REPORT 166717

10 April 2003

Phone: +45 79 23 33 33
Fax: +45 75 56 44 77

Our ref.: JKG/HHA/aia
Report no.: 03-166717
Project no.: 11476.01

Verified: Approved:

Elsam. Offshore Wind Farm. Horns Rev
Annual Status Report for the Environmental Monitoring Programme
1 January 2002 – 31 December 2002

Tech-wise A/S is an international consulting engineering company specialised in energy and environment

Tech-wise A/S
Kraftværksvej 53
DK-7000 Fredericia

Table of contents:

1. Construction of the Wind Farm

The entire construction of the wind farm took place during 2002 except for the driving of a few piles for the transformer platform in late 2001.

In order to give an understanding of the activities during the construction process this section briefly describes and illustrates the various phases of the work.

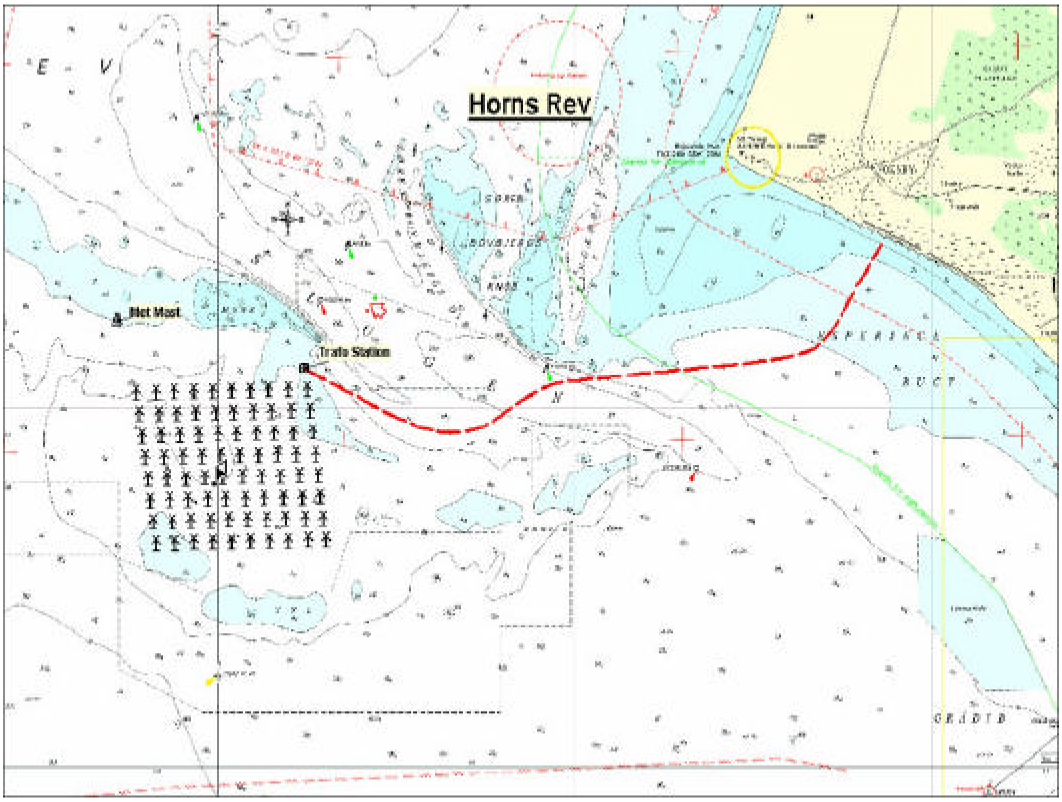


Figure 1 The wind farm is located west-south-west of Blåvands Huk, the nearest wind turbine being 14 km from shore.

Construction at the site started in September 2001 with the driving of a few piles for the transformer station. Work was stopped during the winter and recommenced at the beginning of March 2002. It lasted until the last cable was buried in mid-September 2002.

During construction 15 – 20 different vessels navigated the site daily.

Installation of foundations, including scour protection, lasted from 12 March 2002 until 9 August 2002 with pile driving from 2 April 2002 until 1 August 2002. Installation of turbines started on 7 May 2002 and the last turbine was installed 21 August 2002. Cables were laid and buried from 19 May 2002 until 13 September 2002.

Figure 2 The complete transformer station was lifted onto its 3 supporting piles on 16 April 2002.

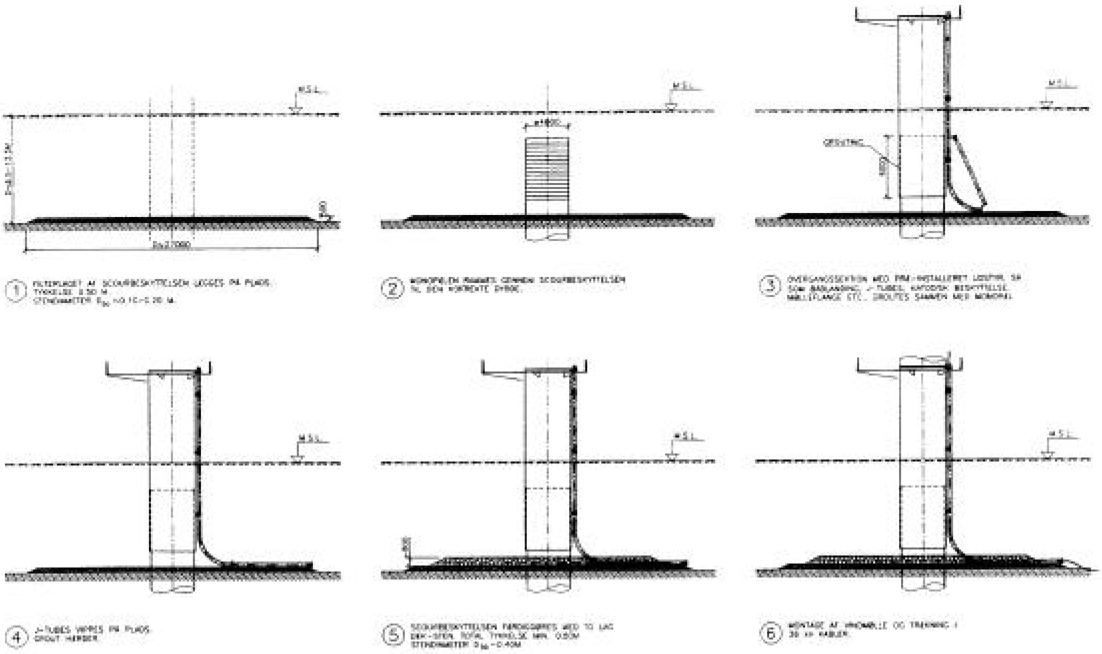


Figure 3 Construction of the monopile foundations consisted of laying of filter stones, pile driving, installation and grouting of transition piece, laying of scour protection and cable connection.

Figure 4 Dumping of filter stones. The stones are 30 – 200 mm with an average (d50) of 100 mm.

Figure 5 Driving of monopiles took place from a jack-up rig


Figure 6 The piles were driven into the sea bed using a 500 t hydraulic hammer. The operation took about 1 hour. Acoustic scaring devices for porpoises and seals were deployed from 1½ hours before start of driving until the end of driving.

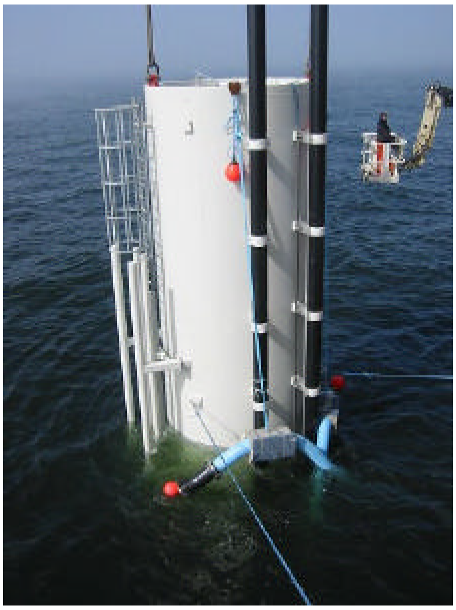



Figure 7 A transition piece was lowered over the pile and secured in place by injecting mortar into the annulus between pile and transition piece.

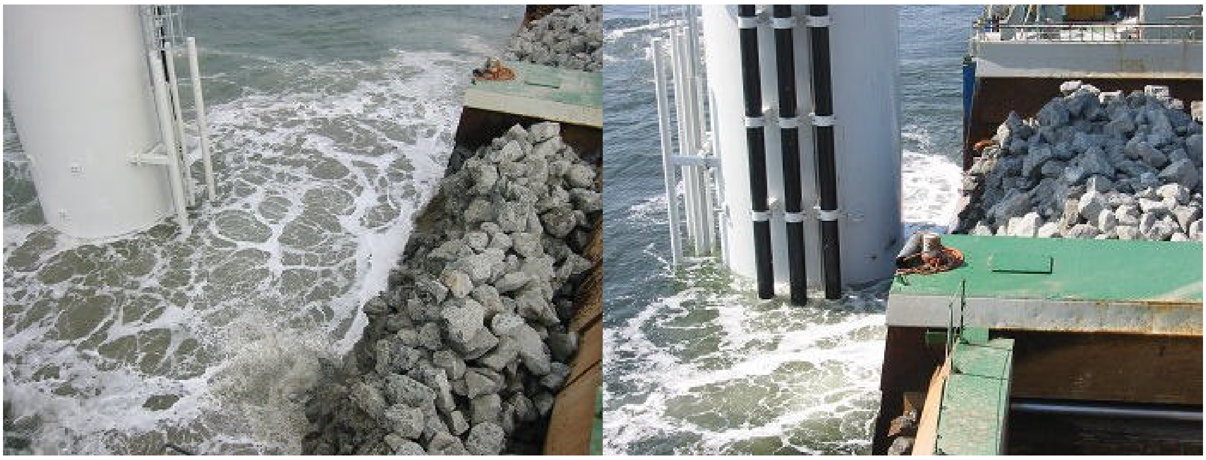


Figure 8 The scour protection was dumped around the foundation. Scour protection are stones ranging from 350 – 550 mm with an average (d50) of 400 mm.

Figure 9 Final installation of platform and J-tubes for cables took place while turbines were pre-assembled and loaded in Esbjerg.

Figure 10 Turbines were transported to the site and erected by 2 purpose-built ships.

Figure 11 Each ship carried 2 complete turbines per trip.

Figure 12 Cables were floated out, connected and finally buried at a minimum depth of 1 m below sea bed by water jetting.

Figure 13 Seen from above it is clear that the turbines do not cram the ocean.

2. Monitoring Programmes 2002

The monitoring programmes are proposed by the Environment Committee of the Danish Offshore Wind Farm Demonstration Projects and carried out after final approval by the Danish Energy Agency.

For the wind farms at Nysted and Horns Rev respectively, the monitoring is concerned with birds, marine mammals (seals and harbour porpoises), fish, bottom flora and fauna, hydrography and geomorphology, magnetic and electric fields from cables, noise and vibrations and some theme projects concerning hard substrate habitat and visual and socio-economic effects.

To secure as many results as possible seen from an environmental point of view it has been decided to try to focus on different issues at the two wind farm areas. At Horns Rev it has been decided to focus on harbour porpoises, birds and the two theme projects concerning the effect of introducing hard substrate habitat and the visual and socio-economic effect.

A baseline situation for seals has been conducted and an effect survey on the short term effect of the construction phase has been performed. The results of these studies will be presented in the status report and in section 2.3 of this report.

Harbour porpoises have been monitored before and during the construction of the farm to be able to determine if the porpoises will be affected by the construction phase. For more details about the results of the monitoring in 2002 please see section 2.4 and the status report.

At Horns Rev the main focus on birds will be on the disturbance effect caused by the presence of the wind turbines. The assessment of the collision risk will only commence after construction of the farm in 2003, and is not described further here. For more information about the monitoring programme and the results please see section 2.2 and the status report.

The theme project concerning survey of the effect of the introduction of hard substrate habitat includes fouling on the foundations and adjacent scour protection and the effect on the fish. A base-line survey has been made for both fish (finalised 2002) and bottom flora and fauna (finalised 2001). In 2003 a sampling programme on foundations and scour protection will be initiated to follow a new epifauna on the foundations including scour protection. The results from this survey will be used to evaluate the basic fouling, which will be used to evaluate the need for further investigations of fish.

The last mentioned theme project, visual and socio-economic effect, has been set up during 2002 and is expected to begin in 2003.

The monitoring programme concerns the entire wind farm including turbines and cables.

2.1 Hard bottom substrate

The conclusion of the environmental impact assessment is that the introduction of a hard bottom substrate in the form of foundations and adjacent scour protection has a potential to function as an artificial reef, giving the possibility of a richer fauna. The main effect of the artificial reef is expected to be the attraction of fish. After the construction of the park, it will be investigated whether fouling will take place on the foundations.

Concerning fish the main conclusion of the environmental impact assessment is that the fish populations vary greatly from one year to the next. Based on this it was assessed to be inappropriate to monitor the fish population in general. But it was decided to follow the fish populations regarding the introduction of hard substrate habitat (foundations) in the area.

In 2001 a monitoring programme was launched. A baseline survey was carried out in 2001 and 2002. The objectives of the monitoring programme are:

1. To survey fish attraction relative to single foundations and to the wind farm
2. To survey the potential fish production enhancement of single foundations and of the wind farm

No annual status report was received from DIFRES.

2.1.1 Description of the Programme

Objective

In 2002 the baseline survey for the artificial reef effect on fish should be finalised.

The survey was conduced in the same way as the first part in 2001.

Methods

The artificial reef impact on fish attraction and potential production from each wind turbine foundation, as well as the entire wind farm will be examined by surveying the fish assemblages prior to and after construction of the wind turbines, from transects from individual wind turbines placed in different positions in the wind farm. The BACI (before/after/control/impact) model was implemented involving fishing surveys in the wind farm area and in the reference area before and after the construction. Multi-meshed gillnets developed by the Danish Institute for Fisheries Research (KFG-12) are used as described below. Univariate and multivariate analyses will be conducted on the catch results to test the various hypotheses.

Reference area

In co-operation with the local fishing organisations, the boundaries of the reference area were chosen. The criteria for the choice of reference area were that it should be:

- At a sufficient distance as not to be impacted by the wind farm
- Same depth as in the wind farm area, or within the range
- Similar fish assemblages as in the wind farm (from historical information from the fisheries organisations on the fishing patterns and type of fish or mussels fished in the two areas)

The position of the reference area is as follows in WGS-84 coordinate system:

55º31’0 N 07º43’0 E,
55º32’0 N 07º43’0 E,
55º31’0 N 07º44’0 E,
55º32’0 N 07º44’0 E.

The gillnets

The multi-mesh gillnets called KFG are developed by DIFRES and consist of 12 gillnets of different mesh size ranging from 6.6 to 117 mm knot to knot (KFG-12). This gillnet was developed for catching all sizes and types of marine fish in a coastal environment. Mesh sizes and thread diameters are shown in Table 1 The knot to knot mesh sizes and thread diameters of the different mesh sizes constituting KFG-12 research gillnets..

Mesh no.	Mesh size (mm)	Thread diameter (mm)
1	6.5	0.09
2	8.5	0.09
3	11.0	0.09
4	14.3	0.12
5	18.6	0.14
6	24.2	0.15
7	31.4	0.17
8	40.9	0.20
9	53.1	0.24
10	69.0	0.28
11	89.8	0.34
12	116.7	0.40

Table 1 The knot to knot mesh sizes and thread diameters of the different mesh sizes constituting KFG-12 research gillnets.

Each mesh panel is 6 m long, mounted on a buoyancy line and lead line, with a hanging ratio of 0.3 (the hanging ratio defines how tightly or loosely the net is bound and is important for determining the gillnet's efficiency for catching roundfish or flatfish). See

Figure 14The preliminary survey HR01-1 was conducted in August in the general area of Horns Rev at six fishing stations each with one KFG-12 gillnet consisting of 12 mesh panels. for a sketch of the gillnet. The mesh panels are randomly distributed in each KFG-12 with around 0.5 m space in between. The net is around 1.5 m in height. From the catches in the preliminary survey it was apparent that all mesh sizes should be maintained. Thus, each KFG-12 is around 80 m in total length.

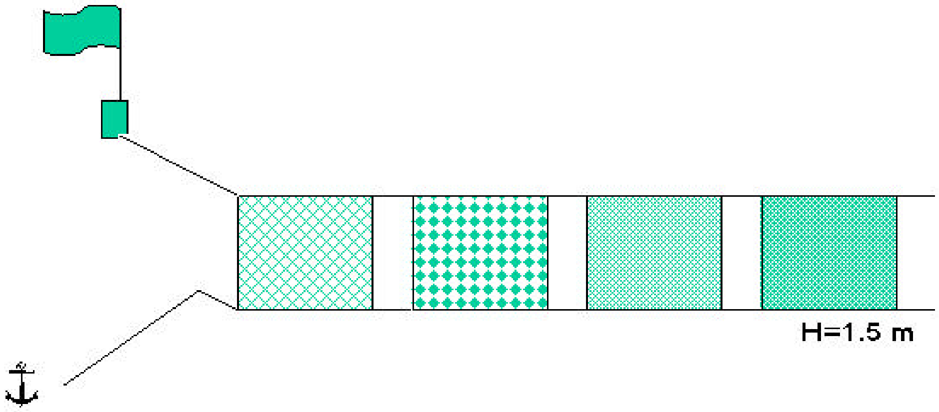


Figure 14The preliminary survey HR01-1 was conducted in August in the general area of Horns Rev at six fishing stations each with one KFG-12 gillnet consisting of 12 mesh panels.

Survey

The second - and last - baseline survey was conducted in March. Twenty-four replicate sampling were conducted at each station (3 in the reference site and 3 at positions for 3 wind turbine positions). Wind turbine numbers 55, 58 and 95 were chosen, placed centrally, at the south-edge and at the east-edge of the intended wind farm rectangle. The catch data were computed in a database at DIFRES and quality checked at the level of individual recordings.

2.1.2 Results of monitoring

The first baseline survey (September 2001)

During the first survey (September 2001) a total of 21 species were caught. The dominant species was whiting, but flatfish like dab, plaice and sole were also caught in some quantity. Multivariate analysis of the catch data from the wind farm area and reference area showed no differences between these two areas.

The second baseline survey (March 2002)

During the second survey (March 2002) a total of 22 species were caught. The dominant species was sand eel, but flatfish such as dab, sole and plaice were also caught in some quantity. Multivariate analysis of the catch data from the wind farm area and reference area showed differences between seasons but no differences between these two areas. DIFRES did not have time to report the results form 2002 yet, so these results will be available later.

2.1.3 Deviations from the programme

The programme in 2002 followed the same programme as in 2001 without change.

2.1.4 Conclusions

The baseline survey has now been completed with one survey in September 2001 and one in March 2002, just before the construction of the wind farm was initiated.

Univariate and multivariate analysis of the catch data from the wind farm area and the reference area show no differences between wind farm area and reference area.

2.2 Birds

In the EIA it was concluded that there are high concentrations of resting and migrating birds in the area around Horns Rev and especially around Blåvands Huk. But to what extent these birds will be affected by the wind farm is not clear, and therefore the monitoring programme for birds is set up.

A baseline survey has been conducted from 1999 to 2001 and in 2002 surveys to detect the impacts during construction have been carried out.

This part of the report presents the results of the bird counts up to now and the analyses of the effect of the construction of the wind farm.

The results are presented in the annual status report from National Environmental Research Institute "Baseline investigations of birds in relation to an offshore wind farm at Horns Rev, and results from the year of construction"[1]

2.2.1 Description of the programme

Objective

The objectives of the counts in 2002 were to obtain data for the construction period, compare to the baseline and determine whether there was any impact from the construction.

The main purposes of the counts were:

1. to map the numbers and distributions of birds in the area throughout the year
2. to assess the relative densities and numbers of different species present

For a more detailed description of the scope for the bird studies and the methods used see the report "Effects on birds of an offshore wind farm at Horns Rev" [2].

2.2.2 Method

Aerial surveys

Mapping of bird distributions followed the method applied during the 1999-2001 surveys. Data on bird numbers and distribution were obtained from a total of three aerial surveys during January 2002 to April 2002. The survey area, approximately 1.700 km^2, comprises the wind farm area and the surrounding area in zones around the wind farm

---

1 Base-Line investigations of birds in relation to an offshore wind farm at Horns Rev, and results from the year of construction. NERI report 2003

2 Effects on birds of an offshore wind farm at Horns Rev: Environmental impact assessment. NERI report 2000.

area of +2 km and +4 km, which are used as reference areas. See Figure 15 for the survey area, the +2 km and +4 km zones and survey transect lines.

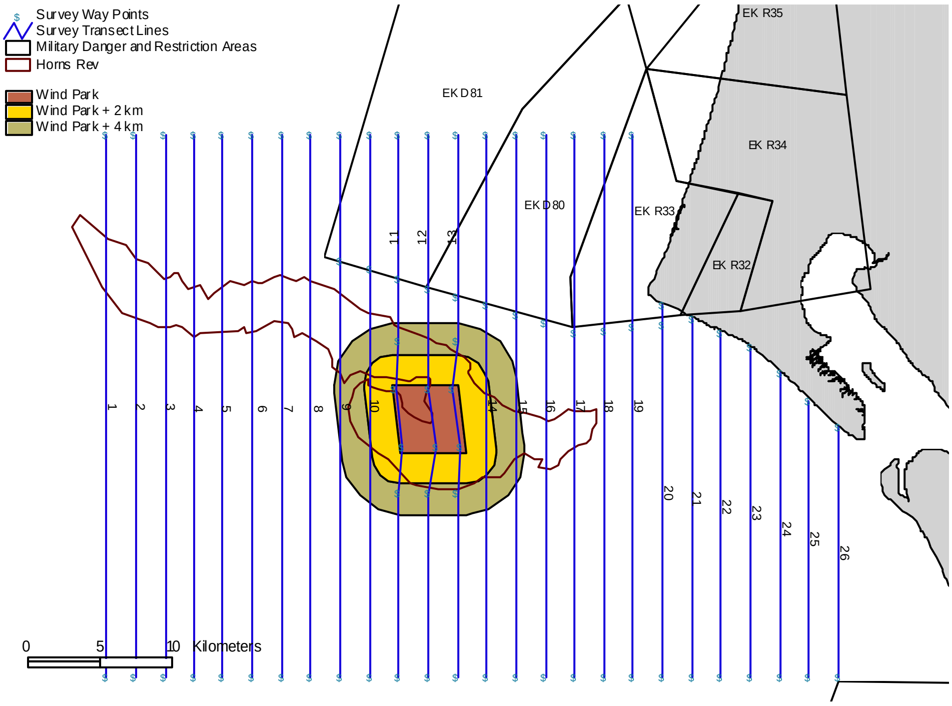


Figure 15 The survey area including the ideal survey transects (thin lines north-south) for aerial surveys. The red line is the 10 m contour of Horns Rev. The squares north of the park are the military danger and restriction areas.

The surveys were conducted from a high wing, twin-engine Partenavia P-68 Observer, designed for general reconnaissance purposes, flying at an altitude of 76 m (250 feet) and with a cruising speed of approximately 185 km/t (100 knots).

The majority of observations were considered to be accurate within four seconds. With a flight speed of 185 km/h the positional accuracy on the longitudinal axis was within 206 m. In few situations with high bird densities, grouping of observations in periods of up to 10 seconds have occurred, leading to an accuracy of observation positioning of up to 515 m.

As the survey results are highly sensible to weather conditions, surveys were not carried out when wind speed exceeded 6 m/s, because detectability of birds on the sea surface was severely reduced. Low visibility or glare also reduced detectability. In cases of severe glare, observations from one side of the aircraft were temporarily discontinued. Military activity prevented full coverage of the north-eastern part of the survey area in some surveys.

In 2002 surveys took place on 7 January, 12 March and 9 April.

During the January survey there were no activities at the reef and only the basic frame of the transformer station and associated scaffolds were present in the area.

On 12 March 2002, one ship was making surveys of the seabed for deposition of erosion cover.

On 9 April 2002 one jack-up and one associated vessel were engaged at the transformer station, while three vessels were engaged in seabed surveys/deposition of erosion cover, mounting of basic turbine foundations and deposition of scour protection at no less than eight turbines. On 9 April the poles and basic turbine foundations were in place for a total of six turbines.

During 9 April some boat traffic between shore and transformer station may have occurred at various times, but at unknown frequency. Likewise, some traffic of vessels within and close to the wind farm area has taken place, as three boats frequented eight turbines during that date.

2.2.3 Data analysis

After transcription of observation data and flight track data into tables, a combination of ArcView GIS and TurboPascal software was used to add a position to each bird observation and to assign observations to transect band and side of flight track.

For each survey distribution maps were produced for each of the relevant bird species showing the locations and sizes of the observed flocks. Total bird numbers in each survey were obtained from simple addition of all observations. In comparison between different surveys, bird numbers were corrected for total transect length covered.

To assess the numbers of birds of the different species, that would be susceptible to potential disturbance effects from the wind farm, and to assess the importance of wind farm area and the adjacent waters, bird preference for the wind farm area and different adjacent zones of potential impact relative to their preference for the whole survey area is described. For these zones the preference of the most numerously occurring species was calculated using Jacobs selectivity index.

Jacobs selectivity index (D) varies between –1 (all birds present outside the area of interest) and +1 (all birds inside the area of interest), and is calculated as:

$$D = \frac{(r - p)}{(r + p - 2rp)}$$

with r = the proportion of birds in the area of interest compared to the birds in the entire survey area, and p = the proportion of the transect length in the area of interest compared to the total transect length in the entire survey area. The difference between the two proportions is tested as the difference between the observed number of birds in the area of interest and the number expected in this area, estimated from the share of the length of transect in relation to transect length in the total area (one-sample ?^{2}-test). Since construction activities were ongoing during the last survey year (September 2001-April 2002), the analyses were made exclusively for data recorded during August 1999-August 2001 when no disturbance in the Horns Rev area associated with the wind farm took place, and for data exclusively collected during the period of construction (September 2001-April 2002).

As the period of construction did not include an August survey it was not possible to assess disturbance effects for species, which have peak occurrence at this time of the season. These species include Gannet *Sula bassanus*, Arctic/Common Tern *Sterna pardisaea/hirundo*, Sandwich Tern *Sterna sandvicensis*, Common Gull *Larus canus* and Black-headed Gull *Larus ridibundus*.

To assess the minimum detectable change in bird numbers within and close to the wind farm area, an ?^{2} two-sample test was applied to the numbers recorded within the wind farm area, and within the wind farm and +2 and +4 km zones during the baseline years compared against varying reductions and increases. Similarly ?^{2} two–sample tests were used to elucidate potential disturbance effects during the period of construction compared to the baseline. In case bird numbers were too small to allow ?^{2}-tests, Fisher's exact test was applied. In all ?^{2}-tests a Yates correction was used to make a continuity adjustment.

The non-parametric Kruskal-Wallis tests were used to test for differences in the annual number of birds recorded per transect kilometre between the three survey years.

Some closely related species occurring within the survey area are very similar in plumage and difficult to identify during the aerial surveys. These include:

- Red- and Black-throated Diver
- Arctic, Pomarine and Long-tailed Skua
- Arctic and Common Tern
- Guillemot and Razorbill

It is supposed that the species within these groups are impacted to the same degree and therefore lumped into groups in the following analyses.

2.2.4 Results of Monitoring 2002

The number of birds recorded in the surveys conducted from 1999 to 2002 are shown below. The first two years cover the baseline and the last year covers the construction phase.

Species	Period		Total	WF	WF +2km	WF +4km
Divers	Baseline	1999/00	773	11	32	48
	Baseline	2000/01	504	10	32	45
	Construction	2001/02	322	1	2	12
Gannet	Baseline	1999/00	306	0	6	40
	Baseline	2000/01	136	0	1	5
	Construction	2001/02	12	0	0	0
Arctic/Common Tern	Baseline	1999/00	1,343	9	33	94
	Baseline	2000/01	217	0	3	7
	Construction	2001/02	5	0	0	0
Sandwich Tern	Baseline	1999/00	73	0	5	6
	Baseline	2000/01	298	0	2	2
	Construction	2001/02	54	0	0	1
Alcids	Baseline	1999/00	608	3	15	53
	Baseline	2000/01	334	7	11	33
	Construction	2001/02	207	0	0	0
Eider	Baseline	1999/00	3,331	1	1	1
	Baseline	2000/01	8,441	0	0	0
	Construction	2001/02	1,349	0	0	0
Common Scoter	Baseline	1999/00	41,158	4	9	55
	Baseline	2000/01	52,165	513	3,089	10,369
	Construction	2001/02	49,823	378	1,629	2,546
Common Gull	Baseline	1999/00	191	1	2	10
	Baseline	2000/01	70	1	1	6
	Construction	2001/02	21	1	1	1
Black-headed Gull	Baseline	1999/00	37	0	1	1
	Baseline	2000/01	421	0	0	0
	Construction	2001/02	15	0	0	0
Herring Gull	Baseline	1999/00	10,509	2	38	136
	Baseline	2000/01	4,905	4	11	80
	Construction	2001/02	4,131	23	254	625
Great Black-backed Gull	Baseline	1999/00	229	0	1	9
	Baseline	2000/01	145	0	2	3
	Construction	2001/02	108	0	3	11
Kittiwake	Baseline	1999/00	1,161	11	35	83
	Baseline	2000/01	783	5	27	66
	Construction	2001/02	700	3	4	16
Little Gull	Baseline	1999/00	13	0	0	1
	Baseline	2000/01	37	0	1	2
	Construction	2001/02	286	0	3	11

Table 2 The total number of birds recorded within the total survey area and within the wind farm (WF), in the wind farm area +2 km zone (WF +2 km) and in the wind farm + 4 km zone (WF +4 km) during the base-line years and during the period of construction. Birds recorded during August 2001 are not included.

2.2.5 Effects of the construction activities

The preference analyses of birds in the wind farm area and adjacent +2 and +4 km during the period of construction are shown in Table 2. Including data from September 2001-April 2002, the analyses did not include Gannet, Arctic/Common Tern, Sandwich Tern, Common Gull and Black-headed Gull, all of which all have peak occurrence in August. However, for the remaining species, the analyses showed that the birds occurred in lower than expected numbers in the wind farm area. Considering the wind farm area +2 and +4 km zones, most species occurred in lower numbers than expected except for Herring Gull which occurred in significantly higher numbers than expected, and Great Black-backed Gull, which occurred in expected numbers.

	WF			WF +2 km			WF +4 km			Total
	%	**D**	**p**	**%**	**D**	**p**	**%**	**D**	**p**	
Divers	0.31	-0.66	-	0.62	-0.78	***	3.73	-0.46	***	322
Alcids	0.00	-1.00	-	0.00	-1.00	**	0.00	-1.00	***	207
Common scoter	0.76	-0.33	***	3.27	-0.21	***	5.11	-0.33	***	49.823
Eider	0.00	-1.00	***	0.00	-1.00	***	0.00	-1.00	-	1.349
Herring gull	0.56	-0.47	***	6.15	0.12	***	15.13	0.25	***	4.131
Great Black -backed gull	0.00	-1.00	-	2.78	-0.29	ns	10.19	0.03	ns	108
Kittiwake	0.43	-0.56	*	0.57	-0.80	***	2.29	-0.64	***	700
Little gull	0.00	-1.00	-	1.05	-0.66	**	3.85	-0.45	**	286
Size of the area to the total area (% of transect km)										
	1.51			4.89			9.57			

Table 3 The percentage of the total number of individuals recorded during the construction period (September 2001-April 2002) in the wind farm area (WF), in the wind farm area and an adjacent 2 km zone (WF +2), and in the wind farm area and an adjacent adjacent4 km zone (WF +2), and in the wind farm area and an adjacent 4 km zone (WF +4). The size of each zone expressed as a percentage of transect kilometres counted within each area as a proportion of the total number of transect kilometres counted within the total survey area is shown.

To evaluate a potential disturbance or attraction effect related to construction activities, an ?^{2}-two sample test was applied to the number of birds recorded during each baseline year on numbers recorded during the construction period in the wind farm area and in the wind farm +2 and +4 km zones respectively (Table 3). The results of the ?^{2} analyses are shown in Table 4.

Species	Years compared	Numbers in last year	WF		WF +2		WF +4	
			?^{2}	P	?^{2}	P	?^{2}	P
Divers	99 vs. 01	low	F	ns	8.30	**	2.31	ns
	00 vs. 01	low	F	ns	15.03	***	7.60	**
Alcids	99 vs. 01	low	F	ns	F	*	20.26	***
	00 vs. 01	low	F	*	F	**	21.78	***
Common Scoter	99 vs. 01	high	298.63	***	1.381.74	***	1995.33	***
	00 vs. 01	low	15.34	***	376.98	***	5073.17	***
Herring Gull	99 vs. 01	high	44.90	***	418.68	***	1.006.25	***
	00 vs. 01	high	14.54	***	228.83	***	489.10	***
Great Black-backed Gull	99 vs. 01	high	-	-	F	*	2.320	ns
	00 vs. 01	high	-	-	F	Ns	4.383	*
Kittiwake	99 vs. 01	low	1.90	ns	12.75	***	16.74	***
	00 vs. 01	low	F	ns	14.99	***	22.89	***

*Table 4 Results of frequency analyses (two-sample ?2, df=1 in all comparisons) of the numbers recorded within and outside the wind farm area, the wind farm area + 2km and the wind farm area +4 km during the base-line years (99=1999/2000 and 00=2000/2001 as well as during the year of construction activities (01=2001/2002). In cases of more than 25% of the cells have expected values less than 5, Fisher's Exact test (F) was applied. Whether higher or lower numbers are recorded during the year of construction compared to the base-line year is indicated for each comparison as either low or high (ns = non-significant, * = P<0.05, ** = P< 0.01, *** = P<0.001)*

Assessed from the ?^{2} analyses, the number of **Divers** in the wind farm area was not significantly lower during the period of construction than during baseline seasons, whereas a significant decline was found in the wind farm area +2 km zone during construction (Table 4). The number of **Alcids** was significantly lower during the year of construction, except in comparison with one baseline year in the wind farm area (Table 4). The number of **Common Scoters** differed significantly to the base-line numbers in all comparisons. Compared to the one baseline year an attraction was found and compared to the other year an avoidance was detected (Table 4). **Herring Gulls** showed a significant increase to the baseline years (Table 4). The number of **Great Black-backed Gulls** only showed an inconsistent significant attraction in the wind farm area + 2 and +4 km (Table 4), hence the construction activities were not found to have affected the distribution of Great Black-backed Gull.

In the wind farm area, numbers of **Kittiwakes** did not deviate significantly from numbers recorded during the baseline years (Table 4). In the wind farm area +2 km and in the wind farm area +4 km a significantly lower number was recorded during construction.

The overall numbers of all bird species recorded in the total survey area during the period of construction did not deviate from the numbers recorded during the baseline years. Even though some species recorded within the wind farm area and the wind farm area +2 km and +4 km zones showed changes in their exploitation of these areas during the period of construction, statistical analyses did not find any consistent significant reductions in bird numbers, which would indicate a disturbance effect from the construction activities. An increase in the number of Herring Gulls was, however, consistently significant compared to the baseline results, which strongly suggested that Herring Gulls were attracted by the construction activities.

In general, the low and variable number of birds consistently recorded within the wind farm and adjacent +2 and +4 km zones makes assessments of potential disturbance effects very tentative as accidental occurrence of even a few individual birds may change the test results. Likewise, the varying levels and extent of actual construction activities on the different survey dates does not constitute a uniform source of disturbance to which data can be compared, and to which different species may react differently and even possess seasonal variation in sensitivity. Furthermore, assessments of disturbance effects were restricted for several species, as data during the period of construction was not obtained in the period of peak occurrence of these species.

In conclusion, the present analyses only found statistical evidence for an attraction effect on Herring Gulls to construction activities at Horns Rev. For species showing a decrease in numbers in the area within and close to the wind farm area, no consistent change in the occurrence of birds could be documented that would indicate a disturbance effect related to construction activities.

Effectively, a disturbance effect from the operating wind farm should for all species, except the Common Scoter, result in a complete abandonment of the wind farm area before any conclusive assessments concerning disturbance effects can be made. However, to safeguard interpretations of disturbance effects even in the case of a complete abandonment of the wind farm area, a significant disturbance effect should preferably also be detected at least in the wind farm +2 km zone in order to elude the high probability of recording no birds in the wind farm area. An attraction effect to the wind farm, on the other hand, seems for most species to be readily detectable, as such an effect is dependent on a relatively low increase in the number of most species.

Considering that disturbance effects from the operating wind farm results in a complete abandonment of the wind farm area, and birds even abandon the wind farm by up to 2 km, the number of birds affected will be so low that it probably has no biological relevance to these species. Of species recorded within and close to the wind farm (Divers, Terns, Alcids and Common Scoter) the numbers that potentially would be affected are inferior compared to the total populations or flyway populations of the species comprising thousands, or tens of thousands, of birds in this part of Danish waters. Likewise, the habitat loss associated with a complete abandonment of the wind farm corresponds to an area of approx 20 km^2 that was previously of no major importance to bird species occurring in the Horns Rev area. Consequently, even if the ongoing programme will be able to detect significant disturbance effects from the operating wind farm, the small number of birds and low importance of the wind farm area suggests that such potential effects will be of no biological or ecological significance to bird species occurring in the area.

2.2.6 Conclusions

Effects of construction activities

Compared to the occurrence of birds during the base-line, slight differences in bird exploitation of the wind farm area and wind farm +2 km and +4 km zones were found during the construction phase. However, the analyses showed that the bird numbers within and close to the wind farm area were not consistently and significantly reduced during this period. Assessed from the actual numbers observed in the wind farm area and the wind farm +2 and +4 km zones, Divers and Alcids occurred in significantly lower numbers at a distance of more than 2.5 km to actual construction activities suggesting that these species may have avoided these activities.

The Herring Gull showed a significant attraction to the wind farm area and to the wind farm +2 and +4 km zones during the construction phase. This species generally aggregates around ships in the offshore habitat and may have been attracted both by ship activities and/or by the possibility of resting on turbine foundations erected in the wind farm area.

Within-year and between-year variation in bird numbers at Horns Rev

The distribution of birds in the survey area showed distinctive differences. Fish-eating species (divers, alcids and gulls) generally showed a variable and widespread occurrence in the offshore part of the survey area. Species foraging on sessile benthic prey (Eider and Common Scoter) showed much more constant and restricted distributions associated with the coastal zone with shallow water.

Several species showed a consistent seasonal pattern in their distribution in the survey area. Most strikingly was the aggregation of Common Scoter at the south-eastern slope of the Horns Rev during the spring, resulting in the relatively high number recorded especially at a distance of between 2 and 4 km from the wind farm. The reason for the exploitation of this area by the Common Scoter is unknown.

General disturbance effect

The planned wind farm area, representing approx 1.2% of the survey area, was of no particular importance to bird species recorded in the Horns Rev area. Bird numbers were generally very small in the wind farm area and in the adjacent 2 km and 4 km zones.

Consequently, a disturbance effect from the operating wind farm on bird exploitation of the area within and close to the wind farm is expected to be limited. If the birds totally avoid exploiting the wind farm area due to disturbance, less than 1% of the different species in the survey area will be affected, except for Divers (1.64%), Arctic/Common Tern (1.35%) and Alcids (1.06%). If the birds should totally avoid the wind farm and the adjacent 4 km zone this will affect approx 11% of the Common Scoter, approx 10%

of the Gannet, 6-9% of the Divers, Arctic/Common Tern, Alcids, Skuas, Common Gull, Kittiwake and Little Gull, while the corresponding proportions of the remaining species in the survey area will range between 1-4%. Compared to the size of the total populations or flyway populations of the species known to occur in the Horns Rev area, the number of birds that may be affected constitute an inferior proportion, implying that the habitat loss is of no biological relevance.

Based on the low and variable numbers of birds recorded within and close to the wind farm during the base-line survey, the power to detect changes in bird numbers was somewhat tentative. The probability of detecting a disturbance effect from the operating wind farm would effectively need a complete abandonment of the wind farm area, but even in that case the low number of birds makes any assessment of disturbance effects very provisional for this area. Considering the wind farm area +2 km and +4 km zones, the analyses proved more reliable due to a higher number of birds included. In these areas a reduction in the number of birds of between 25-50% would in general be detectable with statistical confidence.

2.3 Seals

The harbour seals in the Danish Wadden Sea are considered part of a common population in the International Wadden Sea, stretching from Den Helder in the Netherlands to Blåvands Huk. Remote and inaccessible sand banks in the Wadden Sea are used for haul out and breeding and these are the only areas along the coast of Jutland where the animals can haul out undisturbed.

Harbour seals are generally considered to move very little between haul out banks and exchange between populations in the three Wadden Sea countries is thus also considered to be limited.

According to EU Habitat Directive, seals are protected and the Wadden Sea population further under seal agreement according to the Bonn Convention. It should be determined whether the animals will be disturbed and/or driven out by the construction and operation of the wind farm.

The results are presented in the annual status report from Fisheries and Maritime Museum, Esbjerg; “Satellite tracking of Harbour Seals on Horns Rev, March 2003”.

2.3.1 Description of the programme

It was decided to provide 10 seals with transmitters during the construction period. The transmitter, a satellite-linked system was chosen as the most appropriate. Data loggers were not considered, as retrieving would be very difficult and commercially available systems do not allow for accurate tracking of the position of the animals. As the National Environmental Research Institute have previously equipped harbour seals at Rødsand with Wildlife Computers SDR-T16 tags, it was decided to use this type for the present survey. As GPS/GSM transmitters are still on an experimental basis they were not considered for the present survey.

A total of 10 harbour seals were caught and equipped with satellite transmitters on three separate occasions.

Date	Location	Animals caught	Animals tagged
2002-01-04	Bollert	4	4
2002-02-18	Bollert	17	3
2002-05-06	Koresand	15	3

Table 5 Dates and locations of tagging.

The two first batches were caught, tagged and released on a haul out site on the northern tip of the island Rømø. As no animals were hauled out on Bollert on the last occasion, the animals were caught on a site on the northern side of Juvre Dyb (Koresand) (Figure 16).

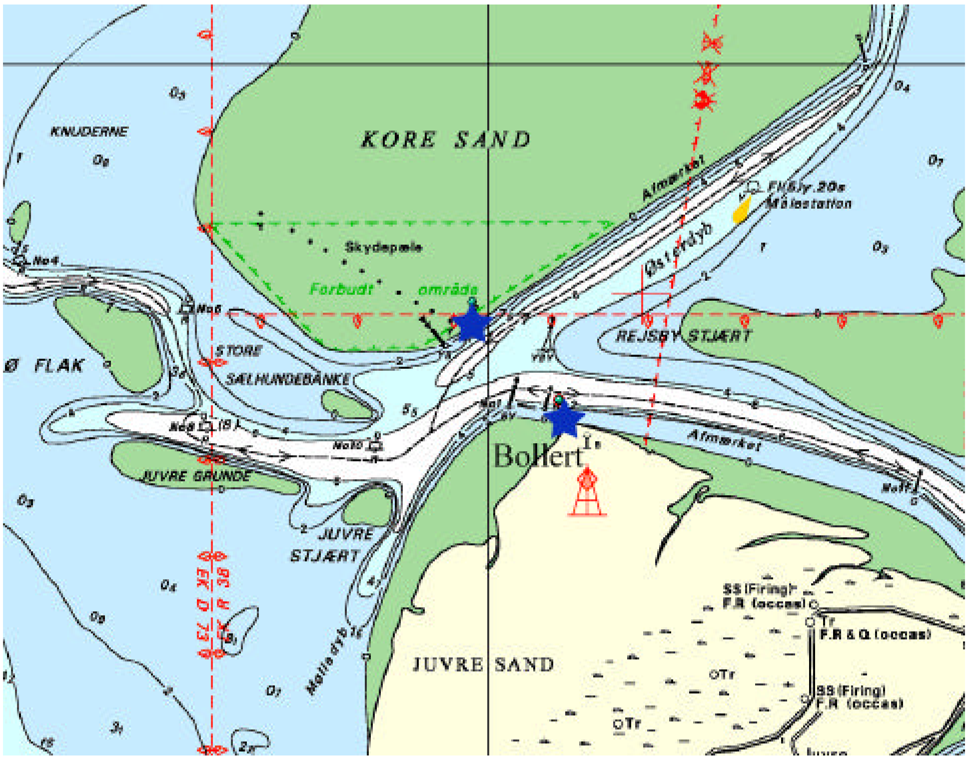


Figure 16 Outer part of Juvre tidal area between Rømø and Mandø with capture and tagging locations indicated by blue stars.

The seals were approached by boat, the rescue vessel from Havneby, Rømø. The seals were caught in a long net, transported in net bags and strapped to benches for mounting of transmitters.

Figure 17 Transmitter glued to the head of a seal. Photo: Svend Tougaard.

Satellite transmitters rely on the ARGOS telemetry and positioning system. Receivers are placed on National Atmospheric and Ocean Administration (NOAA) weather satellites.

Satellites operate in sun-synchronous, polar orbits. One orbit lasts about 100 minutes and from a fixed point on earth the pass duration (time the satellite is visible on the sky) is between 8 and 15 minutes. Each satellite will have about 8 passes per 24 hours at 55 degrees northern latitude and with 5 satellites in total, which means at best there is a visible satellite approx 30% of the time (several satellites may be visible at the same time, reducing the effective coverage). Due to poor coverage in night hours, the transmitters have been set to cease transmissions in the period 22.00-3.00 to extend battery life. No positions will thus be available in this interval but dive data are logged throughout the period.

2.3.2 Objective

The monitoring programme has been set up with the purpose of:

- Mapping the common seal's use of the area of Horns Rev
- Surveying the seals' foraging strategies accordingly

2.3.3 Results of monitoring 2002

Evaluation of transmitter performance

The transmitters in general met expectations. Data were received from all transmitters on the day of deployment and they continued to transmit daily up to the end of their functional lifetime. All transmitters provided position data and dive data.

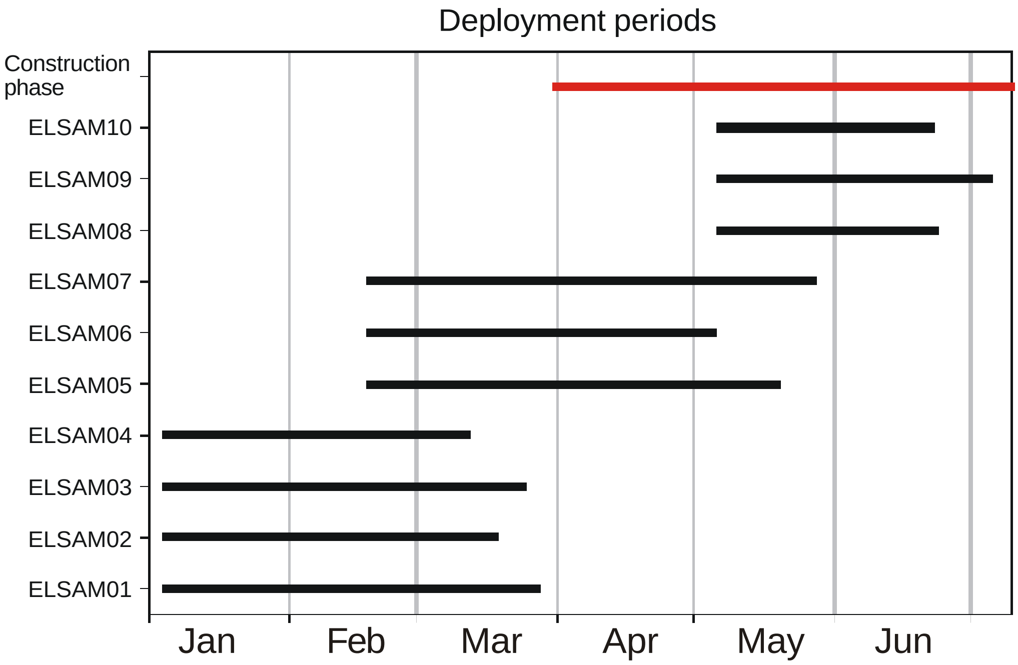


Figure 18 Deployment periods. Top line indicates start of construction phase (pile driving of wind turbine foundations and mounting of wind turbines).

Haul out

A total of 38 haul out bouts by the 8 seals analysed were registered (range 4-7 haul out bouts per seal):

21 (55%) occurred in the Juvre Dyb tidal area.
17 (45%) were distributed over 6 other haul-out areas.

All seals came back to Juvre Dyb tidal area for haul out at least once after tagging, with the exception of one seal, which took off to the Netherlands immediately upon release. One seal used banks in Juvre Dyb tidal area exclusively during the three-month transmission period.

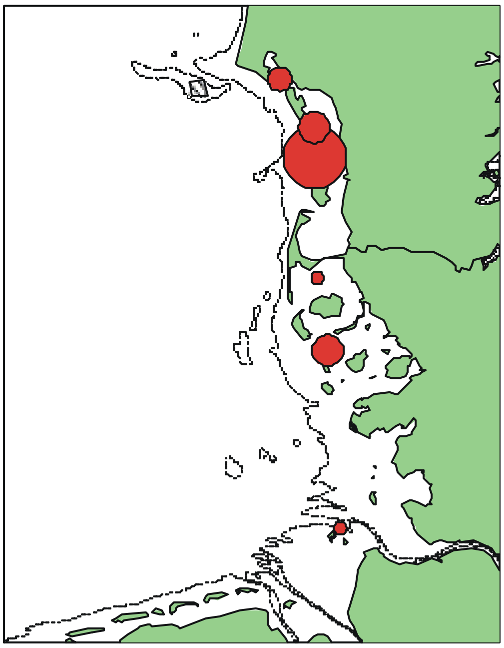


Figure 19 Haul out bouts for the tagged seals.

Foraging trips

Substantial variation was seen in foraging behaviour, both between seals and for each seal. Some variation is undoubtedly also attributable to different transmitter deployment times, but the data material is not sufficient to separate time of year from individual differences between seals. Some main types of foraging behaviours were observed, illustrated in Figure 20. One type (Figure 20, magenta line) were long trips far out into the North Sea, predominantly towards the northwest, and most clearly seen in the three pups. These trips were of long duration, up to three weeks. A second type of foraging, predominant in the young animals, were shorter, less focused trips to the area around the reef (Figure 20, blue line) or into the German Bight (Figure 20, red line). The third type were short and frequent trips to areas close to the shore (examples not shown). The latter types of trips are difficult to quantify due to the limited spatial and temporal resolution of the positional data, but was the predominant behaviour of one of the two adult animals.

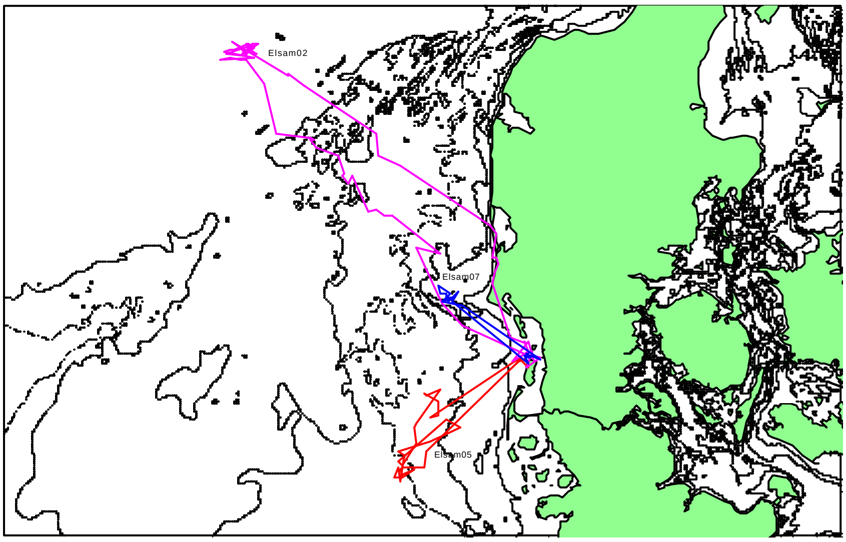


Figure 20 Selected examples of foraging trips. Purple: Seal on an 18-day trip to the deeper parts of the North Sea. Note the visit to Holmsland Klit and Vejers on return journey. Red: Seal on a 15-day trip to the German Bight. Blue: Seal on a 10-day trip

2.3.4 Conclusions

The most significant result of the present survey in relation to Horn's Reef is probably that the previous view of the seal's use of the reef should be revised. The reef seems to be a central corridor for movements between foraging areas and haul out banks and of lesser importance as foraging area, compared to previous expectations. The seals spent less than 0.1% of their time in the farm area compared to the area they visited in the entire North Sea. The limited extent of the present wind farm, compared to the entire reef makes it unlikely that it will be a barrier to movement. In case of future extensions of the Horn's Reef wind farm or other constructions in the area, the possibility of barrier effects should be considered.

Disturbances from construction

In the environmental impact assessment on the Horns Rev wind farm it was anticipated that seals would leave the area during construction and return again following completion of the wind farm. No firm conclusions can be reached on this issue from the present data. The animals in general spent little time in or immediately around the farm area, both before and during the construction phase. Considerable traffic across the reef by most of the seals was recorded however, both before and during construction. Some animals also spent shorter or longer periods in the reef area, presumably foraging, both before and during construction. There is thus no reason to believe that construction - most notably the noisy pile driving of monopiles into the seabed - had any large-scale effect on the seals in the area. As accurate tracking of the animals with high temporal resolution was not possible with the type of transmitter available, it is not possible to evaluate whether the mitigations employed in order to reduce the risk of hearing damage in seals and harbour porpoises were effective.

2.4 Harbour Porpoises

On the basis of two years of ship-based surveys and analyses of historic data, the impact assessment regarding harbour porpoises for the Horns Rev wind farm was finalised in February 2000. The results of the impact assessment suggested that short-term effects on harbour porpoises would take place as a result of disturbance during the construction phase caused by a large number of service boats and sound emissions from the pile driving activities[3] [4]. The EIA envisioned that porpoises would disappear from the wind farm area during construction, and subsequently return to the area after the construction activities have ceased.

Following the EIA, a monitoring programme was launched to measure the level of disturbance during the construction period and long-term effects on harbour porpoises at Horns Rev.

Data from the beginning of 2003 are included as the construction period was extended to about April 2003.

The results are presented in the annual status report from Hedeselskabet "Short-term effects of the construction of wind turbines on harbour porpoises at Horns Rev" 28. March 2003

2.4.1 Description of the programme

Objective

The programme has been designed in relation to the following hypotheses:

1. During the construction phase, a major impact on harbour porpoises is expected in the wind farm area. The ratio of density and acoustic activity of harbour porpoises in the impact area to the reference areas will presumably decrease.

2. During the operational phase following construction of the wind turbines, harbour porpoises will return to the wind farm area. Compared to the baseline, the change in the ratio of density and acoustic activity of harbour porpoises in the impact area to the reference areas will not exceed 25 %.

---

[3] Environmental impact assessment. Investigation of marine mammals in relation to the establishment of a marine wind farm at Horns Rev. Fisheries and Maritime Museum, Esbjerg, Ornis Consult A/S and Zoological 'Museum, University of Copenhagen, 2000.

[4] Havmøller Horns Rev. Vurdering af virkninger på miljøet. VVM-redegørelse. Maj 2000, Elsamprojekt 2000.

2.4.2 Method

Towed POD and stationary PODs have supplemented visual surveys.

Visual surveys - Investigation of distribution responses

The central questions for this investigation deals with possible effects of the wind turbines on distribution of harbour porpoises on a short time scale (during construction). Two types of surveys have been conducted: regular and additional surveys. In the regular line transect surveys the same set of parallel transect lines is sailed on all surveys, assuring even coverage of all areas and direct comparability between surveys[5]. In addition, surveys lines are laid out *ad hoc* in order to maximise the number of animals observed and conduct behavioural observations (see below). Survey data have been utilised to compare the difference in the density of animals just before, during and just after the construction phase with focus on the changes in relation to periods where pile driving operations took place.

A total of 12 surveys were made between 12 March 2002 and 18 March 2003 (see Table 6), of which eight were regular surveys. One survey was carried out on 12 March 2002 before the construction activities started. During the pile driving, monthly surveys were made in March, April and May 2002. During the last part of the pile driving in late July and beginning of August 2002 the day to day variation in the distribution and behaviour of harbour porpoises at Horns Rev was followed closely. After the pile driving activities ceased one survey was made in August 2002, followed by a break of almost six months due to the close down of the environmental investigations in September 2002. After investigations resumed in 2003, two surveys were made in February and March.

The survey design allowed for the determination of the fine-scale distribution of animals, which was mapped over a one-day survey. Relative densities of harbour porpoises were sampled along 12 east-west running transect lines. A relatively high resolution of the data was achieved by dividing each transect into segments of 2 time minutes (approximately equivalent to 500 m transect distance). Each segment constituted a sample of relative density within 800 m perpendicular distance. The distance between lines was 1.25 nautical miles. In addition to the estimation of fine-scale distribution patterns the surveys were also used to produce estimates of the relative abundance of harbour porpoises in the surveyed area. The surveys were made using line transect methodology following standards developed during the baseline investigation.

Visual surveys - Behavioural responses

In order to describe possible reactions from the harbour porpoises to the noise emissions from the pile driving operations behavioural observations were carried out. It was

---

5 Elsam. Offshore Wind Farm. Horns Rev, "Annual Status Report for the Environmental Monitoring Programme", 1 January 2002 – 31 December 2002 envisaged that possible behavioural reactions of harbour porpoises to the noise emissions would include strong escape reactions at close range and interrupted feeding activities at distances of several kilometres. Behavioural characteristics of the animals, in particular feeding activity and type and direction of movements were determined by sailing at low speed along lines oriented in a zigzag pattern towards the pile driving site, schematically illustrated in Figure 21. Lines were laid out after regular surveys had provided information on areas with high densities of porpoises.

The following codes were used for harbour porpoise behavioural responses:

Directional	Calm movement with clear direction
Non-directional	Calm movement without clear direction (foraging)
Logging	Calm rest at the surface
Porpoising	Rapid swimming near the surface

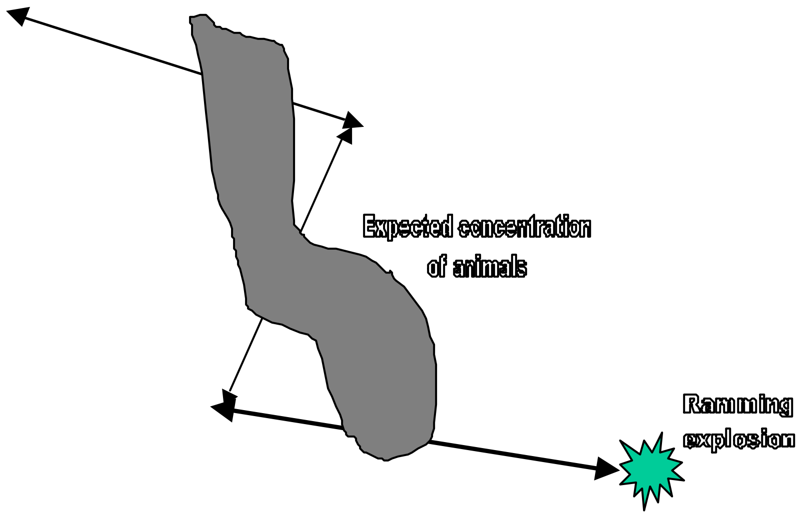


Figure 21 General layout of additional survey lines for behavioural observations, aimed at maximising number of observed animals during pile driving.

In order to evaluate possible differences in behaviour with distance from pile driving, the distance to the centre of the wind farm was calculated for all observations and observations grouped into four distance categories. Categories were arbitrarily selected to assure an approximately even distribution of observations across classes. The four classes were below 10 km, between 10 and 15 km, between 15 and 20 km and above 20 km from the centre of the wind farm.

Behavioural observations were conducted on surveys before pile driving commenced, during and after the pile driving was completed. Data were grouped into observations during pile driving operations (30 March to 2 August) as well as before and after.

Visual surveys - Collection of hydrographical data

One CTD station (Anderaa RCM 9), logging temperature and salinity was deployed at 10 m depth in the construction area, and has measured temperature and salinity at 10-minute intervals.

The spatial hydrographical variability encountered during the ship surveys was recorded by continuous measurements of temperature and salinity at a depth of approximately 3 m using a calibrated salinometer (WTW 340). In order to collect more information on the large-scale variability in hydrography, especially of the oscillation of the Continental Coastal Current, Geographic Resource Analysis and Science A/S at the Institute of Geography University of Copenhagen delivered NOAA AVHRR SST data with a spatial resolution of 1.1 km.

Visual surveys - Geo-statistical analyses

Densities of harbour porpoises were calculated for each transect segment using a general probability of observation within the scanned transect area of 0.39 (95% confidence interval 0.36-0.42), which was derived from analyses of sighting distances from all regular surveys by using the uniform model with cosine adjustments in DISTANCE. DISTANCE was also used for estimation of total abundance for each survey. Sighting rates change considerably with Beaufort sea state. Therefore, only data collected during sea state 2 or less were used for analysis.

Visual surveys - Line transect population estimation

Total estimates of the abundance of harbour porpoise in the investigation area during each regular survey were made using the model for general detection described above in DISTANCE (Ver. 4.2).

Towed POD

In addition to visual surveys the feasibility of using towed PODs to detect porpoises acoustically during surveys was tested. During 8 of the visual surveys a POD was towed after the survey boat. The POD used for towing is a more sensitive version (T-POD2) than the permanently deployed PODs (T-POD).

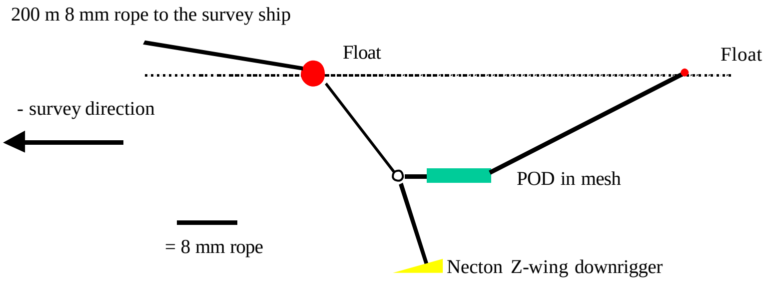


Figure 22 Drawing of the POD towing rig used for the acoustic surveys. The aft float was only used on some surveys, as it was found not to contribute significantly to stability.

Compared to the period covered by the previous status report (2001 season) a few changes have been applied to the handling of the PODs. Deployment of PODs on position 8, which is the innermost position on the eastern side of Slugen has been discontinued and thus only 7 positions have been monitored. PODs deployed on position 8 were extremely vulnerable to damage from fishing vessels operating in the area and after several instances of either direct vandalism or accidents resulting in loss of buoys and PODs it was decided to withdraw the equipment and skip the position.
Steel cages for mounting PODs implemented in the spring 2002 are now in use on all positions with good results. No PODs mounted in cages have disappeared.

From January 2003 two new PODs (T-POD3) with higher sensitivity were deployed together with old T-PODs to intercalibrate the data obtained from the two versions of the PODs.

Problems during the regular service visits to the PODs, scheduled at 60-day intervals, as well as other factors have resulted in considerable periods where data were not collected, as described in the results. Unfortunately, this weakens the power of conclusions that can be drawn on impact of the construction activities.

2.4.3 Results of monitoring 2002

Surveys

Surveys were conducted throughout the period, with a total of 17 survey days. Table 6 presents an overview of the surveys.

Survey	Ship	Date	Time	Lines	Porpoise sightings	Porpoises total	Seal sightings	Seals total
S02N01	M/S Alice Becker	12-03-2002	7:58-18:32	1,3,5,6,7,8	11	13	4	4
S02N02	M/S Gitte Iversen	23-03-2002	6:52-18:50	1,2,3,4,5	10	14	0	0
S02N03	M/S Gitte Iversen	24-03-2002	6:00-16:38	12,11,10,9,8,7,6,5	30	49	5	5
S02N03A	M/S Gitte Iversen	24-03-2002	16:42-19:04	Behaviour	31	96	9	9
S02N04	M/S Gitte Iversen	20-04-2002	7:48-20:40	1,2,3,4,5,6,7,8,9	30	63	19	19
S02N05	M/S Gitte Iversen	21-04-2002	16:32-19:32	4,5,6	2	3	4	4
S02N05A	M/S Gitte Iversen	21-04-2002	6:22-13:26	Behaviour	54	80	22	22
S02N06	M/S Christoffer	08-06-2002	10:21-20:54	1,2,3,4,5,6,7	1	1	1	1
S02N07	M/S Christoffer	09-06-2002	5:26-9:12	8,9,10	3	4	1	1
S07N07A	M/S Christoffer	09-06-2002	9:18-16:04	Behaviour	1	1	2	2
S02N08	M/S Gitte Iversen	28-07-2002	6:50-21:13	1,2,3,4,5,6,7,8.9,10	54	143	11	15
S02N09A	M/S Gitte Iversen	29-07-2002	9:42-20:02	Behaviour	29	89	4	4
S02N10A	M/S Gitte Iversen	30-07-2002	6:04-19:16	Behaviour	92	287	10	10
S02N11A	M/S Gitte Iversen	31-07-2002	9:12-20:23	Behaviour	38	94	8	8
S02N12A	M/S Gitte Iversen	01-08-2002	8:50-21:40	Behaviour	70	151	16	16
S02N13A	M/S Gitte Iversen	02-08-2002	6:06-13:23	Behaviour	4	5	4	4
S02N14	M/S Christoffer	08-08-2002	6:09-20:59	1,2,3,4,5,6,7,8,9,10	96	306	17	17
S03N01	M/S Christoffer	12-02-2003	8:00-17:06	1,2,3,4,5,6,7	8	13	1	1
S03N02	M/S Christoffer	13-02-2003	8:00-14:48	8,9,10,11,12	5	10	0	0
S03N02A	M/S Christoffer	13-02-2003	14:48-17:05	Behaviour	2	4	1	1
S03N03	M/S Christoffer	18-03-2003	6:50-18:22	1,2,3,4,5,6,7,8.9,10	12	15	1	1

Table 6 Surveys conducted from March 2002 to March 2003. Surveys marked with "A" were sailed along ad hoc lines, the rest along the predefined lines L1-L12.

The hydrographical data, as reflected by both the CTD station, the surveys and the SST images, show a significant inflow of estuarine water masses from the rivers in the German Bight during the entire survey period. This is indicated both by relatively low salinities for the wind farm area and by the width of surface waters with low salinities (< 30 psu) and relatively high temperatures in both winter and summer.

Harbour porpoise distribution

The series of surveys revealed large variations in the abundance of animals at Horns Rev. Individual surveys were characterised by medium or high densities (> 3 animals per km^2) mainly within a restricted area over the central and western parts of the reef, and in Slugen. No concentrations were seen near or within the wind farm area. Strong salinity fronts were apparent on the 23-24 March and 8-9 June 2002 as well as on the 12-13 February and 18 March 2003. Concentrations of harbour porpoises were aligned along these fronts, except on the 8-9 June when very few animals were sighted. The fronts passed through the wind farm area or in the immediate vicinity of the area during all four periods, but only one sighting of one animal was made (23 March 2002). During the period of daily surveys between 28 July and 1 August the variation in the distribution could be followed. During this period of stable and relatively moderate salinity over the whole area, the main concentration of animals was very resident around the Vov Vov bank on the western edge of the reef, and the core of the porpoise distribution only changed position over a range of less than five km during these five days.

Calves were observed in the same areas as the main concentrations of harbour porpoises with the bulk of observations being made in the central and western parts of the Horns Rev. A single calf was observed in the wind farm area.

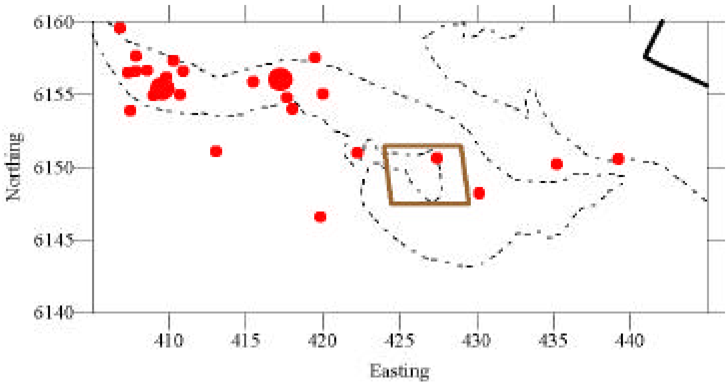


Figure 23 Sightings of calves during the surveys on Horns Reef in 2002. Smaller dots indicate one animal; larger dots two animals

Population estimates

Estimates of pod size, pod density and total density and abundance of harbour porpoises could be obtained for six of the eight regular surveys (Table 7). The abundance of animals clearly increased from spring/early summer to late summer/early autumn in 2002, whereas the abundance estimate for February 2003 was comparable to early March 2002. During the peak period coinciding with the period in which young calves are normally seen, the point estimates indicated a population of 700-1000 animals, which is in line with prior estimates of the number of porpoises in the area. It should be kept in mind, however, that both the estimates from 28 July and 8 August have wide confidence intervals, due to the high variance in sighting rates between transect lines.

Behavioural observations

Distribution of observation classes is shown in Figure 24. About 90% of the observations consisted of directionally or non-directionally moving animals. Behaviours were significantly different between observations under pile driving and outside (χ^2 = 21.353, $P < 0.001$). It can be seen that directionally moving animals were highly overrepresented during pile driving, compared to the three remaining behaviours.

It should be mentioned that mitigations aimed at reducing the risk of inflicting permanent hearing damage to marine mammals were adopted during ramming procedures. Two types of procedures were used. In the first period (from 30 March to

12 April) a ramp-up procedure was followed, which consisted of 2-3 light blows to the monopile followed by a 2 minute break, all repeated three times. The ramming then proceeded with gradually increasing energy. In the remaining period (14 April onwards) acoustic warning/deterring devises were employed. These consisted of a porpoise pinger (Aquamark100) mounted on each of the anchors of the ramming rig (Buzzard) and automatically activated when the anchors were set about 1,5 hours prior to ramming operations. In addition a single seal scaring device (Lofitech) was lowered from the ramming rig about 0.5 hours prior ramming.

Observations were separated into classes of distance from the wind farm. For observations outside pile driving there were no significant difference between distance classes (χ^2 = 9.93 P = 0.127), whereas it was highly significant for the pile driving observations (χ^2 = 24.729 P < 0.001).

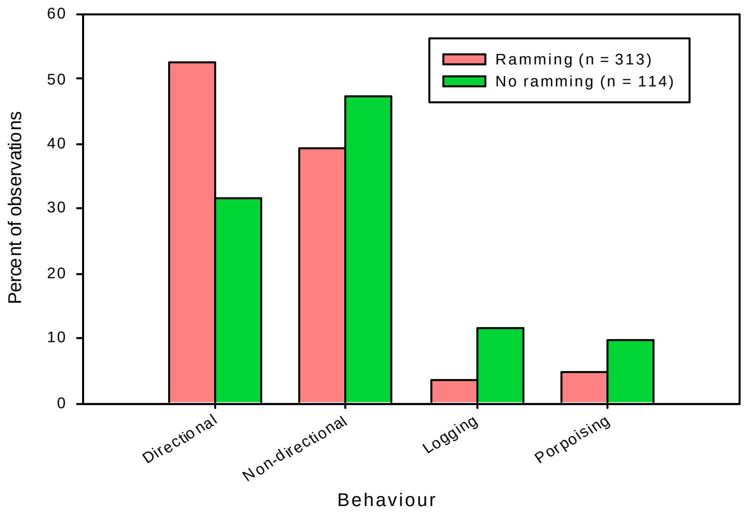


Figure 24 Behaviour of harbour porpoises on surveys in period with pile driving (March 30th to August 2nd) and on surveys before and after.

Stationary PODS data

The activity of harbour porpoises in the Horns Rev region has been assessed by means of porpoise detectors (PODs) described above. The first PODs were deployed at Horns Rev in July 2001 and the present report analyses data collected from the PODs up to mid October 2002 (no data are available for the period between November 2002 and March 2003). The time series obtained from the POD signals also contain major gaps due to technical problems.

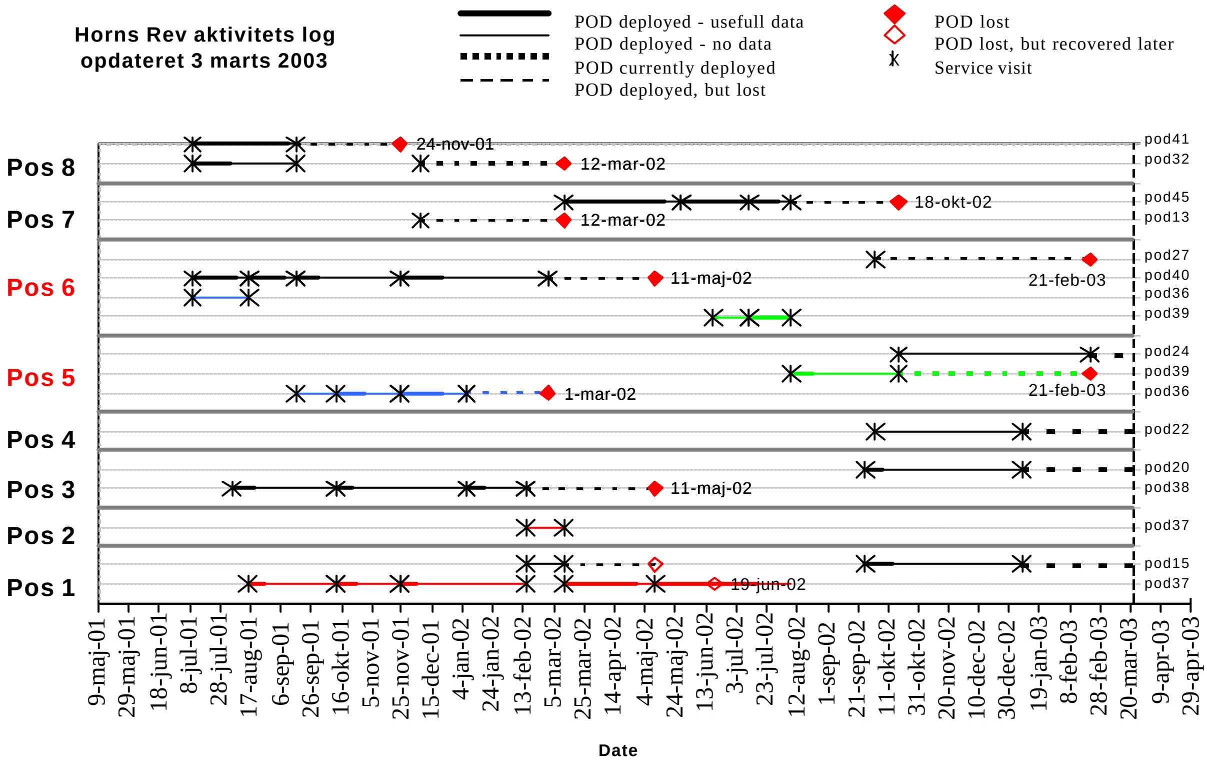


Figure 25 Schematic illustration of POD-deployments from onset of the monitoring program to last service visit in February 2003. Position 5 and 6 are impact area (wind farm).

Daily statistics

The daily click frequency (percentage of recording minutes with clicks) and intensity (average number of clicks per minute with activity) were calculated from the POD data. The temporal variations and variation between positions and PODs appear relatively smaller for intensities compared to frequencies. In order to test whether systematic temporal correlation was apparent autocorrelation functions for intensity and frequency were calculated for each sequence of a specific POD at a specific location. None of the 13 sequences were found to be temporally correlated (data not shown) and we thus assume that these daily indicators are independent observations.

Due to the problems associated with unsupervised POD deployments for longer periods and changes of PODs between different locations, the variation attributed to seasons and variation between PODs are partially confounded. This implies that it cannot be exactly determined how much of the variation is seasonal and how much is due to shifting of PODs at specific locations.

BACI analysis for baseline versus construction

A BACI analysis for determining a potential effect of the construction phase on daily activity statistics was conducted, Table 7.

Table 7 describes variation between area (control versus impact), stations within area, seasonal variation described by monthly means, variation between periods (before versus after) and differences in these periods between the two areas (BACI-effect). P-values, given in the first line, were determined by type III SS, ie the difference in variation described by the model including, versus not including, the considered effect. The coefficient of determination (R^2) was calculated on transformed data. Averages were found using back-transforms of marginal means from ANOVA in order to account for non-balance in data. The BACI effect was calculated as (IA-IB)-(CA-CB). Data from PODs deployed at Pos. 1, 3, 5 and 6 were used.

Indicator	BACI results					
	Area	Station (area)	Month	Period	Area *period	R^2
Daily intensity	<0.0001	0.6467	<0.0001	0.4798	0.0035	0.2208
	Medians	**Control**	**Impact**			
	Before	28.2	26.1	27.1	**BACI=**	-7.2
	After	31.4	22.1	26.3		
		29.7	24.0			
Daily frequency	<0.0001	<0.0001	<0.0001	0.0001	0.2658	0.4801
	Medians	**Control**	**Impact**			
	Before	4.12%	0.81%	2.16%	**BACI=**	1.33%
	After	2.38%	0.40%	1.19%		
		3.19%	0.59%			

Table 7 BACI analysis for daily indicators (intensity and frequency)

Both indicators showed significant variations between control and impact areas, although there was no significant difference when considering the baseline period only for daily intensity, Table 8..

Table 8 describes variation between area (control versus impact), stations within area, differences in PODs within specific station and area, seasonal variation described by monthly averages and differences in seasonal variation between the two areas. For each indicator the least significant effect was discarded until all remaining effects were significant at a 5% significance level. P-values were determined by type III SS, ie the difference in variation described by the model including, versus not including, the considered effect. POD data from baseline period only.

Indicator	P-values for effects in model determined by type III SS (marginal variation)					
	Area	Station (area)	PODid (station area)	Month	Area *month	R^2
Daily intensity	0.2696	0.7677	0.8781	0.0170	0.6980	0.0919
	0.2130	0.3034	-	0.0140	0.6857	0.0909
	0.3279	0.2955	-	0.0074	-	0.0785
	-	0.3682	-	0.0074	-	0.0785
	-	-	-	0.0190	-	0.0615
Daily frequency	0.0590	<0.0001	0.9720	<0.0001	0.0262	0.6187
	0.0004	<0.0001		<0.0001	0.0056	0.6186

Table 8 Analysis of Variance (ANOVA) for daily indicators (intensity and frequency)

There was no difference in the daily intensity for the two periods, before and after, whereas daily frequency decreased approximately 50% overall for all positions. The BACI effect (area*period) was significant for daily intensities, which declined in the impact area and increased in the control area.

BACI analysis for days with pile driving during construction

The construction period consisted of 80 short-term events of pile driving of the foundations into the sediments, a process creating a high noise level. It is hypothesised that these pile driving activities could have an effect on the porpoise activity. The daily indicators during the construction period (after) were grouped into days with pile driving and ordinary construction days, and a BACI type analysis was carried out to determine if there was any effect on porpoise activity during pile driving in the construction period.

Days with pile driving activity were found to have lower daily intensity (significant) and frequency (not significant) in both control and impact area. However, the decreases during days with pile driving in both of these indicators were of the same magnitude in both areas, indicating that: 1) pile driving activity had little effect on daily activity levels and the significance of the pile driving factor is attributable to temporal variations or 2) the control area was affected by pile driving activity in the same manner as the impact area. The first implies that pile driving was generally carried out on days with lower activity over the entire Horns Rev, whereas the latter implies that Pos. 7 (control) and Pos. 6 (impact) are both affected by pile driving activity, as these are the only two PODs providing simultaneous data from both control and impact area. It should also be recognised that the limited number of days with pile driving with POD recordings does not allow for detection of minor differences in daily frequencies.

Combining the daily indicators with pile driving activity does not provide an ideal picture of the effect of pile driving, because pile driving is a short-term activity (typically 1-1.5 hour) that may take place at any time over the course of the day.

However, by using daily indicators it is implicitly assumed that porpoise activity over the entire day, including the time from midnight to start of pile driving, is affected by this activity. Hence, the analysis above can only provide weak indications for a potential effect of pile driving activity. Applying the same type of analysis to encounter statistics during and after the pile driving should provide a better approach to assessing the potential effect of pile driving.

2.4.4 Summary of stationary POD analysis

The monitoring efforts resulted in a rather small data set of POD recordings, which has to some extent limited the ability to obtain a coherent picture of all the variations affecting porpoise activity in the Horns Rev area. Fortunately, the density of porpoises in the area is high and this has resulted in a useful data set despite the relatively short periods of logging.

The baseline survey showed that variation due to shifting of PODs is relatively small compared to all the other sources of variation. If the seasonal variation by monthly averages is described, it was found that Pos. 1, 3 and 6, and to some extent Pos. 5, showed similar temporal trends, whereas Pos. 8 was different. Pos. 1, 3, 5 and 6 were used for the general environmental impact assessment during the construction period, and Pos. 7 was included for assessing short term effects.

The daily click frequency level decreased over the entire Horns Rev from the baseline survey to the construction period. This tendency was also reflected in shorter duration of porpoise encounters whereas waiting times remained unchanged. This general decrease from baseline to construction period could be associated with changes in seasonal densities or potentially also the construction activity as pile driving was found to affect the entire Horns Rev. Due to the limited data set, little information is available on seasonal and inter-annual variation to determine the most likely cause of this general change in activity from baseline to construction period.

Pile driving activities affected porpoise activity at all monitoring positions in the Horns Rev region with lower click intensities and increasing waiting times following pile driving. Thus, there is an immediate, but short-lived response to pile driving activities.
In conclusion, pile driving activity has a short-term substantial effect on the porpoise activity over the entire reef. The generally lower acoustic activity level during the construction period could potentially be associated with construction activities. However, as this change was observed at all POD positions, it cannot be excluded that the lower activity could be due to general temporal variations in porpoise densities in this part of the North Sea as well.

2.4.5 Conclusions

Data from the deployed PODs provided strong indications that pile driving affects the porpoise acoustic activity on time scales of a few hours, although smaller long-term changes could not be assessed due to data limitations. The impact of pile driving activity seemed to have a short-lived effect on harbour porpoise acoustic activity in the Horns Reef area in general, as the activity returned to normal levels approximately 3-4 hours after pile driving activity had ceased. The pile driving activity had an effect on positions within both impact area and control areas. The porpoises thus either left the area during pile driving operations or changed their behaviour in ways that resulted in less sonar signals being picked up by the PODs. Hence, pile driving activity has reduced the activity of harbour porpoises in the entire Horns Rev area for a short period after which the activity resumed.

The statistics on daily intensities indicated a significant negative BACI effect over the entire period, indicating that the resumed level of activity in the wind farm area was lower during the construction period compared to the baseline. This would be expected, due to the potential disturbance from the large number of service vessels continuously present in the area.

On a larger temporal and spatial scale the acoustic statistics on daily intensity and frequency showed that the pile driving activity had affected the activity of the animals in both control and impact area, and that the decreases during pile driving in both of these indicators were of the same magnitude. On this basis and on the basis of the behavioural observations and sampled densities it is evident that both the impact and the control areas at Horns Rev were affected over larger time scales by the pile driving activity. The test of differences in observed behaviours indicated an impact on the proportion of potentially feeding animals (judged from their non-directional behaviour) within a distance of 10-15 km from the wind farm.

It is concluded that individual pile drivings had an effect on the acoustic behaviour of harbour porpoises on the reef, lasting up to 3-4 hours after the end of each pile driving. It must be mentioned, that measures aimed at reducing the risk of inflicting permanent hearing damage to marine mammals were adopted during ramming procedures (ramp up and pingers/seal scaring devices). There were more general effects on abundance and behaviour of the animals in the construction period. It is not clear, however, whether this change in behaviour is truly attributable to the construction or whether it is related to overall temporal variation. Collection of data in the coming summer months should help to clarify this issue.

Towed POD

The performance of the towed pod was not impressive. Hit rates realised (comparing with visual sightings) indicate that the sensitivity of the POD is not sufficient to be used for towing. The highest hit rate was obtained on a survey with only one visual observation where also one acoustic recording was made. The remaining hit rates were between 0% and 45.5 %. Two surveys encountered high numbers of visual observations (29 groups each) but the hit rates for these were no more than 3.4 and 10.3 %.
There is some degree of temporal agreement between acoustic and visual observations, as 40 % of the acoustic events were found within 2.4 minutes after a visual sighting and 60 % were found within 5 minutes

It can be concluded that towed PODs do not give the expected outcome in the form of data sufficient to consolidate or replace data from normal visual surveys as they have been carried out during the monitoring programme. If acoustic surveys are to continue a towed array of hydrophones specifically designed for the purpose should be employed instead of the T-POD, which is designed for stationary deployment.

2.5 Sand eels and clams

The conclusion from the environmental impact assessment is that the fish populations vary greatly from one year to the next. Based on this it was assessed to be inappropriate to monitor the fish population in general.

Sand eels are a good indicator for changes in the sediment in the sea bottom, and is an important food source for marine mammals, fish and sea-birds. For these reasons the international expert panel (IAPEME) has recommended that the occurrence of sand eels is investigated.

As the programme for monitoring sand eels will give some by-catches of clams (Spisula solida), which have been very common at Horns Rev, these are also analysed and reported in this programme. Apart from the clams there will also be by-catches of other animals, and the occurrence of these is also reported.

The results from 2002 are presented in details in the DIFRES report "Sand eels and clams (*Spisula* sp.) in the wind turbine park at Horns Rev"[6].

2.5.1 Description of the programme

Objective

The construction of the wind farm is not supposed to effect the sand eel population in the Horns Rev area because the impact area seems to constitute a small fraction of a larger area with sand eel habitats. However, within the area of the wind turbines sand eel abundance might be affected if the surface sediment changes due to the construction of the wind turbine or if the abundance of sand eel predators increase in the impact area after the wind turbines has been built (the so-called artificial reef effect). To investigate if these effects will occur the field programme carried out in February/march 2002 (the subject of this report) will have to be repeated after the wind turbines have been constructed.

Methods

The distribution and relative abundance of sand eels and shellfish in the area of the wind turbines at Horns Rev was mapped in conjunction with seabed samplings during three surveys in February and March 2002.

In total 63 positions (position 1 to 63) were defined in a regular grid in the area of the wind turbines (in the following denoted the impact area), and 9 positions (position 64 to 72) in an area north-west of the wind turbines (in the following denoted the control area). Of these positions, 9 positions were chosen randomly in the impact area and 3

6 Sand eels and clams (*Spisula* Sp.) in the wind turbine park at Horns Reef. Danish Institute for Fisheries Research. Department of Marine Fisheries. April 2003.

positions in the control area. Sand eel and shellfish density and seabed characteristics were measured at these 12 positions (in the following denoted the sample locations).

The impact area (the area of the wind turbines) and the control area are shown in Figure 26. The impact area covers approx 26.5 km^2 and the control area approx 1 km^2.

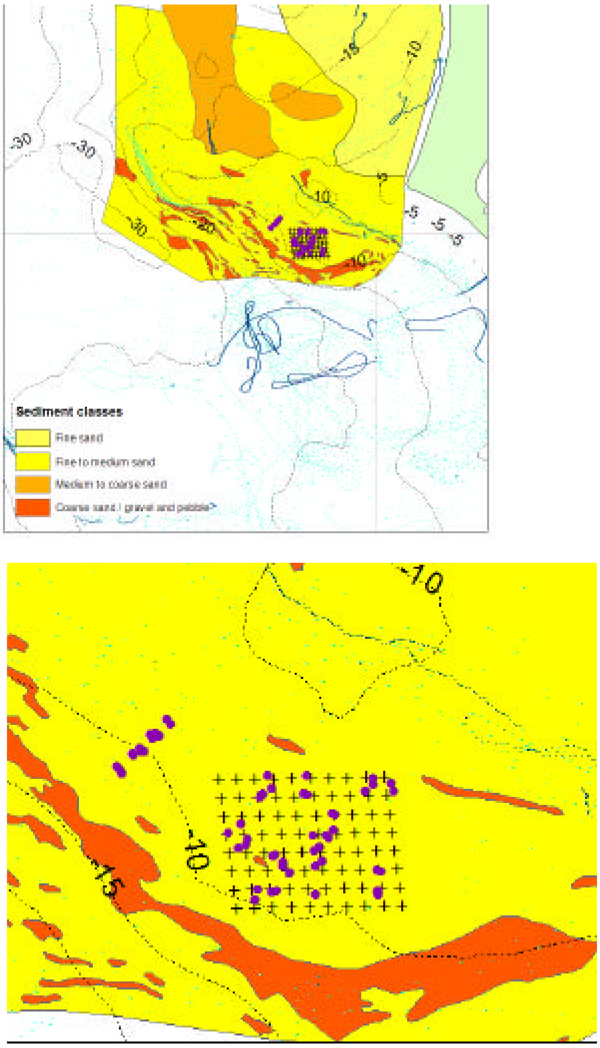


Figure 26 Surface sediments in the region of the windmill park. Black hatched lines are 5m depth contours. The location of windmills is indicated by black crosses. The light blue (all data) and dark blue (filtered data) areas are sand æl fishing grounds.

A special dredge developed by DIFRES (sand eel dredge) was used to collect samples and measure relative densities of fish and shellfish Figure 27. The dredge has been found to provide accurate measures of relative densities of sand eels in the seabed.

Figure 27 Modified scallop dredge used to collect samples.

Five replicate 10 min. dredge samples were carried out at each of the sample locations, with each haul covering between 815 m^2 and 1,111 m^2. The start and end positions of the dredge hauls appear for each of the sample locations from Figure 28. The fish and shellfish caught in the dredge were frozen for later analysis in the laboratory.

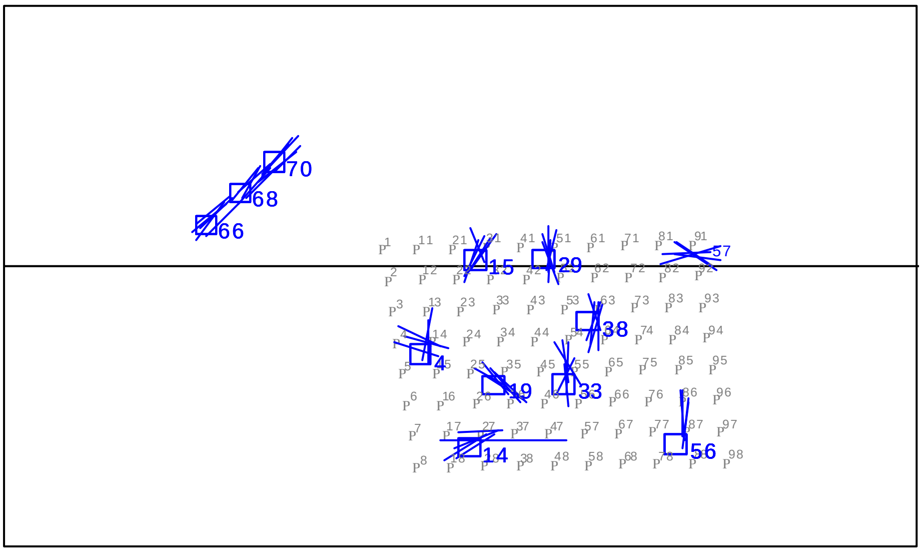


Figure 28 Overview of sampling locations and wind turbines. The grey symbols and numbers are wind turbines and wind turbine numbers, the blue lines are tracks fished with the modified scallop dredge, the blue squares and numbers indicate the position s of van Veen sampling and the numbering of the sample locations.

Sand eels

Sand eels were counted and the weight and length of the fish was measured in gram and mm. Maturity was determined using the key of Macer (1966). The sand eels were afterwards identified in species using the criterion given in Table 9. The different species of sand eels (see Table 10) are relative easy to identify, except for the two species of *Ammodytes*. These two species can be distinguished from organization of the belly scales and the scales at the caudal fin. However, these characters cannot be used for sand eels that are first caught in the sediment by the scallop dredge and afterwards frozen and defrosted in the laboratory. In the laboratory these characters had disappeared. Instead a new character was identified. Preliminary analyses indicated that pigmentation, forming a m-band at the base of the caudal fin, could be used to distinguish between the two species of *Ammodytes*. To verify the species determination the numbers of vertebrae were counted from x-ray pictures of all sand eels caught during the surveys as this character seem to be robust in identification of the species.

	A. marinus	***A. tobianus***	***H. lanceolatus***	***G. semisquamatus***
Spawning time	Dec-Jan	Feb-Apr Sep-Nov	Summer	Summer
Ripe adults	Nov-Jan	Mar-Apr Nov-Dec	Apr-Jul	March-Jul
Premaxillae protrusible	Yes	Yes	No	Yes
Dark spot on either side of snout	Absent	Absent	Present	Absent
Lateral line system	Not branched	Not branched	Not branched	Branched
Vomerine teeth	Absent	Absent	Present Single bicuspid tooth	Absent
Pigmentation on head	Slight, usually inconspicuous	Conspicuous, sharply contrasting with unpigmented areas		
Belly scales organization	Loosely arranged	In tight chevrons		
Scales over musculature base of caudal fin	Absent	Present		
M-band at the base of the caudal fin *)	Absent	Present	Absent	Absent
Total vertebral number included the urostyle	65-75	61-66	65-69	65-72
Dorsal fin ray number	56-63	49-58	53-60	56-59
Anal fin ray number	29-33	24-32	27-32	28-32

*Table 9 Characters of sand eels. Based on Reay (1970, 1973, 1986) and Macer (1966), except *) which is a new character discovered by DIFRES*

Genera	Latin Name	English Name	Danish Name
Ammodytes Artedi 1738	***Ammodytes marinus*** Raitt 1934	Raitt's sand eel	Havtobis
	Ammodytes tobianus Linnaeus 1758 (= ***A. lancea*** Cuvier 1829)	Sand eel	Kysttobis
Gymnammodytes Duncker and Mohr 1939	***Gymnammodytes semisquamatus*** (Jourdain 1879)	Smooth sand eel	Nøgentobis
Hyperoplus Gunther 1862	***Hyperoplus lanceolatus*** (LeSauvage 1824)	Greater sand eel	Tobis konge
	Hyperoplus immaculatus (Corbin 1950)	Corbin's sand eel	Uplettet tobis konge

Table 10 Latin and common names of the five species of sand eels in the North Sea.

Shellfish

The different spices of shellfish were counted and the length and weight of individual shellfish was measured in mm and in gram. Due to the very low number of *S. solida* caught in the survey some relevant data from DIFRES's older investigation of the *S. solida* stock at Horns Rev from 1993 are presented in this report.

The swept area of each dredge haul was calculated and used to estimate relative densities of sand eels and shellfish.

2.5.2 Results of baseline survey 2002

In February and March 2002, before beginning construction of the wind farm, the baseline studies were carried out. Three surveys took place as described below.

Date	**Vessel**	**Survey locations**	**Sediment sampling**	**Sand eel sampling**
21/2	Sea water fish	29, 38, 56	X	X
28/2-1/3	Sea water fish	4, 14, 15, 19, 33, 57, 66, 68, 70		X
24/3-25/3	Cardium	4, 14, 15, 19, 29, 33, 38, 56, 66, 68, 70	X	

Table 11 Overview of survey and survey operations

Number of samples collected at each of the sample locations appears from Table 12.

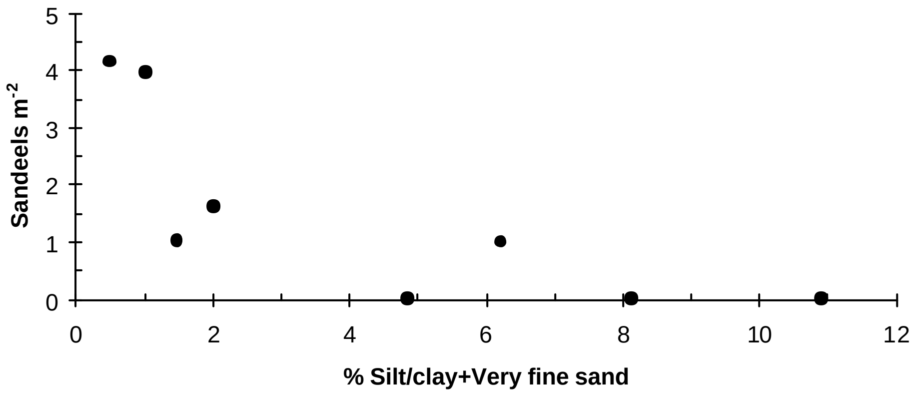
		Gear		**Sum**
		Dredge	**Van Veen**	**N**
Area	**Location**			
Control	66	5	5	***10***
	68	5	5	***10***
	70	5	5	***10***
Impact	4	5	5	***10***
	14	5	5	***10***
	15	5	5	***10***
	19	5	5	***10***
	29	5	8	***13***
	33	5	5	***10***
	38	5	8	***13***
	56	5	8	***13***
	57	5	0	***5***
Sum		**60**	**64**	***124***

Table 12 Number of samples collected at each location in February and March 2002 by gear type.

The sediment composition in the wind turbine area

In both control area and impact area the weight fraction of silt/clay + very fine is smaller than 2% at all sample locations and thus clearly below the 6% limit above which sand eels would avoid the sediment (Figure 29). Judged from the sediment composition both impact area and the control area are considered sand eel habitats. Furthermore, a much larger area around the wind farm is also likely to be sand eel habitat.

A



B

Figure 29 Average densities of sand eels plotted against average content of the Wentworth sediment classes silt/clay + very fine sand (<0.09mm) in the sediment, based on a) laboratory experiments and b) field experiments.

There seems to be a decrease in both depth and content of silt/clay + very fine sand from north to south-east towards the area with coarse sand. This pattern in depth and sediment composition was substantiated by a relationship between depth and the content of very fine sand in the sediment. A similar relationship was not found between depth and silt/clay content in the sediment, which confirms the difficulties of making accurate measurements of the content of this sediment class in seabed samples.

2.5.3 Results for sand eels

541 sand eels were caught in the scallop dredge during the surveys: 152 *A. marinus*, 50 *A. tobianus*, 273 *H. lanceolatus* and 67 sand eels that could not be identified. Sand eels were found in the sediment at all sample locations in small densities (Table 13), which confirms the classification of the sediment in the survey area as sand eel habitat. Similar densities of sand eels were found in the control area as well as in the impact area. The average density of sand eels in the sediment was 0.0102m^{-2} in the control area and 0.0096m^{-2} in the impact area. These densities are much smaller than densities measured in many other areas of sand eel habitat in the North Sea. However, long time average densities in this area may be larger as sand eel densities show large variations between years, due to large variations in mortality and recruitment. The most abundant species of sand eel in both impact area and control area was *H. lanceolatus* followed by *A. marinus* and *A. tobianus*. No *G. semisquamatus* were caught during the surveys.

	Area														
	Control				**Impact**										
	Location				**Location**										
	66	68	70	Av.	4	14	15	19	29	33	38	56	57	Av.	Av.
spec_txt															
A. marinus	2.5	3.5	3.9	3.3	1.2	1.9	5.1	1.0	4.2	1.6	3.6	2.4	1.1	2.5	0.5
A. tobianus	0.8	3.0	0.9	1.6	0.8	1.5	1.0	1.2	0.5	1.9	0.0	1.8	1.4	1.1	0.3
G.semisquamatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H. lanceolatus	2.7	7.4	5.3	5.1	5.8	2.1	11.3	2.1	5.0	5.6	8.5	6.7	3.6	5.6	0.9
Sand eel ssp.	0.0	0.5	0.0	0.2	0.0	0.2	0.2	0.7	1.1	0.0	0.2	0.0	0.9	0.4	0.3
Sum	6.1	14.4	10.2	10.2	7.8	5.7	17.6	5.0	10.8	9.1	12.4	10.8	6.9	9.6	9.7

Table 13 Average densities of sand eels (sand eels·m-2·1000) by species, area and sample location.

No major differences were found in neither age nor length compositions of sand eels between the impact area and control area. The majority of the sand eels caught were age 3 and younger.

For both *A. marinus* and *H. lanceolatus* there seemed to be a decrease in densities from north to south-west towards the areas of coarse sand. This trend in density was not found for *A. tobianus*.

A positive relationship seems to exist between depth and sand eel density.

Sand eel distribution and possible wind farm effect on sand eels

The area of the wind farm seems to constitute a small part of an area of sand eel habitat in the Horns Rev area. Furthermore, areas of sand eel habitat with higher densities of sand eels seem to be located north and south of the wind farm in areas where commercial fishing takes place. The decrease in densities of sand eel in the seabed towards the area with coarse sand seems to contradict this view. However, the observed decrease in density of sand eels in the seabed towards the area of coarse sand might be insignificant compared to the high densities of sand eels that probably exist in the area with coarse sand south of the wind farm. This however will have to be verified during future surveys.

The relationship between depth and sand eel density may be due to the high velocity of water above the seabed, and subsequently disturbance of the surface sediment layer. In other words, because the sediment in the area surveyed is suitable for sand eels they may prefer to bury in areas with less disturbance of the surface sediment. The same relationship between depth and sand eel density can be inferred from the investigation of Wright et al. (2000) for the same depth range as that found in the survey area of this survey.

The construction of the wind turbines is not supposed to effect the sand eel population in the Horns Rev area because the impact area seems to constitute a small fraction of an area with sand eel habitat. However, within the area of the wind turbines sand eel abundance might be affected if the surface sediment changes due to the construction of the wind farm or if the abundance of sand eel predators increases in the impact area after the wind turbines has been built. To investigate if these effects will occur the field programme that was carried out in February/March 2002 will have to be repeated after the wind farm has been established.

As the construction of the wind farm does not seem to affect the sand eel population in the Horns Rev area and commercial sand eel fishing does not seem to take place in the wind farm area construction of the wind farm is not likely to have any effect on commercial fishing of sand eels in the Horns Rev area. An exception might be where the submarine cable from the wind turbines crosses sand eel fishing grounds if fishing in these areas will be hindered.

2.5.4 Results for the clam Spisula solida

The abundance of the clam Spisula solida was several thousand times higher in 1993 compared to 2002 at Horns Rev within the wind farm area and control areas. Whether an abundance that high of clams will appear at Horns Rev again in the future is difficult to foresee, but the potential is present in the form of preferred sediment type by the clams - coarse grained sand with a grain sizes around 2 mm. In areas with this sediment type the highest abundances of clams was found in the 1993 survey.

Size and weight distribution

The wind farm area: Very few *Spisula solida* (n = 25) were found in the wind turbine area (26.5 km^2) in March 2002. Out of 9 stations examined (stations 4, 14, 15, 19, 29, 33, 38, 56 and 57) *S. solida* was found in 8 stations. At each station 5 replicate 10 minute dredge hauls were taken using a special sand eel dredge developed by DIFRES. *S. solida* was found in 16 hauls out of 45.

The control area: Only three *S. solida* was found in the three dredge stations in the control area west of the farm area.

The estimated biomass of *S. solida* at the wind turbine and the control areas was around 4 kgs of *S. solida* pr. km^2. In all the estimated biomass of *S. solida* in the wind turbine area was 104 kgs (26.5 km^2) and in the control area only 4 kgs (1 km^2).

Conclusion: In March 2002 the stock of *S. solida* in the wind turbine area was of no commercial interest. Previous stock has been of commercial interest since the early 1990's (see chapter below). There is therefore a possibility that a commercial biomass of clams (*S. solida*) may appear in the future at Horns Rev and so also in the wind farm area, however how soon and how large is difficult to predict.

2.5.5 Results for other animals

Fifteen fish species, two shrimp species, and eight bivalve species were found in the samples taken in February and March 2002. The most common fish species found was greater sand eel (*Hyperoplus lanceolatus*) in the wind turbine area (a little less in the control area). The second most common fish species was the sand Gobi (*Pomatoschistus minutes*) with a number of around 3.000 pr. km^2 in both the wind farm area and the control area. Dab (*Limanda limanda*) and plaice (*Pleuronectes platessa*) were just as common between 1.300 and 1.800 pr. km^2. All other fish species at Horns Rev were around a few hundred pr. km^2. The number of fish observed is less than observed in the period 1989 –1999 but the species observed are the same. The differences in the observed amount may be due to the use of different sampling methods in this survey and in the 1989-1999 survey.

Shellfish species found in the wind farm area and control area were taken with a van Veen grab (0.2 m^2) sampler in March 2002.

The most abundant shellfish species were brown shrimps (*Crangon crangon*) and bivalve *Syndosmya (Abra) alba* at a number of around 31.000 and 16.500 pr. km^2 respectively. The clam (*S. solida*) was observed in a number of 1.300 pr. km^2, which is much lower than observed in 1993 when the number observed was approx 17.000 pr. km^2.

2.5.6 Deviations from the programme

Originally only one survey was planned, but due to weather conditions three surveys were used to complete the field sampling programme.

2.5.7 Conclusions

Sand eels

The construction of the wind farm is not supposed to effect the sand eel population in the Horns Rev area because the impact area seems to constitute a small fraction of a larger area with sand eel habitat. However, within the wind farm area sand eel abundance might be affected if the surface sediment changes due to the construction of the wind farm or if the abundance of sand eel predators increase in the impact area after the wind farm has been built (the so-called artificial reef effect). To investigate if these effects will occur the field programme that was carried out in February/March 2002 will have to be repeated after the wind farm has been constructed.

Shellfish

The most common species of shellfish on Horns Rev in both the wind farm area and control area was brown shrimps (*Crangon crangon*) at an abundance of between 15.000 and 31.000 pr. km^2. *Syndosmya (Abra) alba* a small bivalve was observed at an abundance of around 16.500 pr. km^2 in the wind farm area and around 2.500 in the control area. The clam (*Spisula solida*) was observed at an abundance of 1.300 pr. km^2, which is much lower than observed in 1993, when the abundance were around 17.000 pr. km^2. Potentially a high abundance of *S. solida* may appear in the future, but how soon and how large is difficult to predict from the data compiled in this report.

Other animals

Fifteen other fish species besides sand eels were observed in the dredge samples taken on Horns Rev in February and March 2002. The most common species were *Pomatoschistus minutus* at a number of around 3.000 pr. km^2. Plaice (*Pleuronectes platessa*) was observed in a number of around 1.800 pr. km^2, dab (*Limanda limanda*) in a number of around 1.300 pr. km^2 and *Calloinymus lyra* at a number of around 1.600 pr. km^2. The other fish species were observed in a number of around a few hundred pr. km^2.

3. Conclusion

This annual report, which is a baseline and/or an evaluation of the effects of construction phase, is based on extracts from our consultants' annual reports. These annual reports are individual reports, in which surveys have been made during the year 2002 and reported in the beginning of 2003. Detailed information on methods, programmes and conclusions can be found in these reports.

In general it should be noted that apparently the construction phase has not had any unintended effects on the parameters surveyed. Therefore we can also conclude that the protective measures established by Elsam, especially scaring devices/ramp-ups for marine mammals, have had the intended effect.

Especially interesting parameters that should be mentioned are:

Birds:
The seagull species 'Herring Gulls' was found to be attracted by the wind farm during the construction period. The number of Divers has decreased, however statistically this decrease is very small as very few Divers have been observed under the baseline.

Porpoises:
Porpoises generally stayed away from the construction area during pile driving. This effect was intended and scaring devices were deployed in order to ensure that the animals' hearing was not permanently damaged.

Seals:
The purpose of the programme has not been to show statistically significant effects during the construction phase. The purpose was to get an idea of their behaviour during the construction phase – within the wind farm as well as on the reef. It has been concluded that Horns Rev is not used as a foraging area as much as expected. It is used as transit area for bigger foraging sites in the North Sea.

Sand eels and Spisula:
A baseline survey of sand eels within the wind farm area has been made. It is shown that sand eels are found in the wind farm area. Spisula have been found in the wind farm area but not in the amount expected.

Hard substrate habitat:
Baseline surveys on fish have been made during the spring of 2002. The programme regarding the effects on the fish is not expected to continue.

References

1. Base-Line investigations of birds in relation to an offshore wind farm at Horns Rev, and results from the year of construction. NERI report 2003

2. Effects on birds of an offshore wind farm at Horns Rev: Environmental impact assessment. NERI report 2000.

3. Environmental impact assessment. Investigation of marine mammals in relation to the establishment of a marine wind farm at Horns Rev. Fisheries and Maritime Museum, Esbjerg, Ornis Consult A/S and Zoological 'Museum, University of Copenhagen, 2000.

4. Havmøller Horns Rev. Vurdering af virkninger på miljøet. VVM-redegørelse. Maj 2000, Elsamprojekt 2000.

5. Elsam. Offshore Wind Farm. Horns Rev, "Annual Status Report for the Environmental Monitoring Programme", 1 January 2002 – 31 December 2002

6. Sand eels and clams (*Spisula* Sp.) in the wind turbine park at Horns Reef. Danish Institute for Fisheries Research. Department of Marine Fisheries. April 2003.