observation logs were kept during piling activities noting numbers and behaviour of marine mammals.	• Sightings were reviewed and the potential for cetaceans to be affected by construction was assessed by the cetacean co-coordinator. • A pinger was used during construction.	• The cetacean co-ordinator was not an unbiased observer/assessor. • The level of observer training is not defined nor are the methods used to observe marine mammals. • It is unclear whether dedicated observers monitored for marine mammals during piling or were incidental sightings logged only. • It is unclear how affect of construction was assessed using sightings data. • The post construction monitoring report mentions the use of a pinger as a mitigation measure however there is no information on the type of pinger used or how or when it was deployed.
Burbo Bank	• Marine mammal sightings were recorded during ornithological surveys.	• Soft starts were implemented during piling operations.	• Marine mammal sighting abilities limited by concurrent bird survey. • There is no record on how the soft starts were implemented or whether there was any marine mammal sightings noted during construction work.
North Hoyle	• Marine mammal sightings were recorded during ornithological surveys.	• No mitigation.	• No specific marine mammal monitoring or mitigation took place. • Marine mammal sighting abilities limited by concurrent bird survey.
Kentish Flats	• No marine mammal monitoring required.	• No mitigation.	• No marine mammal monitoring or mitigation carried out.
Lyn & Inner Dowsing	• No monitoring required but an MMMP was put in place.	• Visual observations carried out one hour before and during piling operations to ensure that no marine mammals were within 500 metres of the pile during the 30 minute period preceding the start of piling. • PAM output was monitored by MMO prior to commencement of piling. • A soft start was to be implemented for all piling events.	• Twenty piling events out of a total of 63 commenced after nightfall when only acoustic surveying was possible. • If the weather was too bad for the MMO to get to the site then the fisheries liaison officer was to monitor for marine mammals. • PAM does not detect seals –the primary species of interest at this site.
Scroby Sands	• Aerial surveys of seal haulouts were carried out pre, during and post construction.		• No aerial survey monitoring during piling activities which took place from October 21st 2003 until January 1st 2004.
Robin Rigg	• No monitoring required but an MMMP was put in place. • Line transect surveys for marine mammals.	• A soft start was to be implemented for all piling events. • MMO's carried out observations in 500m exclusion zone prior to piling.	• Only raw monitoring data available –no analysis/report.

Monitoring and Other Site Specific Issues

- No mitigation monitoring was carried out even though there was a known grey seal haul out just 10km from construction and incidental marine mammal sightings were noted during preconstruction ornithological surveys.

4.1.4 Kentish Flats

The Kentish Flats offshore wind farm is situated outside the main shipping lanes of the Thames 10km from the East Quay in Whitstable. Construction started in 2004 and was completed in 2005. It consists of 30 turbines each combining to generate a total of 90MW of electricity.

Licence conditions

There were no FEPA license requirements for marine mammal monitoring.

Marine Mammal Monitoring

No marine mammal monitoring was required under FEPA licensing for the Kentish Flats wind farm. The Environmental Impact Assessment concluded that risks to cetaceans were minimal based on the fact they do not frequently use the area and that construction activities were thought to have a non significant effect on seals.

Monitoring and Other Site Specific Issues

- No marine mammal monitoring or mitigation was carried out.

4.1.5 Scroby Sands

Scroby Sands wind farm consists of 30x2MW turbines, 2kms offshore from North Denes, Great Yarmouth, Norfolk. This particular wind farm site was built near to a known haul out area for seals at Scroby Sands. The Scroby Sands haul out is just 2 km from the development. It is a breeding haul out for harbour seals and is also used as a non-breeding haul out for grey seals. The nearest breeding colony of grey seals is 20km away at Horsey. The FEPA license required a specific monitoring program for seals.

Licence conditions

Under FEPA licence conditions for seals:

"9.14 The Licence Holder should carry out a monitoring program for seals as agreed with the Sea Mammal Research Unit (SMRU). This should take the form of 2 fly-overs per month at low water for six summer months (April to September) pre, during and post construction. The data collected during each fly-over shall be copied to the SMRU and a written report provided to the Licensing Authority at 3 monthly intervals."

Marine Mammal Monitoring

Aerial surveys for seals were carried out from March 2002 until October 2006. A total of 67 aerial surveys were carried out during preconstruction, construction and post construction. However as the licence required monitoring take place during summer months – there was no monitoring during piling activities which took place from October 21st 2003 until January 1st 2004. Statistically significant changes were seen in seal numbers during the monitoring programme. There was an increase in grey seal numbers and a decrease in harbour seal numbers during construction (see Table 4). Following construction, harbour seal numbers continued to be depressed into the

operational phase. Following initial analysis of aerial survey data and the significant change in local seal populations it was recommended that monitoring additional to FEPA licence requirements take place in 2006 and further pup production surveys were carried out (Skeate & Perrow, 2008).

Table 4: Mean numbers of seals counted during aerial surveys at Scroby Sands throughout development of Scroby Sands wind farm (from Skeate & Perrow 2008).

Development phase	Year	Harbour seals	Grey seals
Baseline	2002	107	22
	2003	82	15
Construction	2004	52	52
Operation	2005	59	64
	2006	66	61

Monitoring and Other Site Specific Issues

- Monitoring was not consistent or well correlated with construction activities. Specifically, there was no monitoring carried out during pile driving, so any response by seals to this potential disturbance cannot be determined.

- Furthermore, it is also difficult to correlate changes in seal numbers to construction activities or natural population shifts reflecting seasonal patterns or epizootic events.

4.2 Under Construction

Both the Lyn and Inner Dowsing and Robin Rigg wind farms are currently under construction so limited marine mammal monitoring data is available. Rhyl flats, Gunfleet Sands and Thanet wind farm are also under construction but no monitoring data is available yet.

4.2.1 Lyn and Inner Dowsing

The Lynn and Inner Dowsing wind farm is currently under construction 5km off the Lincolnshire coast. The farm consists of 54 turbines to combine to generate 90MW of electricity.

The Wash Region is an important habitat for harbour seals, grey seals and harbour porpoises. The Wash and North Norfolk coast is an SAC for harbour seals. It is the largest colony of harbour seals in England with approximately 7% of the total UK population, with Donna Nook, Blakeney Point and Gibraltar Point considered important haul out sites. Gibraltar Point, a haul out for harbour seals is the closest to the construction site, 6.5-10.5km away. The other haul out sites are over 30km from the construction site.

Licence conditions

Under FEPA licence conditions for cetaceans, pinnipeds and basking sharks

"9.12 During construction the Licence Holder must ensure that disturbance to cetaceans, pinnipeds (seals) and basking sharks is minimised by operating 'soft start' procedures for all drilling and/or driving operations."

Marine Mammal Monitoring and Mitigation

No marine mammal monitoring was required under FEPA licence conditions however baseline data was collected for the Lincs offshore wind farm nearby and this was used to inform the baseline. Natural England and DEFRA requested a procedure of mitigation measures against the potential damage to marine mammals during construction. In response Centrica Ltd commissioned and adopted a project-specific marine mammal monitoring protocol (MMMP) for implementation during foundation installation.

The basic principles of the MMMP (taken from the construction monitoring report RPS Energy 2008) were

- To station two marine mammal observers (MMOs), one of whom operated a passive acoustic monitoring (PAM) system, onboard a crew boat prior to all pile-driving operations. By conducting radial transect surveys around the point of piling. Visual observations were carried out one hour before and during piling operations using naked eye and binoculars. PAM output was monitored by MMO prior to commencement of piling. If the weather was too bad for the MMO to get to the site then the fisheries liaison officer was to monitor for marine mammals,
- To ensure that no marine mammals were within 500 metres of the pile during the 30 minute period preceding the start of piling,
- To implement a soft start for all piling events by slowly 'ramping up' the energy output of the hammer over time for no less than 20 minutes before reaching full power.

Sixty three pile driving operations were carried out and 61 of these complied with the soft start procedure. Two pile driving were non compliant as they were re-drive operations with the pile already driven close to final penetration, so the initial energy used was high. Of the 63 pile-driving operations, 55 were fully compliant with the MMMP. For eight of the piling operations marine mammal observations were either carried out by the Fisheries Liaison Officer onboard of the piling vessel, or not carried out due to offshore operational difficulties or adverse weather conditions preventing mobilisation of the survey boat. Twenty piling events commenced after dark when only PAM was possible. Piling events lasted between 14 minutes and 2 hours 53 minutes. A total of almost 85 hours of acoustic mitigation monitoring and over 82 hours of visual mitigation monitoring were carried out (RPS Energy 2008). Standard JNCC recording data forms were used to record all data. The MMO kept a log of all marine mammal sightings, actions taken and weaknesses in the system. Thirteen marine mammal sightings were made during mitigation monitoring, or within sighting distance of the piling site, including eleven seal sightings and two porpoise sightings. No sightings were made within 500 metres of the piling site in the 30 minutes prior to proposed piling start time and consequently there were no delays to piling activity. No acoustic detections of marine mammals were made (RPS Energy, 2008). The detailed results of this monitoring were published in a comprehensive report (RPS Energy, 2008).

Monitoring and Other Site Specific Issues

While the monitoring carried out was not a FEPA monitoring requirement the mitigation plan put in place is similar to the requirements set out in recent FEPA licences so it is considered worthwhile to examine this data and review it (see also Section 4.5).

- Piling was allowed to start at night using only PAM as mitigation.
- Piling was allowed in all sea states even in conditions when the MMO could not make it out to the site. If the MMO couldn't get on site then the Fisheries Liaison Officer (FLO) carried out the marine mammal monitoring. The FLO was a JNCC certified MMO but did not operate PAM.
- PAM was carried out from a towed array on one survey vessel at a 200m and 500m from the source vessel. The vessel surveyed the outer perimeter (4km) initially at 8kts and then moved into the inner perimeter (1.6km). This procedure gave good acoustic coverage of the area nearest the pile driving.
- As PAM at 200m and 500m from the source did not detect any drilling noise above ambient noise levels, DEFRA and Natural England did not impose the MMMP during drilling operations.

Recommendations are made within the final report (RPS Energy 2008) for the improvement of the protocol, including a refining of the soft start procedure and the use of acoustic deterrent devices during night time starts. It was also suggested that the MMO continues visual observations during piling in case piling is stopped for a long period as another soft start may be required or animals may move into the area if piling is suspended. It was also suggested that one MMO is positioned on board the source vessel. PAM would not be effective during piling due to masking.

4.2.2 Robin Rigg

Robin Rigg wind farm is situated in the Solway Firth and consists of 60 turbines with a total combined power generation capacity of 180MW.

Licence conditions

Under FEPA licence conditions for marine mammals

"The licencee shall ensure that during the construction phase all reasonable steps should be taken to minimise any disturbance to cetaceans. This should include temporary suspension of piling operations if cetaceans are sighted in close proximity to the works. Such 'best practice' guidance and mitigation measures as is identified in any report and/or study shall be incorporated into a working Method Statement."

Marine Mammal Monitoring

A draft marine mammal mitigation statement is available however this is not finalised. As construction is ongoing there is presently no data available on mitigation measures.

Monitoring and Other Site Specific Issues

- Only marine mammal raw data is available to date so difficult to put it in context
- It is uncertain what 'close proximity' is.
- No definition of 'best practice'.

4.3 Key monitoring issues from UK case studies

In the following section monitoring data was reviewed in a more general context, specifically aiming to answer some of the questions posed in the proposal document; comparing differences between sites, assessing what has been learned about the effects of wind farm construction on marine mammals and how the monitoring conditions may need to be changed.

Examine differences between the sites

Wind farm developments in Round 1 and 2 have been restricted to three strategic areas of shallow coastal waters. These areas are the Greater Wash, the Thames Estuary and the North West of England. The operational wind farms; Barrow, Burbo, Scroby Sands, Kentish Flats and North Hoyle had very little or no marine mammal monitoring requirements under the FEPA licence conditions. Barrow, Burbo and North Hoyle are all situated in the North West. Kentish Flats is in the Thames Estuary and Scroby Sands is in the Greater Wash area. The Greater Wash is probably the most sensitive in terms of marine mammal populations with large numbers of seals present in this area. As a likely consequence, only the Scroby Sands development carried out pre, during and post construction monitoring of the seal population. Other operational wind farms had either no marine mammal monitoring requirements or had to minimise disturbance during piling activities only. Various different approaches were used to minimize disturbance across sites, including mitigation monitoring (to ensure no marine mammals were in the area prior to construction), pingers (to scare animals prior to piling) and soft ramp ups (also used to scare animals away from the area). Only in one case (Lyn & Inner Dowsing) was PAM used as well as visual monitoring and during night piling, PAM was used as the only means to detect marine mammals.

The licensed offshore wind farms yet to be constructed have more thorough licensing requirements regarding marine mammals. Some of the Round 2 offshore wind farms will be constructed in similar geographical areas to the Round 1 developments however the licence requirements for marine mammals are far more thorough and detailed. For the larger Round 2 wind farms the construction phase will take longer and so any harmful effects may be prolonged. The wind farms in rounds 1 and 2 are all coastal developments in shallow water. Some wind farms are nearer to seal haul outs than others however seals will travel some distances from their haul outs to feed (see section 2.1). So while a development may be a distance from a haul out it could still be an important foraging area for seals. However, no at-sea foraging area usage study has been considered to date in any FEPA licence conditions.

What has been learned about interactions?

Thus far little can be deduced about interactions between UK wind farm developments and marine mammals, mainly because apart from the Scroby Sands development, there has been no long term marine mammal monitoring at operational sites. Without well designed long term pre, during and post construction monitoring, it is impossible to gauge any level of effect of the construction and operation of a wind farm development on marine mammals. International examples, such as Nysted and Horns Rev (see Section 5), carried out long term marine mammal population studies through the development and early operational phase of the wind farms. Recent FEPA licences include scope for longer term monitoring of marine mammals in the licensed areas, but leave it up to the regulators to decide what is appropriate, so it is not enforced as a licence condition.

Based on the very limited data available;

- Few animals are seen in the monitoring zone during piling activities.
- There is no evidence of any marine mammal fatalities associated with wind farm construction.
- No detections were made using PAM.
- Pingers and soft start procedures appear to be an effective mitigation to having animals in the near vicinity of pile driving operations.
- It appears harbour seals may be more sensitive to construction activities than grey seals.

Assess how successful monitoring conditions have been and whether certain conditions could be discarded or strengthened

To date mitigation monitoring for marine mammals has been carried out to varying degrees at operational wind farms and each development has complied with the FEPA conditions, however the wording in initial licences was unspecific and thus open to interpretation. Consequently, the type and level of monitoring varied substantially. In some cases there was not a dedicated marine mammal observer employed and observations were carried out by the construction crew or by bird surveyors. The use of trained and dedicated MMOs and concurrent use of PAM is strongly recommended in all future monitoring. The Scroby Sands development carried out seal aerial survey monitoring pre, during and post construction, however monitoring was confined to the summer period and thus did not coincide with piling activities (now considered a source with a major potential impact on local seal populations). Clearly, the monitoring plan needs to cover construction activities. Population monitoring to date has concentrated on animal abundance on land but habitat use while at sea in areas thought to be of importance (e.g. in the vicinity of coastal SACs) is an important consideration when assessing impact. Monitoring of animal presence during construction activities (mitigation monitoring) as it has been carried out thus far is considered ineffective to assess the impact of construction.

Many improvements have already been made to the FEPA licence conditions and current licence requirements address many of the issues highlighted during this review of operating wind farms. The new FEPA licence conditions are reviewed below (section 4.5). Summary recommendations of how conditions might be strengthened are summarised at the end of this report. We feel no conditions should be discarded.

Examine the comparability of datasets and reporting style

For all the operational wind farms the marine mammal mitigation procedure if required lacked detail and sightings data have not been readily available. A standard set of monitoring protocols has not been established so data sets from different wind farm sites are not comparable. There has not been a standard method of recording animal sightings, group size, behaviour, environmental conditions and PAM data. Some licences include basking sharks (*Cetorhinus maximus*) and turtles alongside marine mammals for mitigation monitoring. There needs to be consistency regarding the monitoring for these species. They are both protected species, but as they are not marine mammals they may not be taken into account when designing monitoring plans.

4.4 Summary of issues and conclusions relating to operational wind farms in UK waters

Having reviewed the FEPA marine mammal monitoring data available from operational wind farms and those currently undergoing construction, key issues common to most sites are highlighted below;

- Difficult to compare monitoring across sites, as requirements have been very variable for the first wind farms licensed.
- No record of the training or experience level of the marine mammal observers used.
- Marine mammal mitigation monitoring appears to continue in conditions unfavourable to reliable detection, such as poor weather conditions and at night.
- PAM only used during construction of one operational wind farm.
- Poor reporting of observer methodologies and results.
- Poor reporting of how mitigation measures were carried out, such as detailed soft starts procedures or how and when acoustic deterrents were used or extent of exclusion zones.
- There has been no attempt to study the at-sea usage of wind farm sites by seals, relying instead on land based abundance estimates.
- The lack of dedicated pre, during and post construction monitoring means it is difficult to put results of mitigation monitoring carried out during construction into context.
- Marine mammals generally recorded incidentally during dedicated ornithological surveys.
- Monitoring of cetacean distribution, abundance and behaviour, at least on a few selected sites, should occur concurrently with construction activities.
- No monitoring of seal haul out usage during pile driving has been carried out.

4.5 A review of current FEPA licence conditions

FEPA marine mammal monitoring requirements for operating wind farms differ substantially from the more recent licences. While monitoring data are not yet available from these newer FEPA licences it was thought beneficial to compare these requirements with the Round 1 licences. The following details the FEPA marine mammal monitoring conditions for recently licensed developments, followed by comments on each condition. The conditions concentrate on construction mitigation monitoring rather than population monitoring. The need for population monitoring is left to the local regulators. Many issues highlighted above have been addressed in these licences.

- "The Licence Holder must ensure that no construction activities commence until the Licence Holder has agreed in writing with the Licensing Authority and Natural England a Marine

Mammal Mitigation Programme (MMMP) for the mitigation of potential impacts on marine mammals. The MMMP must be submitted to the Licensing Authority".

The design of a mitigation plan for marine mammals ideally will be site-specific so it can take into account sound propagation and the marine mammals that could be present in the area. Mitigation measures can be adapted to suit different target species and the radius of area affected by sound levels capable of inducing auditory injury. This is a major improvement on original licence conditions. Many mitigation measures have been suggested for the construction phase of offshore wind farm development (SMRU Ltd., 2007). Various mitigation measures may be required at different stages of development depending on the risks involved and may have to be adapted to suit the requirements of developments in different areas. The following is a list of the key mitigation measures which can be used during construction of a wind farm. These measures are mainly concerned with mitigating for the harmful effects of noise generated during construction.

Assigning an exclusion zone

Ambient noise levels should be monitored before, during and after construction. The highest anticipated noise levels during construction should be used to design the most effective mitigation measures i.e. exclusion zones. JNCC recommend a minimum 500m exclusion zone to mitigate for noise disturbance during piling activities (JNCC 2009). However, it can be difficult to design exclusion zones for all marine mammal species as different species have different hearing abilities and various sensitivities to noise. The audiograms for many species are unknown, therefore a precautionary approach such as that used in Southall *et al.,* 2007 criteria is recommended.

Visual and passive acoustic monitoring within an exclusion zone

Both shore based and boat based visual monitoring is often carried out to detect presence of marine mammals. Unlike acoustic monitoring, animal identification is relatively easy in good weather conditions and the detection of seals is possible. Also visual monitoring does not rely on technical equipment which may fail in the field. Visual monitoring allows information to be collected on group size and behaviour and also has the possibility of detecting marine mammals even if they are silent. The personnel employed for undertaking the marine mammal monitoring should be experienced at species identification, confident in their ability to assess weather conditions and monitor accordingly and also be non-biased. Adequate visual monitoring cannot be undertaken at night or in poor weather conditions i.e. strong winds, heavy rain, thick fog. In such circumstances acoustic monitoring has proved to be invaluable. Static acoustic monitoring devices such as PODs can by deployed for months at a time and can collect continuous data 24hours a day in all weather conditions, but they do not produce real time data. Hydrophones on the other hand are a useful mitigation monitoring tool and can be used to give real time information and alert the approach or presence of sound producing cetaceans. Infrared scanning technology has also been demonstrated as useful in detecting marine mammals at night (Thomas & Thorne 2001). Given that PAM cannot detect seals or silent cetaceans and visual monitoring is less reliable in poor weather conditions, it is recommended that ideally noisy activities should not commence when poor weather conditions or poor visibility exist.

The use of acoustic deterrents

The use of acoustic deterrents as a mitigation measure during the construction of offshore wind farms has been examined in detail by SMRU Ltd. (2007). By activating an acoustic deterrent before

the start of piling or explosive use, it is hoped that marine mammals would be encouraged to move away from the source so they would be a safe distance from the impending construction noise. It is difficult to study the reactions of marine mammals exposed to high source levels of noise and so for many species it is unknown. The precautionary approach of attempting to temporarily exclude marine mammals from the vicinity of the sound source, while at the same stage trying not to permanently exclude animals from an important habitat, is advised. There is a risk of habituation so it is advised to vary the signals used. Care has to be taken that the acoustic deterrents do not themselves pose a risk to marine mammals. Thus a soft ramp up approach should be used with acoustic deterrents if possible.

Seasonal/ area restrictions

Known areas of importance for marine mammals should when possible be avoided when locating wind farms. Also construction could be postponed during key time periods such as seal breeding seasons.

Engineering designs

Soft starts in piling occur when the initial hammer blows to the pile have low energy and gradually build up to full power. The idea behind this procedure is that animals in the vicinity move away from the noise before it builds up to dangerous levels. However soft starts lengthen the piling process so while it can limit the risk of high level impacts such as permanent threshold shift, it may increase the risk of lower level impacts (SMRU Ltd., 2007). Other mitigation measures may include the use of bubble curtains or insulating the pile. Alternatives to using piles should be investigated for example the use of gravity based foundations or floating platforms which could reduce noise disturbance. For a full review of engineering solutions as mitigation measures associated with offshore wind farms see Nehls *et al.,* (2007).

- "The Licence Holder must ensure that suitably qualified and experienced Marine Mammal Observers (MMO) are appointed and the Licensing Authority and Natural England notified of their identity and credentials, within the MMMP, before any construction work commences. The MMO must maintain a record of any sightings of marine mammals, basking sharks and turtles within the Marine Mammal Monitoring Zone and action taken to avoid any disturbance being caused to them".

JNCC recommend a standard monitoring procedure for piling (JNCC, 2009) and this has been incorporated into the more recent FEPA licences. It is vital that a minimum of two independent observers are used for marine mammal monitoring –both a visual observer (MMO) and a PAM operative. These observers should have experience of observing and identifying marine mammals at sea. If piling operations are expected to take place over an extended time period then additional MMO's and PAM operatives may be required to reduce observer fatigue. The observers should be based on the source vessel if possible to ensure the best 360° view of the impact area. The MMO records marine mammal sightings data, relevant construction activities and responses/actions taken in a suitable database. Data entry must be made simple for fast but error free data collection. Digital record keeping is recommended. Records should be consistent across all sites. In some developments the MMO is required to record sightings of basking sharks and turtles as well as marine mammals and these species should be included on data sheets.

- "The Licence Holder must ensure that piling activities do not commence until half an hour has elapsed during which marine mammals have not been detected in or around the site. The detection should be undertaken both visually (by MMO) and acoustically using appropriate Passive Acoustic Monitoring equipment. Both the observers and equipment must be deployed at a reasonable time (to be identified in the MMMP) before piling is due to commence".

Concurrent visual and acoustic monitoring is very important to try to ensure there are no marine mammals in the monitoring zone. While no method alone can guarantee the detection of marine mammals the combined employment of both visual and acoustic methods significantly raises the chances. However in poor weather conditions the accuracy of both methods can be severely compromised and ideally noisy activities should not commence. While visual and acoustic monitoring can be effective for cetacean detection, it must be noted that seals surface irregularly and so can be more difficult to detect and track visually and they cannot be detected acoustically. Also the statement 'In or around the site' is not specific. It is recommended a minimum exclusion zone is suggested by FEPA. An appropriate exclusion zone could be established based on the frequency and level of noise produced at the site in question, the hearing thresholds of the species in the area and an agreed acceptable received noise level (see JNCC, NE and CCW Guidance on the Protection of Marine European Protected Species from Disturbance and Injury). Alternatively, the exclusion zone should be at least of 500m radius from the source (JNCC, 2009).

- "The Licence Holder must ensure that at times of poor visibility e.g. night-time, foggy conditions and sea state greater than that associated with force 2 winds, enhanced acoustic monitoring of the zone is carried out prior to commencement of relevant construction activity".

Acoustic monitoring cannot detect all species of marine mammal and ideally should not be relied upon solely, particularly if seal mitigation monitoring is required. If only one PAM unit is present it seems difficult to enhance monitoring. This statement suggests that more than one PAM operator and multiple PAM units should be made available. Care should be taken if the visual observer is used as an enhancement (change in monitoring from visual to PAM), particularly in sea states of 3-5 where visual detection of marine mammals is still potentially useful. Clearly when piling activities occur at night the use of two PAM operators might be advantageous. PODs are useful monitoring tools however are of no use for mitigation monitoring as they do not give real time data i.e. the data is collected over time and is then retrieved and analysed. Potentially independent real time hydrophone arrays could be deployed and these could be located around the construction site to improve detection rates. Ideally piling should not commence at night or in bad weather conditions as the risk of not detecting marine mammals is greatly increased.

- "The Licence Holder must ensure that piling commences using an agreed soft start procedure. The duration and nature of this procedure must be discussed and agreed in writing with the Licensing Authority and Natural England prior to commencement of operations and submitted in the MMMP".

A soft start is designed to give marine mammals in the area a chance to leave the ensonified zone before the noise reaches a damaging level. There is a risk that if the soft start is not carried out carefully the noise levels may be enough to induce hearing damage in marine mammals if they are in the vicinity. The efficacy of employing soft starts has not yet been proven. For the operational wind farms which were required to employ soft start procedures during piling no detailed methodology of how these soft starts were carried out is available. Future developments will be obliged to submit a detailed plan of how the soft start procedure will be carried out. JNCC recommends a soft start of no less than 20minutes and that piling is suspended if a marine mammal enters the exclusion zone during the soft start. If piling is paused for over ten minutes, a 'soft start' is required when recommencing. FEPA should consider specifying conditions where re-drives occur and including the improvements in protocol as recommended by RPS Energy in their 2008 report.

- "The Licence Holder must ensure that a reporting methodology is included in the MMMP to enable efficient communication between the MMOs and the skipper of the piling vessel".

This is another important addition to FEPA monitoring requirements. Previous monitoring was poorly reported making it difficult to compare monitoring at different sites. Also a clear methodology avoids confusion between the MMO and the construction crew.

In recent FEPA licences the following condition is included:

- "The need for additional post-construction marine mammal monitoring, over an initial three year period and on-going during the lifetime of the wind farm's operation, will be determined, in consultation with Natural England and the Licensing Authority, at least four months before the scheduled completion of construction."

There needs to be a clear distinction made between monitoring and mitigation. To mitigate is to make something less harmful and involves taking steps to avoid or minimise a negative impact. While to monitor is to observe, supervise; to measure or test at intervals, especially for the purpose of regulation or control. Under the recent FEPA licences there is scope for ongoing marine mammal monitoring but it is left up to the regulatory body concerned to decide whether post-construction monitoring is required. These are of course site specific decisions and will depend on the sensitivity of the site in relation to marine mammals. However if additional monitoring is carried out post construction it will only be valuable if there is adequate data to compare it to i.e. baseline or preconstruction monitoring. One of the purposes of pre construction or baseline monitoring is to investigate species presence in an area and whether there is any well defined seasonal variation in habitat use. If for example it is known that a particular site is an important seasonal breeding area for a seal species then construction should be avoided if possible at this sensitive time. During Round 1 baseline assessment of sites for marine mammals were often incidental, with ornithological surveys noting marine mammals. In many cases insufficient methodology or effort was used so comparison and integration of datasets was difficult. The purpose of a monitoring plan needs to be established at the planning stage as it will affect the methodologies used (e.g., scale, frequency, duration). The methods used to collect data at different stages of development need to be standardised so they are comparable. Power analysis should be carried out to ensure that the

monitoring methodology is capable of measuring all necessary variables with the required precision to detect an effect.

5. INTERNATIONAL CASE STUDIES

Both Horns Rev and Nysted wind farms off Denmark have been monitored throughout all phases of construction with an intensive monitoring programme (see Table 5), the results of which are available (Teilman *et al.,* 2006) and discussed below.

Table 5: Marine mammal monitoring at international wind farms

Windfarm		Monitoring	Mitigation	Issues
Horns Rev	Harbour porpoises	• PODs for acoustic monitoring of porpoises • 30 boat based sighting surveys	• Soft start during piling • Use of pingers or acoustic harassment devices	Monitoring carried out pre, during and post construction.
	Seals	• Seal telemetry		
Nysted	Harbour porpoises	• PODs for acoustic monitoring of porpoises,	• Soft start during piling • Use of pingers or acoustic harassment devices	Monitoring carried out pre, during and post construction.
	Seals	• Aerial surveys of seal haul outs • Video cameras monitoring haul outs • Seal telemetry		

5.1 Horns Rev

Horns Rev wind farm is situated 14-20 km west of Blåvands Huk, which is Denmark's most westerly point. It consists of 80 turbines with a total power generation of 160MW.

Harbour porpoise monitoring

A comprehensive marine mammal monitoring program was initiated in Horns Rev where detailed monitoring took place before, during and after construction. A control or reference area was also studied and a BACI (Before, After, Control, Impact) design was used to analyse effects.

During development at the Horns Rev offshore wind farm harbour porpoises were monitored using both static acoustic monitoring (T-PODs) and ship surveys. Thirty systematic ship surveys were carried out at Horns Rev between 1999 and 2006. Surveys were limited to calm days to maximise sightings of harbour porpoises. Variables such as salinity, temperature, depth and tide were also recorded. Density maps of harbour porpoises at and around Horns Rev were produced during all phases of development.

Results from monitoring during the construction phase (summer 2002) showed a definite effect of construction activities on the distribution and behaviour of harbour porpoises (Tougaard *et al.*, 2003a). The data collected during ship surveys for harbour porpoises correlates well with the

acoustic data collected on T-PODs, Harbour porpoises left the area when pile driving began, but returned a few hours after the end of each pile driving operation. On days with no pile driving the dominant behaviour observed was non-directional travelling associated with feeding. On the days of pile driving the dominant behaviour was directional swimming associated with travelling (Tougaard *et al.*, 2003a). Acoustic studies showed the zone of responsiveness for harbour porpoises to pile driving extended beyond 20kms (Tougaard *et al*, 2009).

Mitigation measures used included a soft start to piling, the use of pingers and acoustic harassment devices. The effects of construction activities were not restricted to the wind farm area. Effects were also observed in reference areas. Fewer animals were observed engaged in foraging behaviour close to the construction site in the period with pile driving, compared to the periods before and after. Both data from acoustic and visual monitoring showed significant changes in porpoise behaviour up to 15km from pile driving construction (Tougaard *et al.* 2003a).

Seal monitoring

Satellite tags were attached to 21 harbour seals 50 km from Horns Rev. The area appears to be important to the seals both for foraging and as a transit area to other feeding grounds further off shore (Tougaard *et al.,* 2003b). No clear evidence was found for a large scale displacement of the seals from the wind farm area or the reef as a whole during the months of construction (pile driving), although the spatial and temporal resolution of telemetry data limits the strength of this conclusion. Based on this, the study concluded there is no reason for serious concern about loss of the wind farm area from the seal's normal habitat (Tougaard *et al.,* 2003b).

5.2 Nysted

Nysted wind farm is located in the western Baltic south of Nysted. There are 72 turbines which combine to generate 165.5MW of electricity. It is situated close (4km) to a large harbour seal and grey seal haul out site at Rødsand.

Harbour porpoise monitoring

Due to the relatively low abundance of harbour porpoise in the western Baltic only acoustic monitoring using T-PODs was conducted at Nysted. Similar to Horns Rev a BACI design was implemented for statistical analysis so a control or reference site was also monitored.

Results from acoustic monitoring indicate a significant decrease in detection of porpoise clicks during construction compared to data gathered during the pre-exposure base-line period (Tougaard *et al.,* 2006, Carstensen *et al*., 2006). Porpoises returned to normal activity levels just days after piling operations ceased. Acoustic harassment devices such as pingers for harbour porpoises and seal scarers for seals were used 30minutes before and during ramming/vibration activity at this site. Ambient noise levels were not measured during construction (Carstensen *et al.,* 2006).

At Nysted, the porpoises left the area during construction and also left the reference area 10km away. After 2 years of monitoring during wind farm operation there remains a lower level of porpoise activity in the wind farm area while levels in the reference area have returned to baseline levels.

Seal monitoring

At the Rødsand seal sanctuary, five harbour seals and six grey seals were tagged prior to construction of the Nysted wind farm. Results from satellite telemetry showed that the harbour seals remained within 50 km of the tagging site year-round, while grey seals made extensive movements up to 850 km away from Rødsand to Sweden, Germany, Estonia and Latvia (Dietz *et al*., 2003). The behaviour of seals at Rødsand was monitored using visual observations from a bird observation tower during the baseline study period and by a remotely controlled camera system during construction and operation. Monthly aerial surveys were also carried out at Rødsand and other haul outs in the area. There are no indications that construction activities from late June 2002 to December 2003 and the first two years of operation in 2004-2005 affected the local Rødsand harbour and grey seal populations differently from the other populations in the western Baltic Sea. One notable effect was there was a reduction in the number of seals hauled out during pile driving. The Rødsand seal population has increased substantially in size in 2004 and 2005 (Teilmann *et al.,* 2006).

5.3 Key Conclusions from international marine mammal monitoring.

Harbour porpoises

- A clear behavioural short-term effect was observed at Horns Reef during the construction phase with porpoises responding at distances up to 20km.
- A weak long-term effect was observed at Horns Reef.
- At Nysted, a stronger impact was observed during construction, with a negative effect persisting 2 years into the operational phase.
- The differences in reactions between sites may relate to their differential usage or due to site or sound propagation differences.

Seals

- No large-scale avoidance was observed by harbour seals at Horns Reef however; data from tagged animals indicate there was limited apparent usage of the area anyway, with seals having much larger home ranges than the wind farm area itself.
- At Nysted significantly fewer seals were hauled out during pile driving.
- No negative effects observed during operational phase for either wind farm site.
- Harbour seal populations around Nysted are generally increasing so this may obscure effects.

General conclusions

- Behavioural reactions of harbour porpoises were found up to 20km away from pile driving activities.
- In order to carry out a BACI (Before-After Control-Impact) experimental design to assess impacts, monitoring should cover the whole period of development with an adequate baseline study, a reference area should be far enough away that it will not be impacted on by development and monitoring should continue well into the operational phase to assess any longer term effects.

- Effects of construction can differ from one wind farm to another depending on the size and type of piles used, the substrate and sound propagation in the water column and the marine mammal species exposed
- Due to the differences in effects of construction activity on porpoises in these two locations, it can be concluded that the same species could react differently to the construction of wind farms in different areas.

6. IMPLICATIONS OF EFFECTS SCALED UP TO ROUND 3 DEVELOPMENTS

Round 3 zones for wind farm development are further offshore some outside the 12 nautical mile limit and will be considerably larger than Round 1 and 2 wind farms. The forecasted potential implications of Round 3 wind farm developments are;

- Cumulative effects on marine mammals may become significant (i.e. more and more key habitat excluded and for longer periods of time).
- More marine mammal species may be affected including some offshore species which have been relatively poorly studied.
- Bigger wind farms will result in greater construction time period and larger areas of impact.
- New turbines are likely to be larger and potentially require larger pilings which will generate more noise.
- Increased construction and maintenance boat traffic will become a larger potential problem.
- Increased need to lay electrical cables could potentially increase chance of impacts by entanglement and electromagnetic field effects.
- Adverse weather conditions further offshore will affect mitigation monitoring procedures for example bad weather will increase the potential for a lot more 'down time' where the MMO and PAM operators are not confident in their detection abilities.

Cumulative effects of developing more and larger scale wind farms potentially involving more piling activities may be damaging to certain marine mammal populations in the long term. It has been demonstrated at international offshore wind farms such as Horns Rev that most porpoises return to the area after the disturbance is finished. However if large scale development takes places over longer time scales animals may be displaced from large areas of habitat for long periods of time. The data from SCANS II indicates the high densities of harbour porpoise in the North Sea (see Figure 3). Round 3 offshore wind developments may coincide with Danish, Dutch or other international developments in the North Sea. It is important for there to be clear communication and international cooperation between all concerned to ensure monitoring plans are comparable, data sets shared and construction schedules are carefully planned to restrict any possible ill effects on local marine mammal populations. It will become increasingly important to consider the cumulative effects of wind farm sites being constructed relatively close together in time, within the range of the same marine mammal populations and to bear in mind that these populations are also being

affected by both other local anthropogenic activities and potentially the larger scale impacts of climate change.

Based mainly on international studies, there seems little doubt that wind farm construction can exclude porpoises at moderate distances. Impacts on local seals haul outs also seem to occur. The impact on other marine mammal species, typically found further offshore is largely unknown, but given the hearing sensitivities of larger whales, construction impacts may be even greater for these species. As Round 3 wind farms may be even further offshore and in deeper water more species will potentially be affected such as white beaked and Atlantic white sided dolphins, common dolphins, killer whale and baleen whales such as minke whales. The audiograms of many species of marine mammal have not been tested so there is little information about the hearing sensitivities of many species (SMRU Ltd., 2007). Minke whales produce sounds in the low frequency range (100-200 Hz) and higher (up to 9 kHz) (Richardson *et al.*, 1995, Gedamke *et al.*, 2001) and it is very likely that they have their best range of hearing at lower frequencies compared to odontocetes. It is possible that minke whales detect wind farm related noise at considerable distances, (tens of km) during pile driving. It is also quite possible that these noise sources mask biological relevant signals within the zone of audibility. Responsiveness to impulsive sounds occurs in other mysticetes, sometimes at considerable distances (McCauley *et al.*, 2000, Richardson *et al.*, 1995, Madsen *et al.*, 2006), so the potential of pile-driving noise to alter the behaviour and cause disturbance to these species cannot be ruled out.

7. CONCLUSIONS

While there have been advances made and lessons learned from the construction of offshore wind farms, there are still many uncertainties about their effects on marine mammals. There is limited data available on the effects of UK wind farm construction on marine mammals. Future developments will be carrying out mitigation monitoring and the results of this should be assessed in a year or two.

UK monitoring has been limited mainly to mitigation monitoring during the construction phase only. While initial FEPA licences for the earlier Round 1 wind farms were highly variable resulting in poor quality data, the more recent licences are much improved. FEPA licences are concerned with the construction phase, so it is understandable why conditions restrict marine mammal monitoring to this stage in wind farm development. However in the case of Scroby Sands monitoring was required pre and post construction also. Given this precedent, the licence authority clearly has the means to request broader monitoring protocols. However, recent licences leave it up to the regulator to decide whether long term monitoring is required after construction, as well as the details of the construction phase monitoring. This will make it harder to compare across studies if conditions imposed will be variable.

Marine mammal monitoring programmes at international sites such as Horns Rev and Nysted have been more comprehensive than any monitoring to date at UK wind farms. The studies at these sites show clear impacts of wind farm construction on marine mammals especially during the construction phase, although there are still several uncertainties. Therefore it is advisable to employ a precautionary approach when planning the construction of offshore windfarms.

Increased coordination is needed between FEPA and the regulator on responsibilities to ensure adequate and consistent marine mammal monitoring is undertaken, reported and analysed. Ideally in the regions of wind farm development where there is no information on possible species present, a comprehensive baseline monitoring programme should be established and carried out at EIA stage to examine what marine mammal species use the area. In addition, if there are indications that the area could be important for certain species, an assessment of habitat use should be carried out to test that hypothesis. A construction monitoring and mitigation programme should then be designed to reflect the information already known about the area, followed where necessary by a post construction monitoring plan to test for longer-term effects (by comparing against the baseline). Mitigation should be adaptive where possible.

Noise monitoring has been carried out on operational wind farms and is a requirement for licensed developments. Measurements on ambient noise levels pre, during and post construction give an indication of the potential effects of noise on the surrounding habitat. These noise measurements are valuable although construction noise will propagate differently in different sites depending on the pile driving methods, site specific substrate type and bathymetry, previous measurements in similar areas may help in designing adequate exclusion zones for mitigation. While pile driving during construction is likely to be the loudest point source of noise, other construction activities will also introduce noise at varying levels into the environment. There will also be a certain amount of operational noise when construction is completed. Differences in noise levels from operating wind farms may in part be related to different wind speeds, recording conditions and sound radiation patterns (Madsen *et al.*, 2006). The impact zones of operating wind turbines for marine mammals depend on the hearing-abilities of the species in question, on sound-propagation conditions, and, possibly on the presence of other noise sources such as shipping (Madsen *et al.*, 2006). If these additional noise sources impact greatly on ambient noise levels there may be a need to mitigate for these in sensitive areas by engineering improvements or even re-routing shipping. For example the main source of noise in operating turbines is the gear box generator vibrations and the effect of these can be reduced by isolators (Ingemansson technology 2003).

More research needs to be carried out on current soft-start procedures to investigate best practise and to evaluate how effective this method is. Soft starts need to be stringently controlled to avoid emitting high source levels too quickly. Currently piling is allowed to commence at night-time with 'enhanced acoustic monitoring'. However as previously stated this will be of no use in detecting seals, which in many areas will be the species of concern. There may be a requirement for seasonal restrictions on piling activities. Certain areas may be important for seal foraging. The use of other mitigation measures should be investigated further. Potentially noisy activities should be stopped at night and poor weather conditions.

Round 3 wind farms will be larger and further offshore. This will raise the potential for the impact of development to be spread over a wider area, for a longer period and affect more offshore species.

8. RECOMMENDATIONS FOR ROUND 3 WIND FARM DEVELOPMENTS

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The following is a list of recommendations for Round 3 development based on what has been learned so far from both UK and international case studies.

8.1 General points

- Well designed pre, during and post construction monitoring are important for some species in order to be able to assess the impact of the development on marine mammals and test predictions made in the EIA. In certain situations, regional information may be sufficient for pre-construction baseline.

- The purpose of a monitoring plan needs to be established at the planning stage as it will affect the methodologies used (e.g., scale, frequency, duration) and be linked to the EIA predictions and licensing decisions (e.g. allowing for pile driving to take place in some areas/times).

- Regulators need to ensure methodology to collect data at different stages of development is standardised across regions so they are comparable.

- New engineering designs should be investigated such as gravity foundations and floating platforms to minimise noise disturbance associated with pile driving.

- Emphasis need to be placed on testing and improving existing mitigation methods and developing more mitigation strategies to deal with newer technologies.

- Studies, which may involve observation, telemetry and photo-id should be conducted at certain sites thought to be particularly important in order to determine the behaviour of relevant species in those areas, and the use they make of it for particular activities associated with their life cycles.

- There is the need for regulators to agree a defined marine mammal exclusion zone for each development and acceptable anthropogenic noise levels (as in the JNCC, NE and CCW Guidance on the Protection of Marine European Protected Species from Disturbance and Injury). .

- Noise measurements taken during all stages of development should be incorporated into marine mammal data analysis.

- Monitoring of noise and marine mammal abundance, distribution and behaviour should be particularly focused during the construction period (when it is most likely to observe important and relevant effects)

8.2 FEPA

- As FEPA licences are concerned with the construction phase only, it appears mainly up to the regulators to ensure adequate long-term monitoring is undertaken at all stages of development if deemed necessary.
- FEPA licences may need to consider potential risks other than pile driving such as boat noise, entanglement, pollution, EMF and boat strikes if identified during the EIA process.
- A clear reporting methodology is vital for efficient communication and in turn efficient mitigating actions if required.
- A clearly defined protocol is needed for each site so that adequate data is recorded and can be compared across different sites taking into account variability in site and environmental conditions.
- Marine mammal data collected at wind farm sites should go to a central repository where it can be accessed easily.
- License requirements for Round 3 should take into account results of monitoring data yet to be collected at Round 2 sites. A review of Round 2 monitoring data should take place in 1-2 years.

8.3 Mitigation monitoring

- In order to establish appropriate mitigation measures it will be necessary to have sufficient baseline data on species presence (both seals and cetaceans) and any seasonality in habitat use in the area.
- More research is required to investigate best practice and the efficiency of current mitigation measures such as 'soft-starts' and to develop novel methods to mitigate during piling. The efficacy of 'soft starts' needs to be assessed in particular and the use of these procedures should be carefully documented and reviewed at a later date.
- More MMO's and PAM operatives will be required for long term piling operations to reduce observer fatigue.
- There are limited mitigation measures to protect seals and so new methods should be investigated.
- Noise monitoring data collected from previous wind farm construction and site specific noise propagation studies should be used to estimate expected noise levels and mitigation measures adapted accordingly (e.g., in estimating or extending exclusion zones).
- While 'enhanced acoustic monitoring' would be useful for pre, during and post construction monitoring, it does not seem an effective measure for mitigation monitoring during poor weather conditions and night piling which is what is requested in FEPA licences. The meaning of 'Enhanced acoustic monitoring' needs to be better defined.

- It is recommended that piling takes place only at night if it commences before nightfall i.e. when the MMO has had sufficient time to monitor the area visually to ensure there are no marine mammals in the vicinity.

- It must be made clear whether mitigation measures apply to other large marine animals such as basking sharks and turtles.

9 REFERENCES

Betke, K, Schultz-von Glahn, M & Matuschek, R (2004). Underwater noise emissions from offshore wind turbines. Paper presented on CFA/DAGA 2004, 2 pp. (http://www.ltap.de/ltap.htm)

BWEA website www.bwea.com

Carstensen, J., Henriksen,O.D. & Teilmann, J. (2006). Impacts of offshore wind farm construction on harbour porpoises: acoustic monitoring of echolocation activity using porpoise detectors (T-PODS). *Marine Ecology Progress Series* 321:295-308.

Diederichs, A, Nehls, G, Dähne, M, Adler, S, Koschinski, S, & Verfuß, U. (2008). Methodologies for measuring and assessing potential changes in marine mammal behaviour, abundance or distribution arising from the construction, operation and decommissioning of offshore windfarms. Commissioned by COWRIE Ltd. 90pp

Dietz, R., Teilmann, J., Henriksen, O.D. & Laidre, K. (2003). Movements of seals from Rødsand seal sanctuary monitored by satellite telemetry. Relative importance of the Nysted Offshore Wind Farm area to the seals. National Environmental Research Institute, Denmark pp 44 – NERI technical Report No 429. http://faglige rapporter.dmu.dk

Dong Energy (2006). Barrow Offshore wind farm construction monitoring report.

Evans, PGH (2008). Concluding remarks. In: Evans PGH (ed) Proceedings of the ASCOBANS/ECS workshop. Offshore wind farms and marine mammals: impacts and methodologies for assessing impacts. ECS special publication series No. 49. European Cetacean Society, San Sebastian, Spain, 21st April 2007, pp 63-67

Gedamke, J, Costa, D.P,& Dunstan, A (2001). Localization and visual verification of a complex minke whale vocalization. J. Acoust. Soc. Am. 109:3038-3047.

Gill, A.B, Gloyne-Phillips I, Neal, K.J & Kimber, J.A (2005). The potential effects of electromagnetic fields generated by sub-sea power cables associated with offshore wind farm developments on electrically and magnetically sensitive marine organisms – a review. Prepared for and commissioned by COWRIE

Hammond, P.S, Berggren, P., Benke, H., Borchers, D.L, Collet, A., Heide-JØrgensen, M.P., Heimlich, S., Hiby, A.R, Leopold, M.F, & Øien, N. (2002). Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. Journal of Applied Ecology 39: 361-376

Hammond, P.S. (2008). Small Cetaceans in the European Atlantic and North Sea (SCANS-II). Final Report to the EU, Life Project Number LIFE04NAT/GB/000245.

Ingemansson Technology (2003). Utgrunden offshore wind farm-measurements of underwater noise. Report 11-00329-03012700. Ingemansson Technology, Gothenburg.

JNCC (2009), Statutory nature conservation agency protocol for minimising the risk of disturbance and injury to marine mammals from piling noise.

Koschinski, S. Culik, B.M., Damsgaard Henriksen, O., Tregenza, N., Ellis, G., Jansen, C. & Kathe, G. (2003). Behavioural reactions of free-ranging porpoises and seals to the noise of a simulated 2MW windpower generator. *Marine Ecology Progress Series* 265:263-273.

Laist, D.W, Knowlton, A.R, Mead, J.G, Collet, A.S, & Podesta. M (2001). Collisions between ships and whales. *Marine Mammal Science*. 17:35-75

Madsen, P.T., Wahlberg, M., Tougaard, J., Lucke, K. & Tyack, P. (2006). Wind turbine underwater noise and marine mammals: implication of current knowledge and data needs. *Marine Ecology Progress Series* 309: 279-295.

McCauley, R.D, Fewtrell, J, Duncan, AJ, Jenner, C, Jenner, M.N, Penrose, J.D, Prince, R.I.T, Adhitya, A, Murdoch, J, & McCabe, C. (2000). Marine Seismic Surveys: Analysis and Propagation of Air Gun Signals; and Effects of Air-Gun Exposure on Humpback Whales, Sea Turtles, Fishes and Squid. Report on research conducted for The Australian Petroleum Production and Exploration Association.

McConnell, B.J., Fedak, M.A., Lovell, P. & Hammond, P.S. (1999). Movements and foraging areas of grey seals in the North Sea. *Journal of Applied Ecology*. 36, 573-590.

Nedwell, J. R., Parvin, S. J., Edwards, B., Workman, R., Brooker, A. G. & Kynoch, J. E. (2007). Measurement and interpretation of underwater noise during construction and operation of offshore windfarms in UK waters. Subacoustech Report No. 544R0738 to COWRIE Ltd. ISBN: 978-0-9554279-5-4.

Nedwell, J.R., & Howell, D. (2004). A review of offshore windfarm related underwater noise sources. – COWRIE report No. 544 R 0308, 57 pp

Nehls, G., Betke, K., Eckelmann, S. & 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 windfarms. BioConsult SH report, Husum, Germany. On behalf of COWRIE Ltd.

nPower Reneweables NHOWF (2008). Final annual FEPA monitoring report (2006-2007) and five year monitoring programme summary.

Palka. D.L, & Hammond, P.S (2001). Accounting for responsive movement in line transect estimates of abundance. *Canadian Journal of Fisheries and Aquatic Sciences* 58:777-787

Polacheck. T., & Thorpe L (1990). The swimming direction of harbor porpoise in relationship to a survey vessel. Report of the International Whaling Commission 40:463-470

Richardson, J.W., Greene, C.R., Malme, C.I. & Thomson, D.H. (1995). Marine Mammals and Noise. Academic Press San Diego, 576PP.

Ross, P, De SR, Addison, R., Van LH, Vos, J, & Osterhaus, A. (1996). Contaminant-induced immunotoxicity in harbour seals: Wildlife at risk? *Toxicology* 112:157-169

Ross, P.S. (2002). The role of immunotoxic environmental contaminants in facilitating the emergence of infectious diseases in marine mammals. *Human and Ecological Risk Assessment* 8(2) 277-292.

RPS Energy (2008). Marine mammal observer's and passive acoustic monitoring operator's report during Lynn and Inner Dowsing offshore wind farm installation.

SCOS (2008). Scientific Committee on Seals Scientific Advice on matters related to the management of seal populations 2008.

Sharples, R.J., Matthiopoulos, J. & Hammond, P.S (2008). Distribution and movements of harbour seals around the coast of Britain: Outer Hebrides, Shetland, Orkney, the Moray Firth, St Andrews Bay, The Wash and the Thames. Report to Geotek. 65pp

Simms, W, & Ross, P.S (2000). Vitamin A physiology and its application as a biomarker of contaminant-related toxicity in marine mammals: A review. *Toxicology and Industrial Health*. September 16:291-302

Skeate, E.R., & Perrow, M.R. (2008). Scroby Sands Offshore wind farm: Seal Monitoring: Analysis of the 2006 post-construction aerial surveys and summary of the monitoring programme results from 2002-2006. Final report to E. ON UK Reneweables Offshore Wind Limited.

SMRU Ltd. (2007). Assessment of the potential for acoustic deterrents to mitigate the impact on marine mammals of underwater noise arising from the construction of offshore windfarms. Commissioned by COWRIE Ltd (project reference DETER-01-07).

Teilmann, J., Tougaard, J., Carstensen, Dietz, R &, Tougaard, S. (2006). Danish Offshore wind –Key Environmental issues. Published by DONG Energy, Vattenfall, The Danish Energy Authority and Th e Danish Forest and Nature Agency 144PP.

Thomas, G.L. & Thorne, R.E. (2001). Night-time predation by Steller sea lions. *Nature* 411:1013.

Thompsen, P. M., McConnell, B.J., Tollit, D.M., Mackey, A., Hunter, C. & Racey, P.A. (1996). Comparative distribution, movements and diet of harbour and grey seals from the Moray Firth, N.E. Scotland. *Journal of Applied Ecology*. 33, 1572-1584.

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

Tougaard, J., Carstensen, J., Ilsted Bech, N. & Teilmann, J. (2006). Final report on the effect of Nysted Offshore Wind Farm on harbour porpoises. National Environment Research Institute.65pp.

Tougaard, J., Ebbesen, I., Tougaard, S., Jensen T. & Teilmann, J. (2003b). Satellite tracking of harbour seals on Horns Reef. Technical report to Techwise A/S, Biological Papers from the Fisheries and Maritime Museum, Esbjerg. No. 3.

Tougaard, J., Carstensen, J., Henriksen, O.D., Skov, H., & Teilmann, J. (2003a). Short-term effects of the construction of wind turbines on harbour porpoises at Horns Reef. - Hedeselskabet, Roskilde, Denmark.

Tougaard, J., Henriksen, O.D. & Miller, L.A., (2009). Underwater noise from three types of offshore wind turbines: Estimation of impact zones for harbor porpoises and harbour seals. *Journal of the Acoustical Society of America* 125(6) 3766-3773.

Tougaard, J., Carstensen, J., Teilmann, J., Skov, H & Rasmussen, P. (2009). Pile driving zone of responsiveness extends beyond 20km for harbour porpoises (*Phocoena phocoena*(L,))(L). *Journal of the Acoustical Society of America* 126(1):11-14.

Appendix 6.1

Marine mammals

Marine mammals include cetaceans (whales, dolphins and porpoises), pinnipeds (true seals, eared seals and walrus), and other species such as polar bears, manatees and sea otters. Cetaceans can be subdivided into two groups based on their feeding methodologies. Baleen whales or mysticetes are the large whales which have rows of stiff fibrous baleen plates in their mouths which they use to filter feed on plankton. The other group are the toothed whales or odontocetes, which consist of sperm whales and also smaller whales, dolphins and porpoises. Odontocetes extensively use echolocation to navigate and find their prey, but all cetaceans are heavily reliant on sound to navigate, feed and interact socially. Over twenty species of cetacean are known to occur regularly off the UK coast including harbour porpoise, bottlenose dolphin, Risso's dolphin, common dolphin, minke whale, killer whale, white sided dolphins and pilot whales. Other rarer species such as sperm whales, white beaked dolphins, striped dolphins and northern bottlenose whales have also been recorded. Abundance information for cetaceans is often limited to areas included in offshore cetacean surveys such as SCANS, SCANS II and CODA. The SCANS (Small Cetacean Abundance in the North Sea and adjacent waters) and SCANS-II (Small cetaceans in the European Atlantic and North Sea) surveys took place in July 1994 and July 2005, respectively (Hammond *et al*., 2002; Hammond 2008). Harbour porpoise (Figure 3) and minke whale (Figure 4) density maps indicate areas of high densities of these species in the North Sea. Information on coastal cetaceans is often collected on dedicated coastal surveys or from public recordings of sightings.

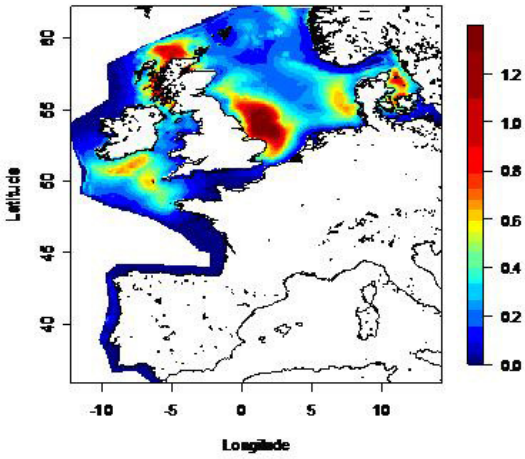

Figure 3: Harbour porpoise estimated density surface (animals per km^2) in 2005, data from SCANS II survey. Taken from Hammond (2008).

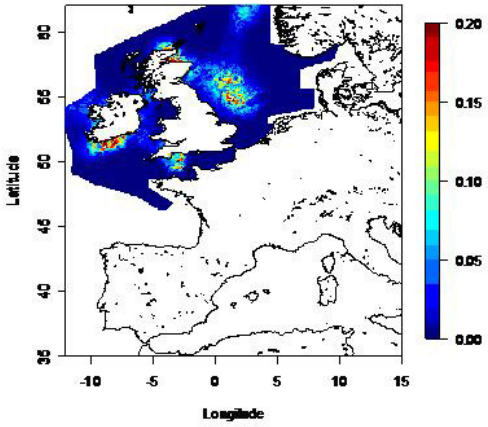

Figure 4: Minke whale estimated density surface (animals per km^2) in 2005, data from SCANS II survey. Taken from Hammond (2008).

Grey seals

Grey seals (*Halichoerus grypus*) and harbour seals (*Phoca vitulina vitulina*) are the two seal species found on UK coasts. Detailed information on seal abundance and distribution is available from studies carried out by the Sea Mammal Research Unit (SMRU). Over 90% of the UK grey seal population breeds in Scotland. Grey seal colonies in England and Wales include the Farne Islands in the northeast, Donna Nook at the mouth of the Humber, Lundy and Pembrokeshire (see Figure 5). Pup production in Donna Nook, Blakeney Point and Horsey was 1,640 in 2007 which indicates an increasing trend in pup production in those sites in recent years (SCOS 2008). Donna Nook is the largest breeding colony of grey seals in England, followed by the Farne Islands. Satellite telemetry

data from tagged seals has been used to create area usage maps (see Figure 6). Grey seals and harbour seals tend to forage within 40-50km of their haul out sites (see Figures 6 & 8). However grey seals are known to travel further (between 125 and 365 km) to new haul-out sites, which may then be their base for subsequent feeding trips (Thompson *et al.,* 1996, McConnell *et al.,* 1999).

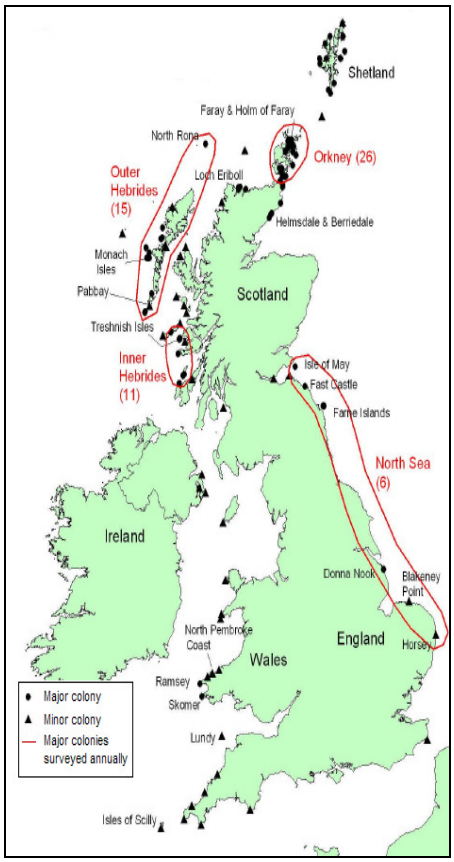

Figure 5: Grey seal major and minor breeding colonies, those circled in red are surveyed annually taken from SCOS 2007.

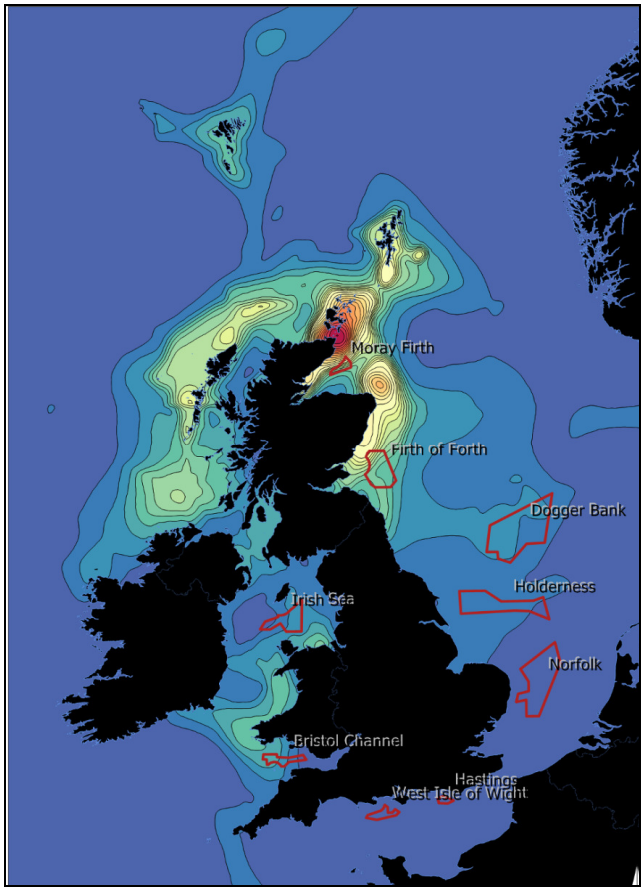

Figure 6: Predicted relative usage of UK grey seals at sea, during a foraging trip. Warmer colours represent areas of higher usage. (SMRU Unpublished).

Harbour seals

About 33% of the world population of the harbour seal sub species *vitulina* occur in the UK (SCOS 2008). Most of the harbour seals breed in Scotland but 11% of the UK harbour seal population is found in England and there are large colonies in the Wash and Greater Thames area (see Figure 7). 95% of the English harbour seal population is found on the Lincolnshire and Norfolk coasts (SCOS 2008). The most recent minimum population estimates from SCOS 2008 are Blakeney Point (550), The Wash (2,162), Donna Nook (214) and Scroby Sands (71). The harbour seal population was drastically reduced during an outbreak of Phocine Distemper Virus (PDV) in 1988 when numbers along the east coast of England dropped by 52%. The effect of this PDV was very evident in the Wash region. Another outbreak of PDV in 2002 resulted in yet another decline in the Wash harbour seal numbers (22%) and to date the population has failed to recover (SCOS 2008). Satellite telemetry data indicates that harbour seals in the Wash tend to forage further offshore than seals in the Scottish Isles (see Figure 8).

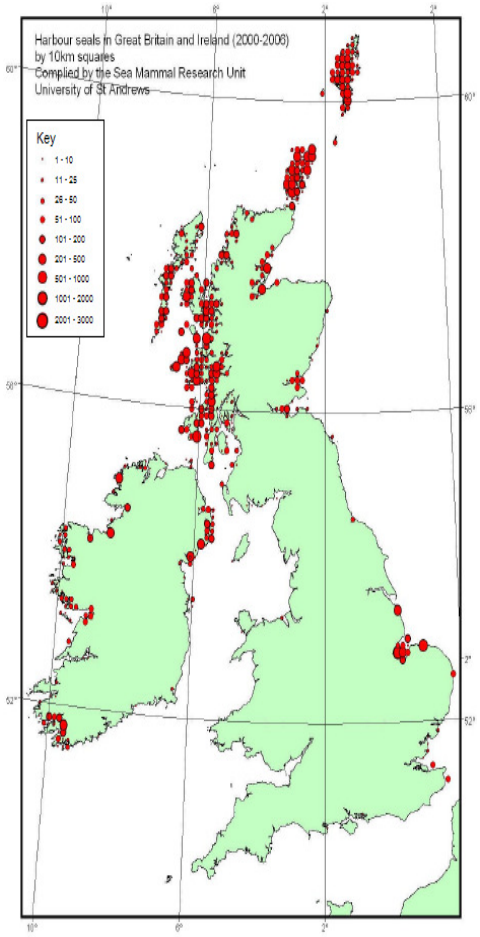

Figure 7: Harbour seal numbers from aerial surveys over the period 2000-2006 (SCOS 2007).

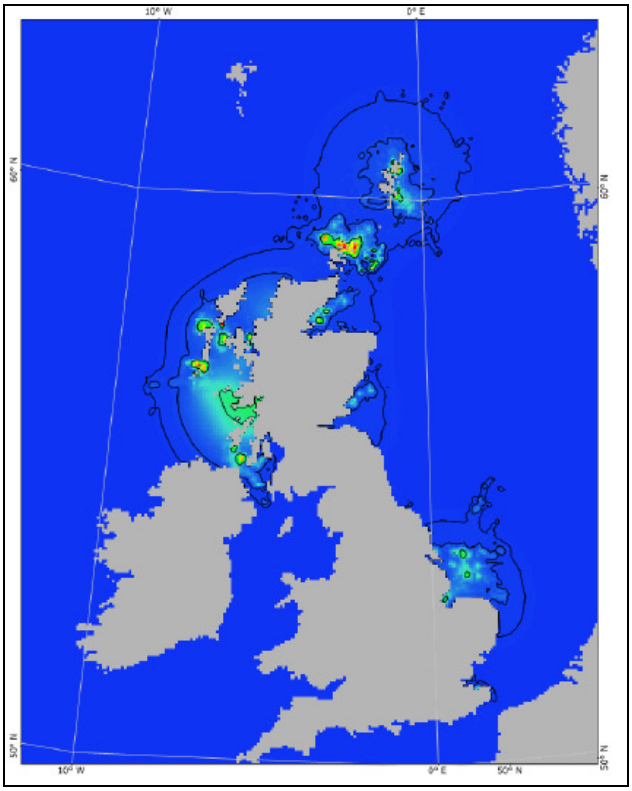

Figure 8: Marine usage of the populations of harbour seals around the coast of Britain. Warmer colours represent areas of higher usage. Taken from Sharples *et al.,* (2008).