Commission particulière
du débat public
Projet de parc éolien
en mer des Deux Côtes

SYNTHESES D'ETUDES ENVIRONNEMENTALES DANOISES

Vous trouverez dans les pages suivantes une sélection de synthèses d'études danoises portant sur les parcs éoliens en mer de Horns Rev et de Nysted. Ces documents sont en anglais. Pour la plupart, une traduction en Français est en cours.

Sommaire

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ENERGI E2

April 2006

EIA Report
Fish

Horns Rev Offshore Wind Farm II

Bio/consult as

in association with

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Summary

This EIA report reviews and assesses the possible impacts on fish from the establishment of Horns Rev 2 Offshore Wind Farm.

Horns Rev 2 Offshore Wind Farm will be established in one of two designated areas situated north of the existing Horns Rev 1 Offshore Wind Farm. Like the latter, the new wind farm will be situated in an area characterised by a harsh marine environment with strong tidal currents and a rough sea, both of which cause very dynamic current and sediment regimes. It is against this very variable and fluctuating environment that all human activities and installations should be seen and assessed.

Despite the harsh environment Horns Rev is an important fish habitat. The sandy sediments and the grain size distribution are strongly reflected in the species composition, and the distribution of the individuals is strongly influenced by the current patterns. Regarding abundance and density sandeels (*Ammotydidae* spp.) dominate the fish fauna at Horns Rev, which is the reason for an intensive commercial fishery for sandeels in the area. Other abundant species are the flatfish plaice (*Pleuronectes platesa*) and dab (*Limanda limanda*) as well as sand goby (*Pomatoschistus minutus*), but many more species are recorded at Horns Rev. Some live permanently at Horns Rev or in the vicinity, while others are occasional or seasonal visitors. Thus, depending on the time of the year the different surveys carried out at Horns Rev rank the species differently regarding abundance. Fish of conservation interest occur only very sparsely and occasionally at Horns Rev.

Noise and vibrations are likely to be the most important impacts on the fish fauna, which is why hearing ability among the fish is an important issue. Based on the literature the most abundant species – sandeels, plaice and dab – are all believed to have low sensitivity to noise and vibrations. Other species are more sensitive due to fact that hearing ability is an important part of the sensory apparatus.

The wind turbines will be founded by use of either monopole or gravitation foundations. Which one of these two foundations will be used is not decided yet, but this report focuses on the monopile foundation since the use of this is associated with the highest levels of impacts, particularly in the form of noise and vibrations. In the case that gravitation foundations are to be used, the impacts on fish are believed to be similar or – more likely – smaller than they will be in the case that monopile foundations are to be used.

The life cycle of the wind farm comprises four phases – the pre-construction phase, the construction phase, the operation phase and the decommissioning phase. Each of these phases comprises a number of impacts – some general and some phase specific.

In the pre-construction phase seismic surveys of the sea floor may give rise to transient emissions of noise and vibrations from seismic guns and vessel activity in the wind farm area. Although unavoidable and associated with high but transient levels of noise, these impacts are considered insignificant to fish. They may flee from the impacted areas or avoid these during the surveys, but no lasting effects are to be expected.

The construction phase is considered the most important to fish in terms of impacts. First of all the erection of the turbines along with the establishment of scour protection is encumbered with high impacts of noise and vibrations, the most important source be the

pile-driving (in case of monopile foundation). Although fish to varying extent are sensitive to both noise and vibrations, the assessments lead all to the conclusion that no significant lasting effects on fish are to be expected. Indeed fish may flee from or avoid the areas with the highest impacts, but as the emissions of noise and vibrations come to an end, things are likely to return to normal within short time.

Secondly, the erection of the turbines and establishment of scour protection at each of the turbines will invariably cause a loss of natural habitat to fish. Amounting to only a few percent of the total wind farm area, this loss is considered insignificant, even to the most abundant and important fish species in the area, the sand eels. In terms of fish habitats the loss of sandy habitats is correspondingly associated with an increase in stony and rocky habitats, i.e. artificial reefs will come into existence.

In the operation phase the presence of the artificial reefs will increasingly have positive effects on the fish fauna, a process that is known as “the artificial reef effect”. Species not presently living at Horns Rev will be attracted to the artificial reefs, some because the stones and rocks constitute their preferred habitat, others because they constitute suitable spawning and nursery areas. Thus, due to the artificial reefs, the establishment of the wind farm is likely to cause a significant positive impact on the fish fauna in the form of increased species richness and diversity. However, in the operation phase there will also be negative impacts in the form of both noise and vibrations and in the form of electromagnetic fields around the power cables. Based on existing knowledge, including that from the monitoring of the fish fauna at Horns Rev 1 Offshore Wind Farm, nevertheless no significant impacts on the fish fauna are to be expected.

Decommissioning of the wind farm will take place when the turbines have served their time, expectedly at least 25 years. Decommissioning of the wind farm will to large extent comprise the same activities and thus the same impacts on fish as will the construction, although the emissions of noise and vibrations are believed to be less intensive. Like the establishment of the scour protection will cause a loss of sandy habitats and creation of stony and rocky habitats, so will a complete decommissioning cause loss of the artificial reefs and regeneration of sandy habitats. This reversal of the situation will invariably mean a loss of the richness and diversity associated with the artificial reefs, and although no lasting nor significant effects are expected on the large scale, the scour protections should preferably be left in place if nothing speaks against this.

In conclusion, the establishment of Horns Rev 2 Offshore Wind Farm invariably involve a number of human activities and alterations of the existing environment at Horns Rev, all of which are associated with impacts on the fish fauna. In a systematic review all negative impacts are nevertheless assessed to be of minor importance or insignificant to the fish fauna, spatially as well as temporally. Thus, no significant negative changes of the fish fauna are expected in the wind farm area or in the adjacent areas. On the other hand significant positive changes are expected due to the artificial reef effect.

Likewise no significant cumulative effects are expected, neither for Horns Rev 2 Offshore Wind Farm on its own or for the two offshore wind farms as a whole. But there may be a positive cumulative effect on the developmental pattern of the fish fauna at Hors Rev 2 Offshore Wind Farm due to the presence of already colonised artificial reefs at Horns Rev 1 Offshore Wind Farm.

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EIA Report
Benthic Communities

Horns Rev 2
Offshore Wind Farm

Bio/consult as
in association with
Carl Bro as
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INSTITUT FOR VAND OG MILJØ

Summary

As part of the Danish Governmental Plan for Renewable Energy, permission was given in 2005 to carry out an Environmental Impact Assessment for the establishment of a new offshore wind farm at Horns Rev.

Knowledge about potential impacts on the marine benthic communities from the establishment and operation of offshore wind farms is available due to the demonstration projects carried out at Horns Rev 1 Offshore Wind Farm. However, provision of supplementary information was found necessary regarding the existing habitats and benthic communities, which include benthic vegetation and invertebrate communities, in the designated wind farm area.

Two alternative sites are designated for the wind farm at Horns Rev 40 km west of Blåvands Huk. Both sites cover an area of approximately 35 km^2 and the water depths range from 5-15 m. The sediment in the wind farm areas display large variability and surface sediments consist of pure medium to coarse sand that is constantly reworked by waves and currents. Along the top of the reef and in shallower parts that are strongly exposed to waves, the sediment is more sorted compared to deeper parts where the sediment is coarser due to exposure to strong currents. Bedforms of small and large sand riffles caused by wave action and evidence of sand transport are found all over in the area. In the northern part of the designated sites, the sediment is generally finer closer to the reef. No unambiguous relationship between the depth regimes and the sediment structure is found at the different sampling sites in the wind farm area.

No vegetation, and no rare and endangered species, is found within the designated wind farm areas. The variations of the benthic infauna composition and community structure reflect the heterogeneous sediment in the area. In general, the benthic infaunal community in the Horns Rev area can be characterised as the *Goniadella-Spisula* or the shallow *Venus* community. These two communities are commonly found at sandbank where the seabed consists of relatively coarse sand and hydrographical conditions are turbulent. In the northern part of the designated wind farm area, the sediment generally shows a more uniform character with finer sand. In such areas, a more typical *Venus* community is found. Even within short distances, differences can be found in the community structure resulting in subdivisions of the main communities inside the designated wind farm areas, which reflects the character species' preferences for different sediment characteristics.

In the Horns Rev area and the wind farm areas, more epifaunal species can be found including the brown shrimp (*Crangon crangon*), which is object of commercial fishing. The benthic communities in the Horns Rev area are generally influenced by trawling and dredging activities. Dredging for the character clam species (*Spisula solida*) and trawling for sandeels are the main fishing activities in the area.

The wind turbines will be founded by use of either monopiles or gravitation foundations. The main impacts on benthic communities from the activities in the pre-construction, construction, operation and decommissioning phases are considered equal for the two foundation types. The sources of impact that are similar to both types of foundations include noise generated from piling activities. However, additional sources of impact

from dredging activities related to the establishment of gravitation foundations include increased smothering and suspended sediments.

In the pre-construction and construction phases, it is expected that noise and vibrations from pile driving activities may have a temporary and negligible local impact on the benthic communities and a very local and negligible destructive effect on infaunal species.

Smothering and increased suspended sediment from dredging activities is expected to have a temporary local negligible effect on benthic communities due to the general loss of fine sand. Benthic communities generally show a high tolerance to smothering with a presumed high recovery rate.

Loss of seabed with native benthic communities and change in substrate type during construction and operation is less than 0.2% of the total wind farm area. The change of habitat type and change from sandy infauna communities to epifouling communities are expected to be local and of minor significance. The deployed hard substrate will rapidly be colonised with algae and invertebrates, which is known to increase the biodiversity in the wind farm area. The succession will increase the diversity over a period of 5-6 years after deployment of the hard substrates, at which time the communities are expected to reach climax.

The physical presence of the wind turbine foundations will have a very local, minor, but permanent effect on the benthic community structure due to changes of the hydrodynamics near the turbines. During operation, significant effects from noise and vibration are not expected. Effects from electromagnetic fields are considered negligible, although migrating crabs, believed to be sensitive to the Earth’s magnetic fields, may be affected.

Effects during decommissioning are generally considered as the same during construction but in the reverse order.

In the operation phase, cumulative impacts are be expected as a consequence of reduced trawling activities inside the wind farm sites, which will be beneficial to benthic communities by enabling very sensitive species to establish and all species to mature more undisturbed. The introduction of more consolidated substrates from more offshore wind farms may generate a cumulative effect by introducing higher species richness and faster colonisation of specific and potentially vulnerable species to newly deployed foundations. No cumulative effects on benthic communities are expected from simultaneous sand and aggregation activities and construction activities.

No specific mitigation measures are necessary because rare or endangered species are not found and only minor impacts from construction, operation and decommissioning activities are expected on the benthic communities inside the designated wind farm areas.

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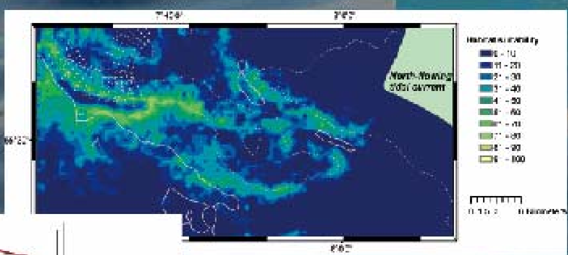
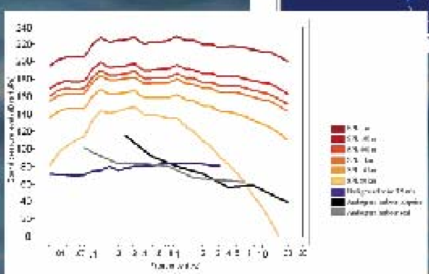
EIA Report
Marine Mammals

Horns Rev 2
Offshore Wind Farm





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7. Conclusions

The impacts to the regularly occurring species of marine mammals at Horns Rev, harbour porpoise and harbour seal, are summarised in Tables 7.1 and 7.2.

The large amount of data available from the biological monitoring program at the Horns Rev 1 Offshore Wind Farm proved sufficient to describe the trends in acoustic activity and habitat quality at the two sites for the Horns Rev 2 Offshore Wind Farm. Time-series from five porpoise detectors (PODs) and 51 fine-scale ship-based surveys provided the basis for the analyses and combined with topographic and hydrodynamic model data key habitats and their variability were defined for the period 2002-2005. Constraints in the extrapolation of Horns Rev 1 Offshore Wind Farm monitoring data to the Horns Rev 2 Offshore Wind Farm sites were found in relation to the variance of acoustic data induced by different T-POD versions and in relation to seasonal biases in the visual data. With respect to the different T-POD versions, the issue was solved by limiting the gradient analysis in acoustic activities in relation to environmental variables to data collected by the T-POD version 1. With respect to seasonal biases, the monitoring data indicated a reduction in the recordings of harbour porpoises during the winter season.

Harbour porpoises are relatively abundant in the Horns Rev area with local population estimates in the range of 500 to 1000 animals. Harbour seals breed in the nearby Wadden Sea and pass Horns Rev on their movements to feeding grounds in deeper waters of the North Sea. Although harbour porpoises are recorded throughout the area, the trend analysis and statistical tests of both acoustic and visual data with physical oceanographical data showed that the species is linked to small-scale dynamics, especially localised up-welling driven by tidal currents, rather than to large-scale dynamics, driven by the estuarine front. The up-welling zones are associated with the slope areas, including the southwestern slope at the southern part of the Horns Rev 2 Offshore Wind Farm sites. The modelled habitat suitability of harbour porpoises at Horns Rev both showed discrete areas of high use in the southwestern slope area, the northeastern slope, the southern slopes in Slugen and the southeastern slope. The northeastern slope of Horns Rev seems mainly to be used during south-flowing tide, while the southwestern slope overlapping the southern parts of the two wind farm sites seems mainly to be used during north-flowing tidal currents. The southwestern slope area during north-flowing tidal current seems to be the overall main habitat for porpoises at Horns Rev. The scale of peak habitat use by harbour porpoises at Horns Rev is approximately 10 km and the area of high habitat quality measures approximately 15% of the total modelled area. Harbour seals displayed more or less identical overall habitat trends as harbour porpoises when evaluated against topographic features, with the shallower, central parts seemingly being used more intensively. For harbour porpoises a strong decreasing gradient in habitat quality was discovered from the southern to the northern parts of the proposed sites.

Impacts were assessed by linking the classified key habitats to detailed investigations of noise-related disturbance using *in situ* measurements together with a method of frequency-related impact assessment. The main focus of the assessment is added effects imposed by under water noise, especially pile driving noise during construction. Based on the integration of models for attenuation of pile driving noise and audiograms for the two species, a zone of audibility is estimated at approximately 80 km and a zone of responsiveness is estimated at 20 km. For both the northern and the southern wind farm site, the range of 20 km will cover 75% of the primary habitat area to both harbour porpoises and harbour seals at Horns Rev. However, these effects should be of short duration, allowing the animals to return to the key areas following pile driving activities. Impacts on marine mammal communication caused by the pile driving noise is probably of limited significance, and with the data at hand probably only of relevance to harbour seal with an estimated masking zone of 80 km. Temporary threshold shift (TTS) zones for porpoises and seals are estimated at 1,000 m and 250 m, respectively. However, the TTS range for harbour porpoises is uncertain and, if frequency dependent TTS is taken into account the impact zone for this species will extend beyond 1,000 m. If unmitigated, TTS impacts may be important, especially in the up-welling area used intensively by porpoises in the southern part of the wind farm sites.

Other impacts during construction are considered as minor. Noise from ships associated with the construction activity could lead to responsive reactions in harbour porpoises and at close range (2-300 m).

Impacts on marine mammals during operation will be limited. The net effect of the establishment of the Horns Rev 2 Offshore Wind Farm may be positive depending on the development of new habitats and hard-substrate communities and the attraction of prey fish to these communities. Underwater turbine noise emissions are estimated to be audible for harbour porpoises only at close range (1-200 m), while harbour seals will be able to detect the sound within 1,000 m. The low levels of noise at predominantly lower frequencies are too low to induce responsiveness, masking or TTS in porpoises. There might be masking of harbour seal sounds but this will happen at close ranges below 1 km.

Impacts on harbour seals and harbour porpoises envisaged during decommissioning are similar to some of the disturbance impacts expected during construction, depending on the activities of pile removal and service boats. The potential disturbance effects will be smallest for decommissioning of gravity foundations.

Cumulative local and regional effects will mainly be an issue in relation to pile driving activities at Horns Rev 2 Offshore Wind Farm. Any possible effects of operation from Horns Rev I will be negligible compared to the effects of the construction phase of Horns Rev 2 Offshore Wind Farm.

Recommended mitigation measures are described with the most promising and well-tested being the application of seal scarers and pingers in combination with ramp-up procedures during pile driving. The seal scarers are judged essential, as they have the most potential for effective mitigation against TTS impacts.

Tabel 7.1. Summarised impacts on marine mammals from construction and operation activities associated with the establishment of Horns Rev 2 Offshore Wind Farm – Monopiles.

Monopiles

Impact	Criteria	Preconstruction	Construction	Operation	Decommissioning
Noise and vibrations	Importance	Regional	Regional	Local	Local
	Magnitude	Minor	Moderate	Minor	Minor
	Persistence	Temporary-short	Temporary-short	Temporary	Temporary
	Likelihood	High	High	High	High
	Other	Direct	Direct	Direct	Direct
	Significance	Minor	Moderate	Minor	Minor
Suspension of sediments	Importance	Local	Local	Local	Local
	Magnitude	Negligible	Minor	Negligible	Minor
	Persistence	Temporary-short	Temporary	Permanent	Temporary
	Likelihood	Low	High	High	High
	Other	Direct/indirect	Direct/indirect	Direct/indirect	Direct/indirect
	Significance	Negligible	Negligible	Negligible	Negligible
Traffic	Importance	Local	Local	Local	Local
	Magnitude	Minor	Minor	Minor	Minor
	Persistence	Temporary-short	Temporary-long	Semi-permanent	Temporary-long
	Likelihood	High	High	High	High
	Other	Direct	Direct	Direct	Direct
	Significance	Minor	Minor	Minor	Minor
Electromagnetic fields	Importance			Local	
	Magnitude			Negligible	
	Persistence			Permanent	
	Likelihood			High	
	Other			-	
	Significance			Negligible	
Reef effect	Importance		Minor	Negligible	Minor
	Magnitude		Minor	Negligible	Minor
	Persistence		-	Permanent	-
	Likelihood		High	High	High
	Other		-	-	-
	Significance		Negligible	Minor - positive	Negligible
Cumulative effects	Importance	Local	Local	Local	Local
	Magnitude	Negligible	Minor	Negligible	Minor
	Persistence	Temporary-short	Temporary	Permanent	Temporary
	Likelihood	Low	Low	Low	Low
	Other	-	Direct	-	Direct
	Significance	Negligible	Negligible	Negligible	Negligible

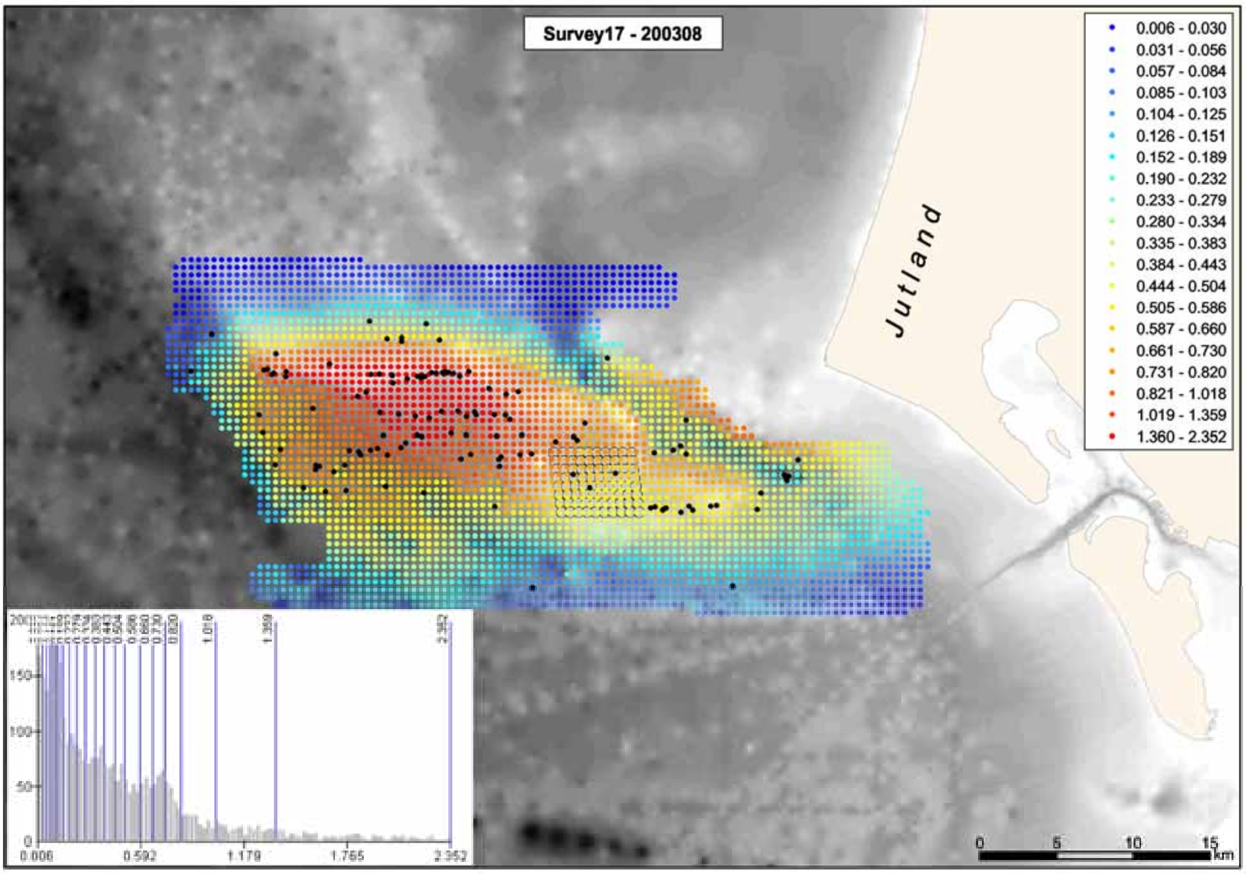
Tabel 7.2. Summarised impacts on marine mammals from construction and operation activities associated with the establishment of Horns Rev 2 Offshore Wind Farm – Gravitation foundations.

Gravitation foundations

Impact	Criteria	Preconstruction	Construction	Operation	Decommissioning
Noise and vibrations	Importance	Regional	Local	Local	Local
	Magnitude	Negligible	Minor	Minor	Minor
	Persistence	Temporary-short	Temporary	Temporary	Temporary
	Likelihood	High	High	High	High
	Other	Other: Direct	Other: Direct	Other: Direct	Other: Direct
	Significance	Negligible	Minor	Minor	Minor
Suspension of sediments	Importance	Local	Local	Local	Local
	Magnitude	Negligible	Minor	Negligible	Minor
	Persistence	Temporary-short	Temporary	Permanent	Temporary
	Likelihood	Low	High	High	High
	Other	Other: Direct/indirect	Other: Direct/indirect	Other: Direct/indirect	Other: Direct/indirect
	Significance	Negligible	Negligible	Negligible	Negligible
Traffic	Importance	Local	Local	Local	Local
	Magnitude	Minor	Minor	Minor	Minor
	Persistence	Temporary-short	Temporary-long	Semi-permanent	Temporary-long
	Likelihood	High	High	High	High
	Other	Other: Direct	Other: Direct	Other: Direct	Other: Direct
	Significance	Minor	Minor	Minor	Minor
Electromagnetic fields	Importance			Local	
	Magnitude			Negligible	
	Persistence			Permanent	
	Likelihood			High	
	Other			Other: -	
	Significance			Negligible	
Reef effect	Importance		Minor	Negligible	Minor
	Magnitude		Minor	Negligible	Minor
	Persistence		-	Permanent	-
	Likelihood		High	High	High
	Other		Other: -	Other: -	Other: -
	Significance		Negligible	Minor - positive	Negligible
Cumulative effects	Importance	Local	Local	Local	Local
	Magnitude	Negligible	Minor	Negligible	Minor
	Persistence	Temporary-short	Temporary	Permanent	Temporary
	Likelihood	Low	Low	Low	Low
	Other	Other: -	Other: Direct	Other: -	Other: Direct
	Significance	Negligible	Negligible	Negligible	Negligible

Harbour Porpoises on Horns Reef
Effects of the Horns Reef Wind Farm

Final Report to Vattenfall A/S



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NERI Commissioned Report
Roskilde, Denmark, November 2006

Summary

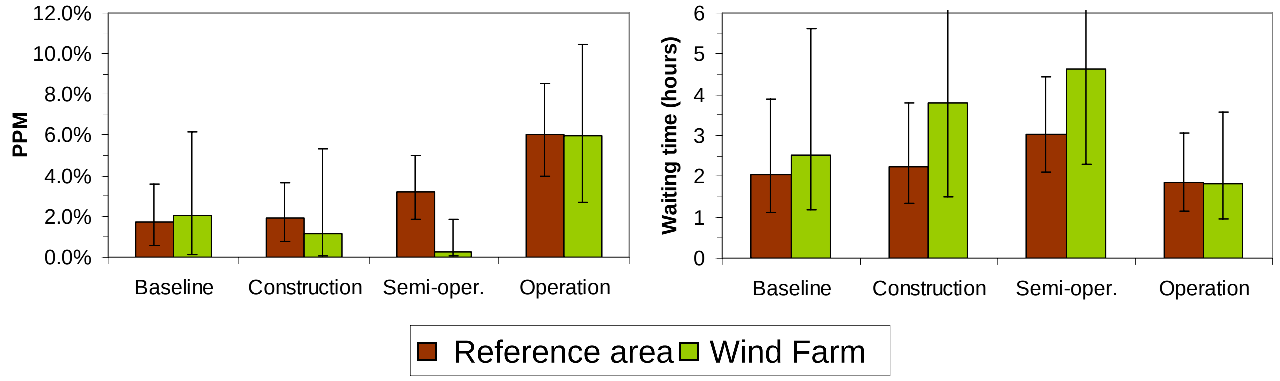
The monitoring program on harbour porpoises at Horns Rev Offshore Wind Farm in the Danish North Sea, initiated in 1999, has now come to an end with collection of final data in 2005 and spring 2006. Seven years of surveys and five years of acoustic recordings of harbour porpoises on Horns Reef have resulted in a unique set of data documenting effects of the construction and operation of one of the world's two largest offshore wind farms.

Horns Reef is a shallow reef consisting entirely of sand and with a complex hydrography. The reef and adjacent areas are important habitats for harbour porpoises. The occurrence of porpoises, as documented by visual surveys from ship and airplane as well as with acoustic dataloggers mounted on the seabed, is patchy in both space and time. There is thus a large variation between visual surveys in the number of animals observed and where they are observed. In general the wind farm area seems to be as important to the porpoises as the rest of the reef.

Effects of wind farm

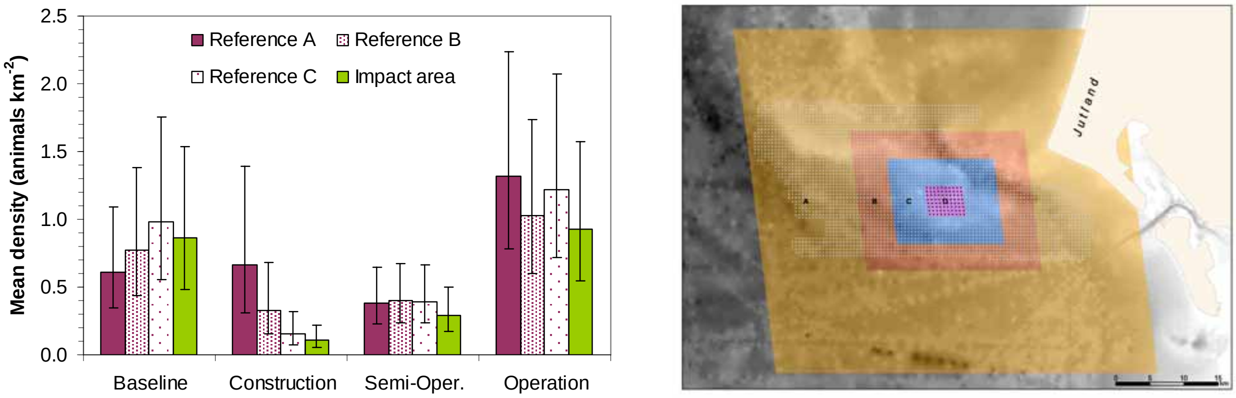
The current dataset, which covers time before, during and after construction of Horns Rev Offshore Wind Farm, indicates a weak negative general effect from the construction and semi-operation on porpoises, with more specific effects linked to pile driving activities. No effects were observed from the operating wind farm.

Acoustic recordings (with T-PODs) did not show any significant change in abundance in the wind farm area as a whole during construction (see figure below). However, there was a significant difference between semi-operation (when intensive maintenance work too place) and operation, measured on the indicator porpoise-positive-minutes (PPM). PPM reached the lowest mean value in the entire monitoring period during semi-operation. Porpoise acoustic activity was higher in the operation phase than during baseline, but this was the case both in the wind farm and in the surrounding reference areas.



Mean values for porpoise positive minutes (PPM, equal to the fraction of a day where porpoises could be detected) and waiting time between porpoise encounters, recorded by acoustic dataloggers (T-PODs) placed inside Horns Rev Offshore Wind Farm and in nearby reference areas. Values are separated into four periods: baseline, construction, semi-operation, and operation. Semi-operation covers a period following construction, where intensive maintenance and service operations occurred and the turbines thus were not operating at full capacity. Error bars indicate 95% confidence limits for the mean values.

Conclusions from the ship surveys point in the same direction as the acoustic data, i.e. a weak negative and local effect of the wind farm during construction but otherwise no significant changes (see figure below). Also ship survey data indicate more porpoises in the area as a whole during the operational period than for any other of the periods, baseline included.



Estimated mean densities of porpoises for combinations of the four areas shown on the map and the four time periods, based on observations from ship surveys conducted throughout the entire period from 1999 to 2005. Error bars show the 95% confidence intervals for the estimated mean densities. Note the gradient in density towards wind farm during construction.

Specific effects of construction

Although the design of the monitoring program was only aimed at detecting general effects of the construction and operation of the wind farm on porpoise abundance, it was nevertheless possible to document specific effects of a single activity: pile drivings. The T-POD data indicate that porpoises left the entire Horns Reef area in response to the loud impulse sound generated by the pile driving operation. After a period of 6-8 hours, activity returned to levels normal for the construction period as a whole.

Responses of porpoises to the construction and operation of Horns Rev Offshore Wind Farm thus lies within what was anticipated in the Environmental Impact Assessment: a partial displacement during construction and return to baseline activity during normal operation.

National Environmental Research Institute
University of Aarhus · Denmark

Changes in bird habitat utilisation around the Horns Rev 1 offshore wind farm, with particular emphasis on Common Scoter

Report request
Commissioned by Vattenfall A/S
2007

Ib Krag Petersen
Anthony D. Fox

Summary

This report presents an analysis of recent changes in waterbird habitat utilisation around the Horns Rev 1 wind farm, with particular emphasis on Common Scoter.

Ornithological investigations of waterbird numbers and distribution in the study area around the Horns Rev 1 wind farm were initiated in 1999. As part of a demonstration programme on the environmental feasibility of offshore wind farms a total of 34 surveys of bird distributions were conducted in the period from 1999 until 2005. In late 2005 and early 2006 additional six surveys were conducted in relation to the Horns Rev 2 EIA process.

Results from the demonstration programme concluded that the distribution of divers and Common Scoter were adversely affected by the presence of the wind turbines at Horns Rev.

In late 2006 and early 2007 Vattenfall A/S maintenance crews and helicopter pilots reported increasing numbers of Common Scoters present within the wind farm site. On that background a series of four surveys of waterbird distribution in the area was programmed during January to April 2007.

Data from surveys in January, February, March and April 2007 showed that Common Scoter was the most numerous bird species in the study area, with a total of 356,635 observed birds. Herring Gulls (7,661), Eider (5,674) and diver sp. (511) were other numerous species in the area.

Common Scoters dramatically changed their distribution in the study area during the period from 1999 to 2007 for reasons other than the presence of the turbines. Therefore a comparison of distribution of this species pre- and post construction of the wind farm, using a traditional BACI concept, was impossible. The analyses presented here thus build on data from the January to April 2004 to 2007.

During three out of four surveys in 2007 more Common Scoters than during any previous surveys were recorded within the foot print of the wind farm. On 25 January 2,112 birds, on 15 February 4,624 birds, on 3 March 1,359 and on 1 April 35 Common Scoters were encountered in the wind farm area.

Analyses of Common Scoter encounter rates in six 2x2 km grid cells within the wind farm area compared to encounter rates in 14 grid cells in the periphery of the wind farm site showed no significant difference for the three early surveys, while significantly lower encounter rates within the wind farm during a survey on 1 April. Based on the summed data set from 2007 there was no significant difference between encounter rates in the wind farm site and the periphery.

Analyses of Common Scoter cumulative distance frequency distributions in 500 m intervals from the wind farm centre point out to a radius of 6

km for each of the years between 2004 and 2007 showed that gradually higher percentages of the birds present within this radius were recorded within the wind farm site. The same pattern was found when analysing the proportion of birds within 3 km of the wind farm centre point to the total number of birds present within 6 km of the centre point, most dramatically amongst the proportion of individuals occurring within the area, which progressively increased from 10% in 2004 to 50% in the results from the survey in 2007.

We therefore conclude that Common Scoter may indeed occur in high densities between newly constructed wind turbines at sea, but this may only occur a number of years after initial construction. We still cannot exclude the explanation that this reflects changes in food supply rather than a change in the behaviour of the birds themselves.

As Common Scoters were virtually absent from Horns Rev prior to the construction of the wind farm it is difficult to judge how many birds the wind farm site would support by 2007, had the wind farm never been constructed. The use of spatial modelling tools may help elucidate whether the present found numbers of birds represent 100% of what could be expected in the absence of the wind turbines, given the nature of the habitat. Such an exercise was beyond the scope of this report.

Spatial modelled density surfaces of Common Scoter, including estimated total numbers within the study area, will be presented in a separate report for each of the four surveys conducted in 2007.

There was no sign that divers, previously concluded to avoid the area of the wind farm and its surroundings, had changed their distribution relative to the wind farm.

National Environmental Research Institute
Ministry of the Environment · Denmark

Final results of bird studies at the offshore wind farms at Nysted and Horns Rev, Denmark

NERI Report
Commissioned by DONG energy and Vattenfall A/S
2006

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Summary

This report presents data on monitoring investigations of birds carried out during 1999-2005 in relation to the construction of the world's first two large offshore wind farms at Horns Rev and Nysted in Denmark. We consider the hazards turbines posed to birds and the physical and ecological effects that these cause. We propose a series of hypotheses relating to these effects on birds at the two sites, testing to see if birds do indeed show reactions to the turbines once erected, relative to their "unaffected" behaviour we monitored during pre-construction baseline studies. In this way, the effects of the construction of the wind farms at sea could be predicted from our hypotheses and validated by post construction monitoring and data collection which was a condition of planning permission for the Danish projects. Throughout, we have restricted our studies primarily to waterbirds, because these are the species that exploit the offshore environment in general and the two study areas in particular, because Denmark has a special responsibility for the maintenance of their populations and the habitat that they use and because long lived birds with relatively low annual breeding success (which include many waterbirds) are those most susceptible to additional mortality. This does not mean that other species (such as many bird of prey and short-lived land birds that pass through the areas on migration) are not important, but their study was generally beyond the scope of these investigations.

In general terms, the potential effects of the construction of a wind farm on birds were considered to arise from three major processes:

1. A behavioural element caused by birds avoiding the vicinity of the turbines as a behavioural response to a visual (or other) stimulus. This can have two effects:
   - a barrier effect affecting bird movement patterns, potentially increasing costs
   - the displacement of birds from favoured distribution, equivalent to habitat loss
2. Physical changes due to construction (physical habitat loss, modification to bottom flora and fauna and creation of novel habitats, e.g. for resting on the static superstructure).
3. A direct demographic element resulting from physical collision with the superstructure (mortality).

We investigated each of these elements at both wind farms collecting data prior to and post construction as outlined under the following headings.

1a) At Horns Rev and Nysted, the barrier effect was studied by mapped bird migration routes combining radar techniques by day and night with specific species identification during daylight hours using telescopes. Radar tracks were entered to a GIS platform to compare the base-line with subsequent post-construction monitoring results. Emphasis was placed upon three key variables:

I. the orientation of migration routes for waterbirds and terrestrial species to measure potential avoidance responses and response distances,
II. the probability that waterbirds will pass through the wind farm area to measure waterbird responses to the entire wind farm,
III. migration intensity, measured by the number of bird flocks that pass into the wind farm area, to measure the effect of avoidance responses on the volume of migration within the wind farm area post construction.

Comparisons of these key variables between individual base-line years were undertaken by controlling for various factors such as weather conditions, season and time of day using multi-factor analysis of variance (ANOVA) and regression analyses.

Results showed birds generally avoided Horns Rev and Nysted wind farms, although responses were highly species specific. Some species (e.g. divers and Gannets) were almost never seen flying between turbines, others rarely (e.g. Common Scoter) whilst others showed little avoidance behaviour (e.g. Cormorants and gulls). Overall, at Horns Rev, 71-86% of all bird flocks heading for the wind farm at 1.5-2 km distance avoided entering into the wind farm between the turbine rows patterns confirmed at Nysted (78%), predominantly amongst waterbirds. There was considerable movement of birds along the periphery of both wind farms, as birds preferentially flew around rather than between the turbines. Such avoidance was calculated to add an additional period of flight equivalent to an extra 0.5-0.7% on normal migration costs of Eiders migrating through Nysted. Changes in flight direction tended to occur closer to the wind farm by night than day at both sites, but avoidance rates remained high in darkness, when it was also shown birds tend to fly higher. Few data on avoidance behaviours were available during conditions of poor visibility, because intense migration generally slows and ceases during such conditions.

1b) Comparison of pre- and post construction aerial surveys of waterbird abundance and distribution in and around the two Danish offshore wind farms generally showed that they avoided the turbines (at least during the three years following construction), although responses were highly species specific. Divers at Horns Rev showed complete avoidance of the wind farm area during the three years post construction period, despite being present in average densities prior to construction. Common Scoter were absent from Horns Rev pre-construction, but occurred in large numbers in the vicinity of the wind farm, but were almost never seen within the turbines despite up to 381,000 in the general area. Terns and auks also occurred in the area but were almost never seen within

the Horns Rev wind farm post erection. Long-tailed Ducks showed statistically significant reductions in density post construction in the Nysted wind farm (and in sectors 2 km outside) where they had shown higher than average densities prior to construction. This strongly suggests major displacement of this species from formerly favoured feeding areas, although the absolute numbers were relatively small and therefore of no significance to the population overall. No bird species demonstrated enhanced use of the waters within the two Danish offshore wind farms after the erection of turbines, but it was clear, for example amongst Cormorants at Nysted, that the wind farm area was used occasionally for social feeding by very large numbers of birds post construction. Although bird displacement (as a result of behavioural avoidance of wind farms) represents effective habitat loss, it is important to assess the relative loss in terms of the proportion of potential feeding habitat (and hence the proportion of birds) affected relative to the areas outside of the wind farm. For most of the species considered here, the proportion is relatively small and therefore likely of little biological consequence. However, the additional cost arising from the construction of many other such wind farms may constitute a more significant effect. Hence, consideration of such cumulative effects of many such developments along an avian flyway represents an important priority in the future.

2) Physical habitat loss and gain was considered trivial, since even accounting for the anti-scour structures, the extent of the change equated to less that 1% of the total area of marine substrate enclosed within the total wind farm. Their effects would therefore be small and difficult to distinguish from other distributional effects described by monitoring changes in bird densities, except for the arrival of new species (which was not observed during these two studies) attracted to novel habitats post construction.

3) The avoidance responses documented above mean that although turbine construction at sea has a major effect on the local (i.e. wind farm project level) distribution, abundance and flight patterns of birds, the corollary is that many fewer birds come within the risk zone of the rotor blade sweep zone. Radar study results demonstrated that birds may show avoidance responses up to 5 km from the turbines, and that >50% of birds heading for the wind farm avoid passing within it. Radar studies at Horns Rev and Nysted also confirm that many birds entering the wind farm reorientate to fly down between turbine rows, frequently equidistant between turbines, further minimising collision risk. The Nysted Thermal Animal Detection System (TADS a remote infra red video monitoring system) and radar studies confirmed that waterbirds (mostly Eider) reduced their flight altitude within the wind farm, flying more often below rotor height than they did outside the wind farm. A stochastic predictive collision model was developed to estimate the numbers of Eiders, the most common species in the area, likely to collide with the sweeping turbine blades each autumn at the Nysted wind farm. Using parameters (including those described above) derived from radar investigations and TADS, and 1,000 iterations of the model, it was predicted with 95% certainty that out of 235,000 passing birds, 0.018-0.020% would collide with all turbines in a single autumn (41-48 individuals), equivalent to less than 0.05% of the annual hunt in Denmark (currently c. 70,000 birds). With such a low level of probability of collision expected at any one turbine, it was predicted that the TADS monitoring system would fail to detect a single collision of a waterbird during more than 2,400 hours of monitoring that was undertaken at the site, and this proved to be the case. This level of monitoring resulted in a mere 11 bird detections well away from the sweep area of the turbine blades, 2 passing bats, two passing objects that were either small birds or bats, a moth and one collision of a small bird.

ENERGI E2 A/S

The Hard Bottom Communities on Foundations in Nysted Offshore Wind Farm and Schönheiders Pulle in 2005 and Development of the Communities in 2003-2005

Final Report
May 2006

af makroalger på stenbeskyttelsen. Desuden forventes forekomst af alger i mindre omfang også på sten i fundamentkamrene samt på mølleskafterne nær overfladen.

Abstract

Deployment of the foundations in Nysted Offshore Wind Farm started in October 2002. The seabed work, including placement of stones in and around the foundations, was finalised in June 2003. The first post-construction survey of the fouling community on shafts and stones was conducted in October 2003. Almost similar investigations were carried out in October 2004 and September 2005. Surveys of the stone reef Schönheiders Pulle were included in 2004 and 2005 with the aim to provide data on a natural hard bottom community close to the wind farm.

Common mussels (*Mytilus edulis*), barnacles (*Balanus improvisus*) and a few associated species of crustaceans (*Gammarus sp*., *Corophium insidiosum* and *Microdeutopus gryllotalpa*) have dominated the fouling community in 2003-2005. The rapid growth of mussels since 2003 resulting in competition for space has almost excluded other sedentary species of invertebrates and macroalgae. A monoculture of mussels has developed on shafts and stones in the foundation chambers in 2005. The biomass of mussels on the vertical shafts of concrete was comparable to the climax community developed on the monitoring mast deployed in 1996 and in the same order of magnitude as the biomass of mussels on bridge piers in Øresund. The biomass of mussels in the foundation chambers and Schönheiders Pulle was comparable. However, the biomass of mussels on the scour protection stones around the foundations was only one third of the biomass of mussels at Schönheiders Pulle. The recruitment success and growth of the mussels on scour protection stones has probably been hampered and delayed by smothering due to sediment spill and re-suspension of sediment due to heavy ship traffic in the construction phase and natural re-suspension of sediment.

The fouling community has been similar west, east, north and south of the foundations since 2003. However, the community on the shafts has changed with increasing depth in 2003-2005 and was also different on stones in the foundation chambers and the scour protection stones in 2005. The vertical zonation of the dominant species of mussels, barnacles and associated species of crustaceans is related to physical and biological factors, which affects input of larvae and food, the growth rate of mussels and space competition.

The diversity of the macroalgae community was low and dominated by red algae both at the turbines and Schönheiders Pulle. This is due to the low salinity in the area. The species richness and the biomass of macroalgae culminated on shafts and stones in the foundation chamber in 2003 and 2004, respectively. Macroalgae was mostly confined to the scour protection stones in 2005 due to the growth and progressive expansion of mussels resulting in space competition. The biomass of macroalgae on the scour protection stones and on stones at Schönheiders Pulle was comparable in 2005. Some of the dominant species of red algae are similar in both areas but some species characteristic for deeper water at Schönheiders Pulle are scarce or absent on the scour protection stones.

During the following few years the biomass of common mussels on scour protection stones will probably approach the biomass of common mussels at Schönheiders Pulle and the biomass of natural populations of mussels on the seabed.

The space competition between mussels and macroalgae on scour protection stones will increase but macroalgae and mussels are expected to coexist on the scour protection stones in the future. Minor populations of macroalgae are also expected on stones in the foundation chambers and on the shafts near the surface.

Final report on aerial monitoring of seals near Nysted Offshore Wind Farm

Technical report to Energi E2 A/S

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1 Summary

Introduction

This report describes the results of the aerial seal surveys of the seal population around Nysted Offshore Wind Farm from 2002-2005. This was done to investigate if seals tend to avoid the disturbance from the wind farm, and use alternative seal sites further away from the wind farm than before the construction. Rødsand seal sanctuary, lies 4 km away from the wind farm, and is therefore the closest land site for seals in the area. Rødsand and five other seal haulout sites in the area are believed to hold a closed harbour seal population with little exchange to other harbour seal populations (management area 4).

Method

Monthly aerial counts of harbour and grey seals were conducted from March 2002 to October 2005. Furthermore, aerial surveys from late August from 1990-2000 are included as part of the baseline data. The aerial surveys provide information on the seasonal and inter-annual use of the different seal haulout sites.

Population increase from 2002 to 2005

The seal epidemic in 2002 killed about 20% of the harbour seals in management area 4, but in August 2003 the number of harbour seals had almost recovered completely. During 2003-2005 the population increased by almost 17%.

Importance of Rødsand during the construction and operation periods

During the construction of the wind farm the relative importance of Rødsand seal sanctuary decreased slightly, but not significantly compared to the other five most important seal localities in the south-western Baltic Sea area (Vitten, Avnø, Bøgestrømmen, Saltholm, Falsterbo). During the operation of the wind farm in 2004 and 2005 the proportion of seals (harbour and grey seals combined) at Rødsand increased to 34 and 33% of seals from the entire management area 4, respectively, and thereby again became the most important seal site in south-western Baltic.

The seasonal proportion of seals at Rødsand

Except for an increasing importance of Rødsand during operation in May and June 2004-2005, no general shift in proportion of seals (harbour and grey seals combined) at Rødsand relative to the other localities was seen. Whether the increasing proportion of seals during operation in May and June 2004-2005 could be due to a positive effect from the wind farm is unknown. The significant seasonal variation between Rødsand and Vitten suggests that some seals move from Rødsand to Vitten in June and July, to return afterwards to Rødsand in August and September. Rødsand remains less important to the harbour seals during October-March.

Effect of the construction and operation periods

There are no indications that the construction activities from late June 2002 to December 2003 and the first two years of operation of the wind farm in 2004-2005 affected the local Rødsand harbour and grey seal populations differently from the other populations in the western Baltic Sea. The Rødsand seal population has increased substantially in size in 2004 and 2005. Whether there are any positive effects from the wind farm, e.g. by creating an artificial reef that attracts more fishes, and hence more seals remains to be investigated.