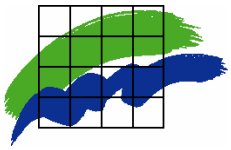

# Summary on seal monitoring 1999-2005 around Nysted and Horns Rev Offshore Wind Farms

## Technical report to Energi E2 A/S and Vattenfall A/S

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# Contents

# 1 Summary

Between 1999 and 2005 harbour seals and grey seals were studied to evaluate their use of Horns Rev and Nysted wind farms and the surrounding areas. Further the effect of construction and operation on resting behaviour on land and population development of seals in the general area was investigated. Both wind farm areas were part of much larger foraging areas. No general change in behaviour at sea or on land could be linked to the wind farms. The only effect detected on land was a reduction in seals resting on land during pile drivings at Nysted Offshore Wind Farm. Ship surveys observations at Horns Rev Offshore Wind Farm supports this observation, as no seals were observed in the wind farm during pile driving.

# 2 Background

In 1996 in the wake of the Kyoto summit the Danish government passed an action plan for energy: Energi 21, in which it was decided to establish 5,500 MW of wind power in Denmark before 2030, 4,000 MW of which was to be established as large scale offshore wind farms. This decision was followed by action in 1998 where the Minister for Environment and Energy commissioned the Danish power companies to establish 750 MW of offshore wind power in Danish waters as a demonstration project. The aim of the project was twofold: 1) to test the feasibility and economy of large scale offshore wind power and 2) to address potential negative effects on the marine environment by establishment of an ambitious environmental monitoring program. The demonstration project includes two wind farms (a total power of 326 MW) one at Horns Reef in the North Sea (Horns Rev Offshore Wind Farm, 80 turbines of 2 MW) and one in the south-western Baltic (Nysted Offshore Wind Farm, 72 turbines of 2.3 MW).

Horns Rev Offshore Wind Farm came in operation by the end of 2002, while Nysted Offshore Wind Farm was operational from December 2003. Initial problems with the turbines at Horns Rev resulted in a high level of activity during most of 2003 and 2004. We therefore refer to the period 2003-2004 as "semi-operation" due to the higher level of disturbance of the animals compared to the normal from 2005 and onwards.

The Environmental Impact Assessments on seals for the two wind farms (Dietz et al. 2000; Tougaard et al. 2000) were completed in 2000 following the guidelines jointly drafted by the Danish Energy Agency and the National Forest and Nature Agency. Since 1999 studies on the distribution and behaviour of the local seal stocks have been studied to evaluate the effect of the wind farms. This report summarises and compares the main results from the demonstration programs and the significance of these results for other wind.

# 3 Seals in the areas around the two wind farms

Harbour seal (*Phoca vitulina*) and grey seal (*Halichoerus grypus*) are the two seal species breeding in Danish waters. The harbour seal is far the most common and breeds on remote sand bars, stone reefs and island all around Denmark, with the exception of the waters south and west of Fyn. The grey seals are occasionally observed at several of the Danish harbour seal sites but it

only breeds in few numbers on Rødsand in the south-western Baltic. The total population of harbour seals in Denmark is about 12,000 individuals while grey seals only number about 50 animals in 2005, however, there are indications that the grey seal population is increasing. (Teilmann unpublished data).

Based on geographic distance and separation, Danish harbour seals are divided into five management areas: The Wadden Sea, Limfjorden, Kattegat, Samsø Belt and south-western Baltic (Jepsen 2005). Based on genetic differences, Olsen (2006) found that the five management areas consist of four populations in that Kattegat and Samsø Belt is part of the same population. Furthermore the genetic results indicate that there is some movement and exchange between the four areas.

When the environmental impact assessments for Nysted and Horns Rev were made, little information was available on seals in the immediate vicinity of Horns Reef and Nysted. It was well known that harbour seals were resting on land sites in the Wadden Sea 20 km and more from Horns Reef and harbour seals together with grey seals 4 km north of the Nysted wind farm area hauled out at Rødsand seal sanctuary and Vitten. From previous studies with radio-transmitters on seals from the Wadden Sea, it was assumed that the shallow areas of Horns Reef could play a central role in foraging for the harbour seals (Nørgaard 1996). The main objective of the monitoring of harbour seals at Horns Reef was thus to establish the importance of the wind farm area and the reef as a whole for foraging of harbour seals from the Wadden Sea. This objective was also part of the program at Nysted, with the important additional question of whether construction and operation of the wind farm influenced the haul out behaviour of harbour and grey seals on the important resting site in the close by Rødsand seal sanctuary.

Interpretation of results from both studies is affected by the general increase in the Danish harbour seal population. Since 1976-77 where hunting was abolished the population has increased with an average of 10-15% annually, only temporarily disrupted by outbreaks of phocine distemper virus disease in 1988 and 2002 (Härkonen et al 2006).

## 3.1 Nysted Offshore Wind Farm

Based on the number of seals on land, Rødsand is considered the most important haulout (places where seals rest on land) and breeding site for harbour seals in Denmark (Teilmann & Heide-Jørgensen 2001).

In summer 2002 all harbour seal colonies in Denmark were hit by a measles-like seal epidemic (phocine distemper virus, PDV; Härkönen et al. 2006). The virus was not lethal to the grey seals. The calculated mortality of harbour seals were about 20% in south-western Baltic. Unfortunately the epidemic occurred simultaneously with the start of construction of Nysted Offshore Wind Farm during the summer 2002. The effect of the construction on the number of animal in the area in 2002 can therefore not be separated from the effect from the epidemic at Rødsand, except when comparing the relative number compared to other haulout sites. However, seals were only affected by the epidemic in 2002 and the population size was almost back to pre-epidemic level in 2003. Therefore possible effects of the wind farm in 2003 and thereafter are considered to be independent of the epidemic.

Rødsand seal sanctuary and the scattered rocks at Vitten and Flintehorne Odde are the seal haulout sites closest to the wind farm (4-5 km north of the wind farm, see Fig. 1) and therefore were expected to be most affected by the construction and operation of the wind farm. The reaction of the seals towards construction and operation of an offshore wind farm, which was considered

possible, is that the seals would use alternative haulout sites or spend more time in the water, as entering the water is the normal escape reaction to all disturbances. Even if the disturbance at the haulout sites has no effect in itself, the physical presence of the wind turbines and the noise from turbines, ships and construction work may lead to temporary or permanent loss of habitats in and near the wind farm. This may result in seals exploring new foraging areas and using haulout sites further away from the wind farm. This worst case scenario formed the basis for design of the monitoring program.

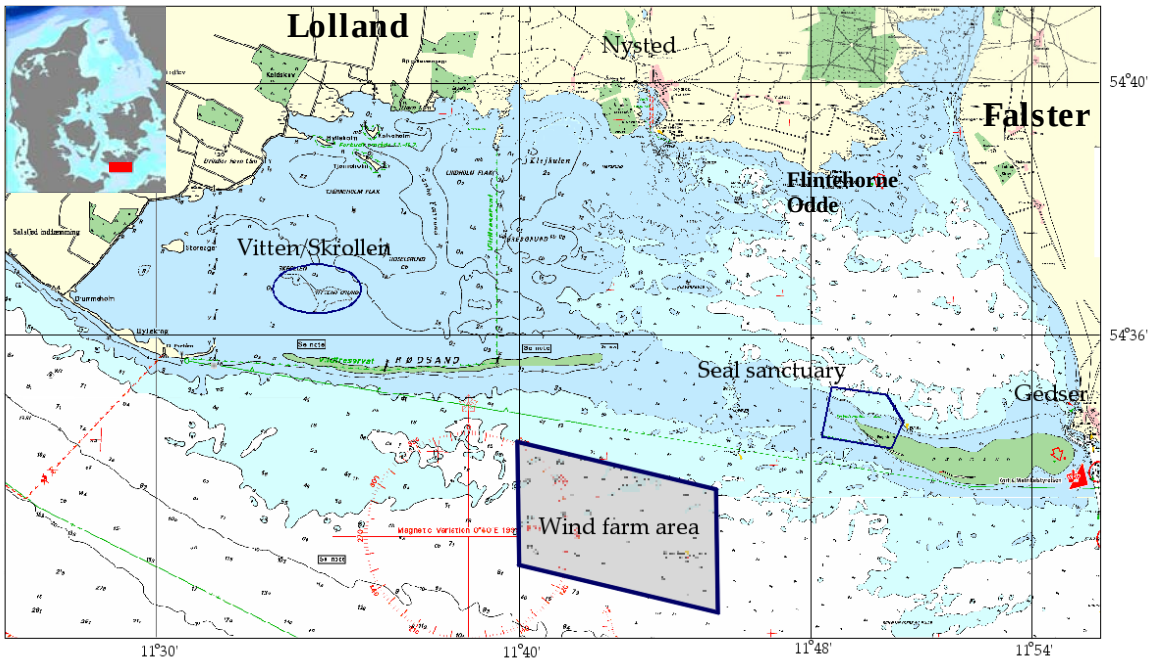


***Figure 1.*** *Map of study area showing the wind farm and the three seal sites in the area: Rødsand seal sanctuary, Vitten/Skrollen and Flintehorne Odde.*

## 3.2 Horns Rev Offshore Wind Farm

The Danish Wadden Sea is the only breeding area for harbour seals on the Danish west coast and also the only area where harbours seals haul out regularly in larger numbers. The shortest distance from the Wadden Sea to the wind farm is about 20 km. The only true haulout site outside the Wadden Sea is close to shore at Blåvands Huk (15 km from the wind farm), where up to 50 seals have been counted at the same time. No breeding has been observed on this site, however.

As in the Baltic the harbour seals in the Wadden Sea were hit by the PDV epidemic in 2002. In the Wadden Sea the mortality was much higher than in the Baltic and up to 50% of the seals died (Härkönen et al 2006). This could have resulted in less feeding competition among the seals and hence result in improved foraging areas closer to the land sites, which could have altered the use of the wind farm area. Such an effect would last some years until the population returns to the previous population level and may therefore confound effects from the wind farm.

In recent years two groups of grey seals has established themselves in the Dutch and German Wadden Sea (Härkönen et al. in press). Increasing numbers of grey seals has been observed in the

Danish Wadden Sea and this may lead to breeding individuals in the near future. However, only harbour seals have been monitored at Horns Reef.

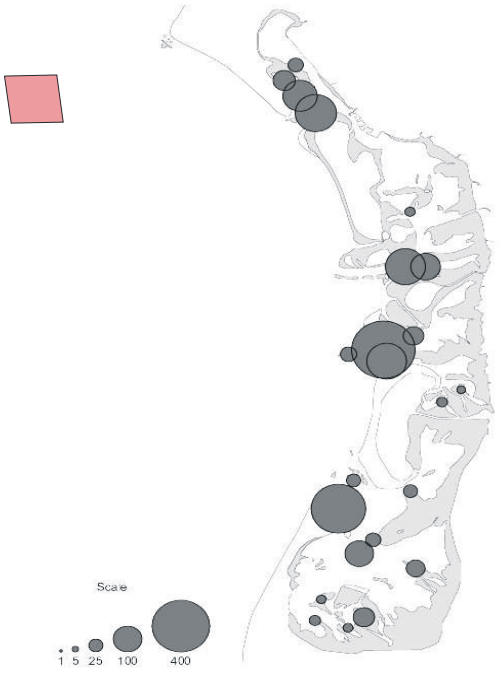


***Figure 2.*** *Harbour seal haul out banks in the Danish Wadden Sea. Circles indicate number of hauled out animals counted on an aerial survey conducted on August 14th 2002, i.e. immediately after the construction period and prior to the PDV outbreak. Red square indicates wind farm area.*

# 4 Monitoring programs on seals

In order to study the possible effects from the construction and operation of the wind farms on the local seal stocks, a number of monitoring programs have been carried out:

**Nysted**

1. Monthly aerial surveys of local and adjacent haulout sites to determine shift in population haulout behaviour.
2. Video and visual monitoring of the seals in Rødsand seal sanctuary, to determine change in haulout behaviour of the seal stock closest to the wind farm.
3. Satellite tracking of harbour and grey seals to determine individual movements and use of the wind farm area.

**Horns Reef**

4. Satellite tracking of harbour seals to determine individual movements and use of the wind farm area.

5. Regular ship surveys to determine the presence of seals in and around the wind farm (conducted in connection with the harbour porpoise monitoring).

As the spatial resolution of the methods used was not sufficient to describe movement patterns and behaviour within the wind farms, we did not evaluate the local effects of the wind farms (attraction to or deterrence from individual turbines).

In the following the main results from the five monitoring studies will be given.

# 5 Results

## 5.1 Aerial surveys in Southwestern Baltic

South-western Baltic contain of 6 main harbour seal localities, 2 sandbars (Rødsand and Falsterbo, southern Sweden), and 4 clusters of large scattered stones in shallow water (Saltholm, Bøgestrømmen, Vitten/Skrollen and Avnø Fjord). These seal localities constitute one population unit with limited exchange to other harbour seal populations in the Baltic proper and Kattegat.

### 5.1.1 Monthly surveys

The number of seals on land shows a clear seasonal variation, with fewer seal during winter and more during summer. As also revealed by the video monitoring (Edrén et al. 2005) only few seals were observed at Rødsand during late autumn, winter and early spring. The number of seals peaked in August. The same general pattern was seen at Falsterbo, Avnø, and Bøgestrømmen, while Saltholm and Vitten show a more variable pattern with relatively more seals during spring (Fig. 3 and Teilmann et al. 2005). This probably means that some harbour seals are moving between sites at certain time of the year to breed, utilise better food resources or rest at more undisturbed or protected haulout sites.

Grey seals were only seen at Falsterbo and Rødsand. A maximum of 23 grey seals were observed at Rødsand in June 2005. The maximum at Falsterbo was 131 in May 2005. Although the maximum number of grey seals was found in 2005 there were no significant trend in observations during 2001-2005. The satellite tracking of grey seals have revealed that Rødsand and Fasterbo are interconnected and part of a larger dispersal complex including a significant part of the Baltic (Dietz et al. 2003).

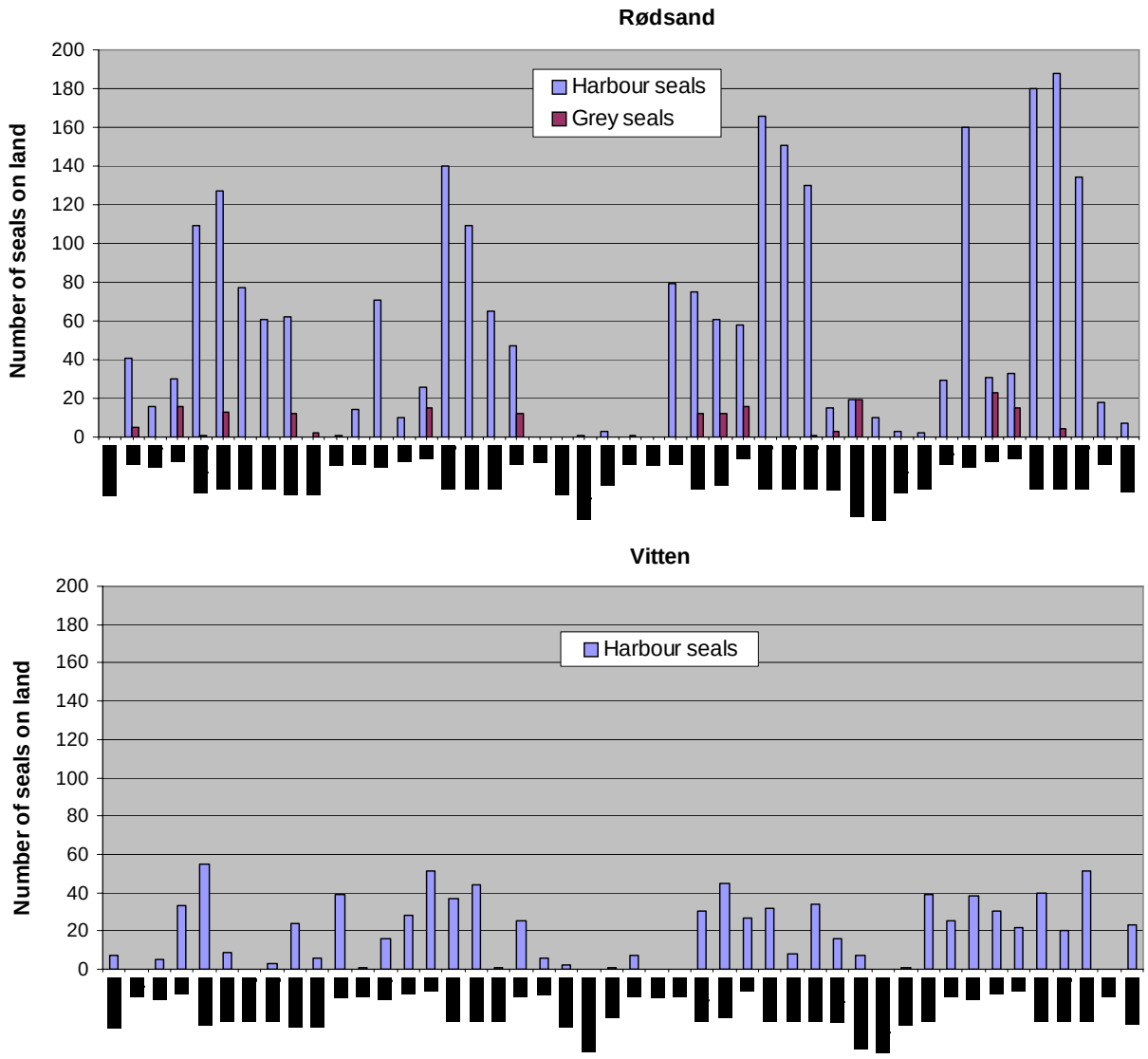


***Figure 3.*** *Results for monthly aerial surveys in south-western Baltic from March 2002 to October 2005. Only Rødsand and Vitten close to the Nysted Offshore Wind Farm is shown. No correction for seals in the water was made. Note that some months are missing and that additional surveys were conducted in late August.*

### 5.1.2 Annual trend

The annual surveys in August represent the best estimate of the population size, because a high and stable number of harbour seals rest on land while moulting. Since 1990 seals have been counted in August as part of the national monitoring program and was used as baseline data. In August, Rødsand had the largest stock of harbour seals. The number of seals at Rødsand, Avnø, and Falsterbo has gradually increased since 1990 except for 2002, when the seal epidemic caused a mortality of about 20% (Fig. 4). The total number of seals had an exponential increase of 8% from 1990-2000 and an increase of 16.7% from 2003-2005. This shows that the population recovered well after the epidemic and that in 2005 the population reached the highest number since countings began in 1990.

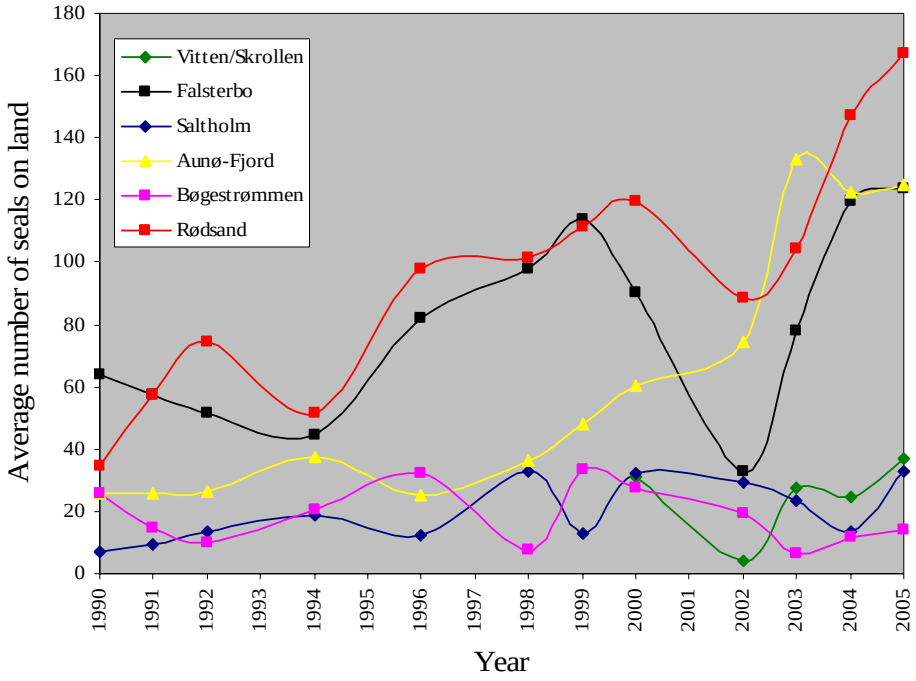


***Figure 4.*** *Annual mean number of harbour seals from the 6 most important localities in south-western Baltic. Each point is an average of the three (except for 1990: 5 and 2002: 4) counts made in late August each year. No correction for seals in the water is made.*

### 5.1.3 Relative importance of Rødsand

The relative importance of Rødsand compared to the other four most important seal localities in the area (Avnø, Bøgestrømmen, Saltholm, Falsterbo (Vitten is not included in this long-term analysis as monitoring first started here in 2000)) was relatively constant around 30-35% (Fig. 5) with the exception of 1990 and 2003 where only 24 and 27% of the seals were found at Rødsand, respectively. During the operation of the wind farm in 2004 and 2005 the proportion at Rødsand increased to 34 and 33%, respectively, making it the most important seal site in south-western Baltic again.

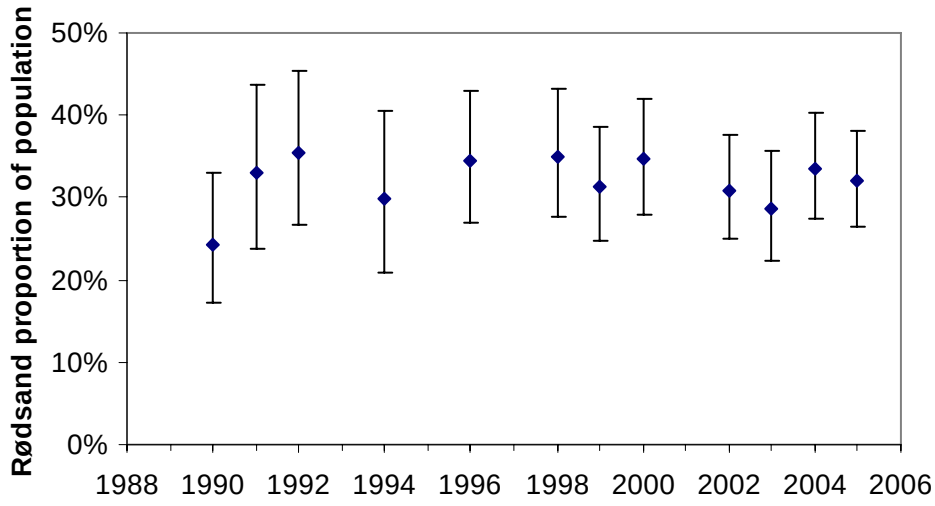

***Figure 5.*** *Estimated proportion of seals at Rødsand in August relative to all five localities (Rødsand, Avnø, Bøgestrømmen, Saltholm and Falsterbo). The error bars show the 95% confidence limits of the estimated proportions.*

### 5.1.4 Potential shift in seasonal proportion

The potential shift from baseline to construction and operation periods taking inter-annual variation and seasonal variation into account was analysed.

The proportion of seals at Rødsand relative to the other localities, analysed on a monthly basis, changed significantly between baseline, construction and operation (p=0.0136). Although there was no general significant change over the year there is a strong seasonal variation with the lowest proportion of seals at Rødsand in February and October followed by January and September. The highest proportion of seals was found on Rødsand in May and August (Fig. 6).

In May the proportion of seals in the baseline was significantly lower than in the construction period (p=0.0210) and in the operation period (p=0.0098). In June the proportion of seals at Rødsand was higher in the operation period compared to both the baseline (p=0.0679) and the construction (p=0.0873). These results indicate that the Rødsand seal population is likely to have increased relative to the other locations during the operation period for the months of May and June, but no change was found for the other months. This could be a result of seals being attracted to the Rødsand area after the wind farm was built.

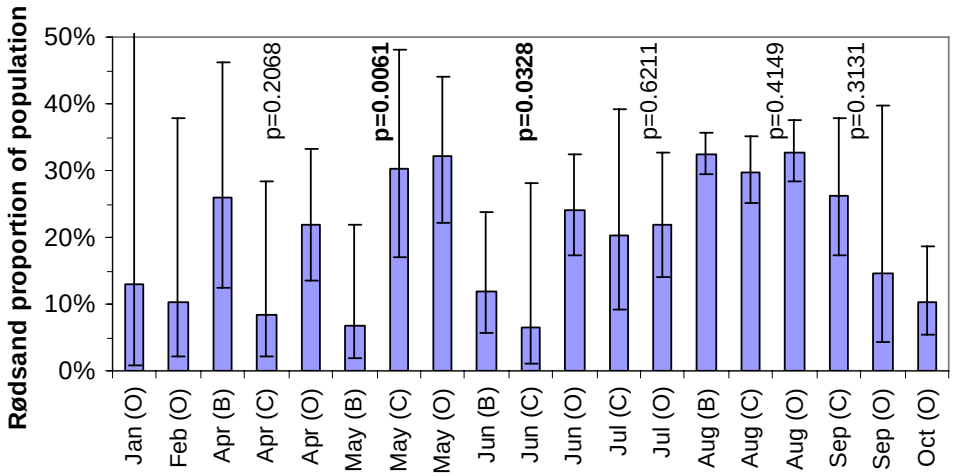


***Figure 6.*** *Estimated proportion of seals at Rødsand relative to all six localities for January-October (Rødsand, Vitten, Avnø, Bøgestrømmen, Saltholm, Falsterbo) by months for baseline (B), construction (C) and operation (O) periods. The error bars show the 95% confidence limits of the estimated proportions. Differences in proportions between the periods were tested for each month by calculating the contrast between estimates (p-values are given above the respective bars, significant tests are given in bold). Note that the test statistics are only given for April, May, June, July and August, and September where surveys were conducted (or more than 0 seals were observed) in minimum two of the three periods (baseline, construction, operation).*

## 5.2 Video and visual monitoring of seal on land at Rødsand

A remote-controlled web-based camera system was used to monitor the seals in daylight hours. Two cameras were mounted on a 6 m high tower in Rødsand seal sanctuary in March 2002. The tower was placed about 300 m from the seals preferred haul-out site without any notable effect on the seals. The camera systems, powered by solar and wind energy were designed to operate under extreme weather conditions. Live images were transmitted to a land station, from where it is streamed to the Internet. In addition to the video recordings the system stored pictures every 5 seconds.

The video registration of the seals at Rødsand seal sanctuary proved to be an efficient method for analysing the effects of the Wind Farm on seals on land. We believe that the stationary camera tower caused no disturbance to the seals, as no reaction from the seals was observed during installation and service visits.

During the baseline period (19 June – 31 August 2001) hourly counts of seals were made in daylight hours from a bird observation tower. The tower was placed on shallow water 1.1 km from the haul-out site in Rødsand seal sanctuary.

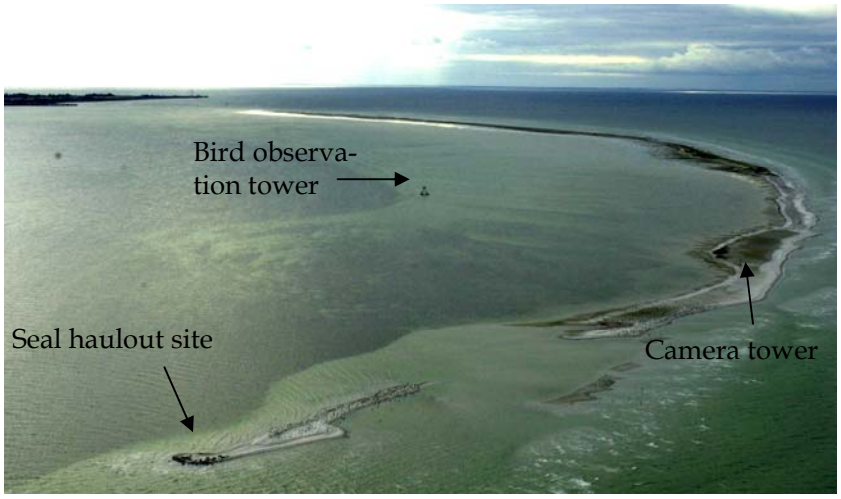


***Figure 7.*** *The sandbank at Rødsand with the seal sanctuary and seals on land in the lower left corner. The camera tower and bird observation tower is shown with arrows. Gedser harbour (about 7 km from the seals) is seen in the background.*

The seasonal variations in the presence of seals in the Rødsand sanctuary were clearly distinctive with a generally low presence during winter months increasing in spring and reaching its maximum in August, when seals were almost permanently present on the sand bank. The diurnal variation showed the highest presence in the middle of the day.

An increased number of seals were on land during southerly winds around 4-8 m/s. Wind speed between 0 and 10 m/s generally correlated with high abundance, few seals were counted on land in strong winds (Edrén et al. 2005).

There was no change in the disturbance rate (seals fleeing into the water) between baseline, construction and operation periods. To avoid disturbance from boat traffic, a regulation from the wind farm company forced service vessels to pass south of the sanctuary in adequate distance. This regulation seems to have benefited the seals, as they often flee into the water when larger ships pass to close to the sanctuary.

The number of seals on land increased 12.5% from the baseline to the construction period. Seals were observed in both the baseline and the construction period for 5 out of 12 months. During the construction years 2002-2003 a significant decline in the number of seals on land were observed from April 2002 to April 2003, whereas data from May, June and July all showed an increase from 2002 to 2003. No significant differences were found in August. This suggests that the construction of the wind farm approximately 4 km away from the seal sanctuary in general had no or only little effect on the presence of seals on land.

Despite the seal epidemic in 2002, the seals increased in numbers at Rødsand from the baseline (2001) to construction (2002-2003), which suggest that there has been no overall negative effect of the construction work on the number of seals at Rødsand. This is consistent with the aerial survey data.

There was, however, a significant decrease in the number of seals on land during sheet pile drivings carried out at a single foundation located approximately 10 km SW of the seal sanctuary (Edrén et al. 2005). The least effect was found during the moulting period in August where the seals are strongly attached to land. The strongest effect was observed in November, where fewer seals show less affinity to being on land. During the sheet piling operations the seals may have stayed in the water, which is a safer environment to them or, have left the area or chose other haul out sites further away from Rødsand during this period.

During the piling at the wind farm an underwater seal scarer and porpoise pingers were used to deter animals away from the immediate vicinity of the site before the actual piling started. Short term sheet piling at Gedser harbour and lighthouse (not connected to the wind farm) did not affect the seals on land negatively.

Detailed baseline observations from the bird tower in June-August 2001 and video countings during the operation phase in June-August 2004 showed an overall significant increase in numbers of both harbour and grey seals (Fig. 8). However, this covers significant differences by month where harbour seals declined in numbers in June, but increased in July and August from baseline to operation. The decrease in June during operation could be due to fewer seals breeding at Rødsand, while more seals used Rødsand during resting, mating and moulting in July-August. For grey seals the numbers increased in June and July, but decreased in August.

The general increase in number of both harbour and grey seals lies within natural reproduction but whether there are any positive effects by the wind farm, e.g. by creating an artificial reef that attracts more fishes, remains to be investigated.

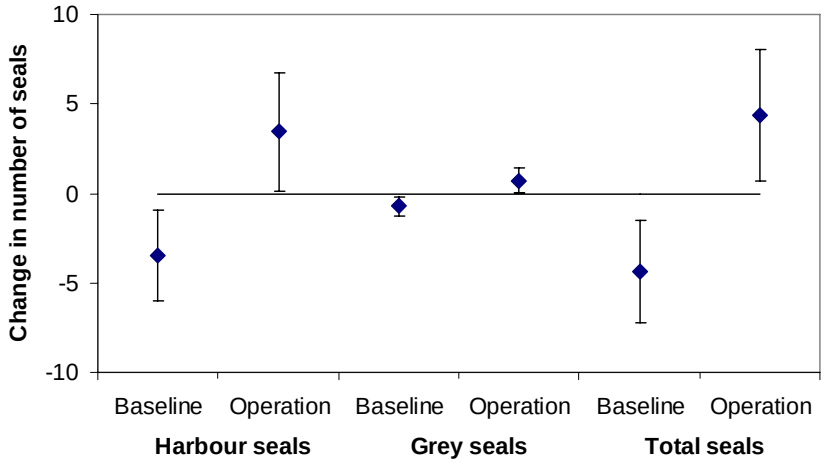

***Figure 8.*** *Estimated change in number of seals on land during baseline and operation for harbour and grey seals and total number of seals. Error bars mark the 95% confidence intervals of the estimates.*

Two, two and one grey seal pups were recorded in 2003, 2004 and 2005, respectively. This is the first time for decades that the grey seal has been breeding on a regular basis in Danish waters. Both the aerial surveys and the video monitoring showed an increase in the number of grey seals which makes Rødsand seal sanctuary the most important place for grey seals in Denmark. Although there was no regular monitoring of the seals at Rødsand, the first breeding grey seals were documented during the construction of the wind farm and again during operation. This suggests that the wind farm has no negative impact on the grey seals in the sanctuary.

## 5.3 Satellite tracking of harbour seals at Nysted

Five harbour seals and six grey seals were caught and tagged with satellite transmitters in Rødsand seal sanctuary during the baseline period. The seals were followed to investigate their use of the sea around the wind farm and if they had preference for certain feeding areas.

In general the results show that harbour seals stay around Rødsand year round ranging up to about 50 km on foraging trips. While grey seals had an even smaller range when staying at Rødsand but made extensive movements as far as to Estonia for some parts of the year (Dietz et al. 2003; Fig. 9). The observed movements into the Baltic proper during the breeding period can be either regarded as social behaviour around the breeding event, or alternatively and probably more likely, the grey seals are returning to the areas where they were born after spending time exploring new areas or more favourable feeding places in the outskirts of their distribution range.

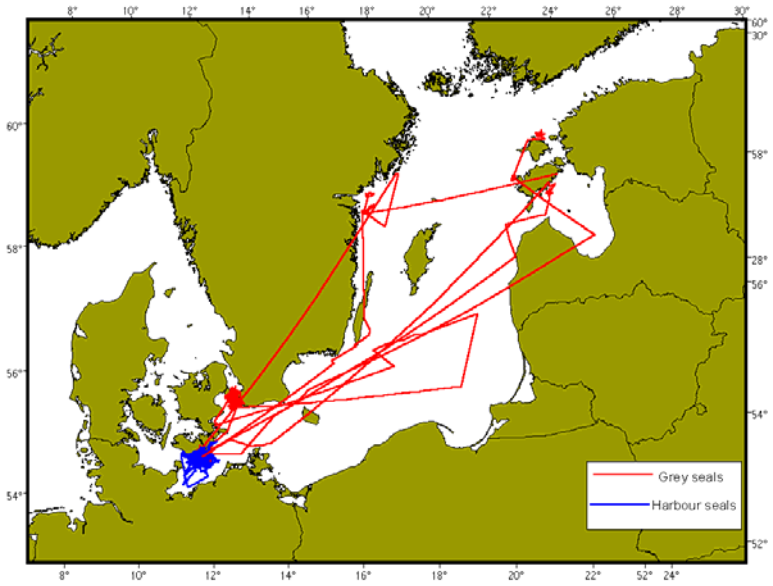


***Figure 9.*** *Movements of all harbour seals (blue lines) and all grey seals (red lines) tracked by satellite during the baseline study at Nysted Offshore Wind Farm.*

### 5.3.1 Use of the wind farm area

Few positions were obtained in the wind farm area during baseline where all tracking occurred. However, all harbour seals had the whole or part of the wind farm area included in their 95% kernel home ranges although only three seals were actually documented to have been in the area (Fig. 10). Based on number of locations, the seals were only seldom present in the wind farm area, as these observations made up only 0.41% of all locations.

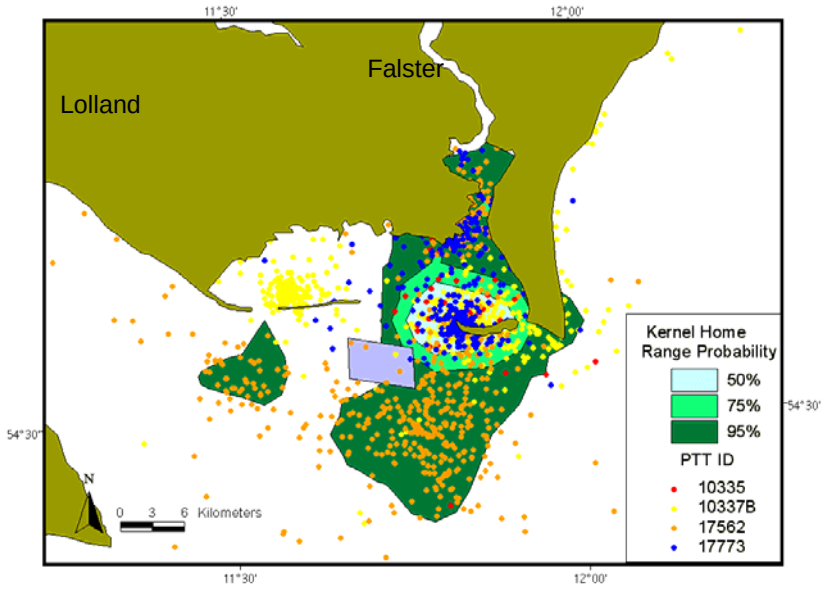


***Figure 10.*** *Locations obtained from satellite tracked harbour seals around Nysted Offshore Wind Farm during the baseline and early construction phase (November 2000 to June 2002). The light blue square indicate the placement of the wind farm. Note the data was obtained before the wind farm was constructed. kernel home ranges indicate the probability that a seal is present within the area at any time.*

The importance of the wind farm area for the grey seals was even lower. Four out of six grey seals had the wind farm area included in their 95% kernel home ranges but only one seal provided one position within the wind farm area making up an average of only 0.07% of all locations (Fig. 11). From the map it is evident that the grey seals spent most of their time in the shallow lagoon north of Rødsand.

The fact that the grey seals move between a number of sites means, that the grey seals may chose alternative areas for haulout and feeding if they are disturbed. In contrast the harbour seals only moved between Rødsand and the other haulout sites in the lagoon north of the wind farm area, which indicates that they do not use alternative haulout areas.

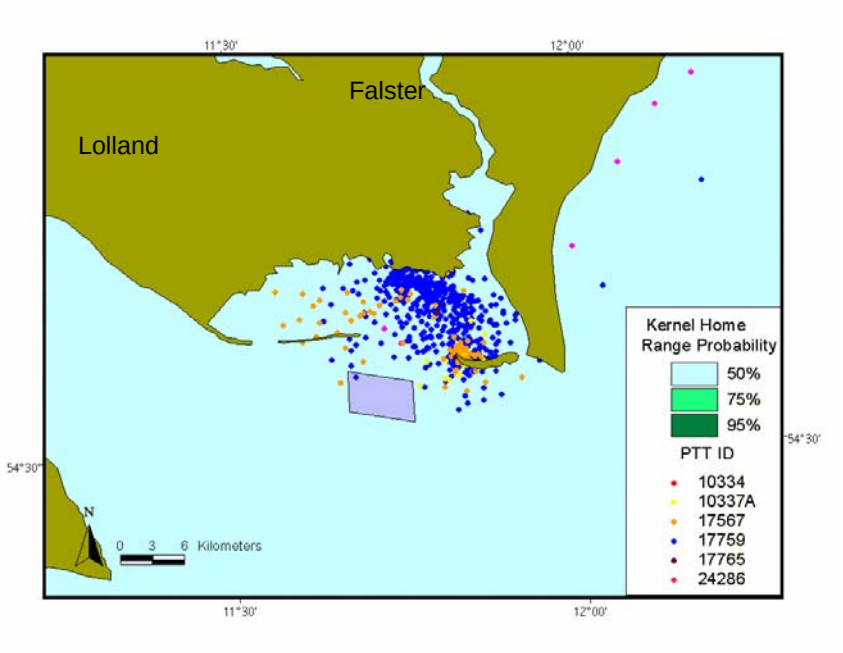


***Figure 11.*** *Locations obtained from the satellite tracked grey seals around Nysted Offshore Wind Farm during the baseline and early construction phase (November 2000 to June 2002). The light blue square indicates the placement of the wind farm. Note the data was obtained before the wind farm was constructed.*

## 5.4 Satellite tracking of harbour seals at Horns Reef

As part of the environmental monitoring program 21 harbour seals were caught in the period 2002-2005 on the island Rømø (about 40 km from Horns Reef) and equipped with satellite transmitters. In addition to satellite transmitters, 21 seals were equipped with a sophisticated datalogger in a co-operation with the University of Kiel. These loggers are capable of collecting high resolution information on the diving behaviour and movement of the seals. To get the data the loggers have to be retrieved from the coast, where they wash up. The loggers are timed to be released after about one month. At present, 7 of the deployed loggers have been retrieved. The primary aim of the investigations was to quantify the importance of Horns Reef as foraging area for harbour seals from the Danish Wadden Sea. A secondary aim was to determine whether seals were present in the wind farm after construction and whether their behaviour was affected by the presence of the turbines.

### 5.4.1 Foraging areas of harbour seals from the Wadden Sea

The study documented that harbour seals from the island Rømø are primarily foraging outside the Wadden Sea in the period September to July. Individual seals appear to have strong preference for smaller, confined areas, which they will return to again and again on their foraging trips. The combined picture of all the tagged seals however, shows a more or less even distribution of seals primarily in an area from Rømø out to approximately 100 km from shore, stretching from Holmslands Klit in north to south of the Danish-German border (Tougaard et al. 2006). Horns Reef and thus also the wind farm is located in the centre of the foraging area of the seals from Rømø and the area is thus of importance to the seals. However, the reef or the wind farm area is only part of a greater area utilised by the seals.

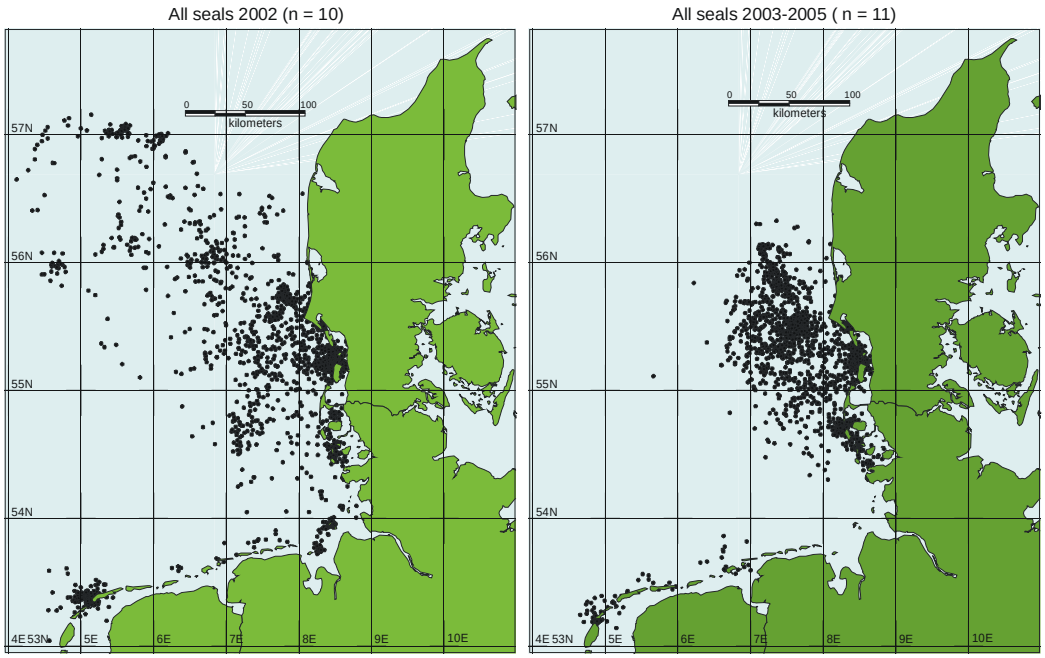


***Figure 12.*** *All ARGOS positions (after filtering) from seals tagged in 2002, covering baseline and construction (left) and seals tagged in 2003-2005 after completion of wind farm (right). Each dot represents one position from one seal.*

### 5.4.2 Effects of construction and operation of the wind farm

The accuracy of the positions retrieved from satellite transmitters and dataloggers turned out to be insufficient to conclude with certainty on the degree to which construction of the wind farm has affected the seals. However, one or more of the tagged seals were inside the wind farm area during the period the transmitters were active. The maps in Fig. 13 shows scattered presence around the reef and the wind farm during baseline and construction periods and a more consistent presence during operation of the wind farm. No correction has been made to adjust for the unequal number of animals and positions in the three periods, with the majority of the data falling into the operational period (roughly four times as many days with data as in baseline and construction periods). This bias should be taken into account when comparing the maps. Common for all three periods was a strong presence around the haulout sites Langli Sand, Langjord and especially Bollert on Rømø, where the seals were tagged, but also that offshore presence of the seals concentrate in localised areas. These areas differ between periods and likely reflect differences between individual seals.

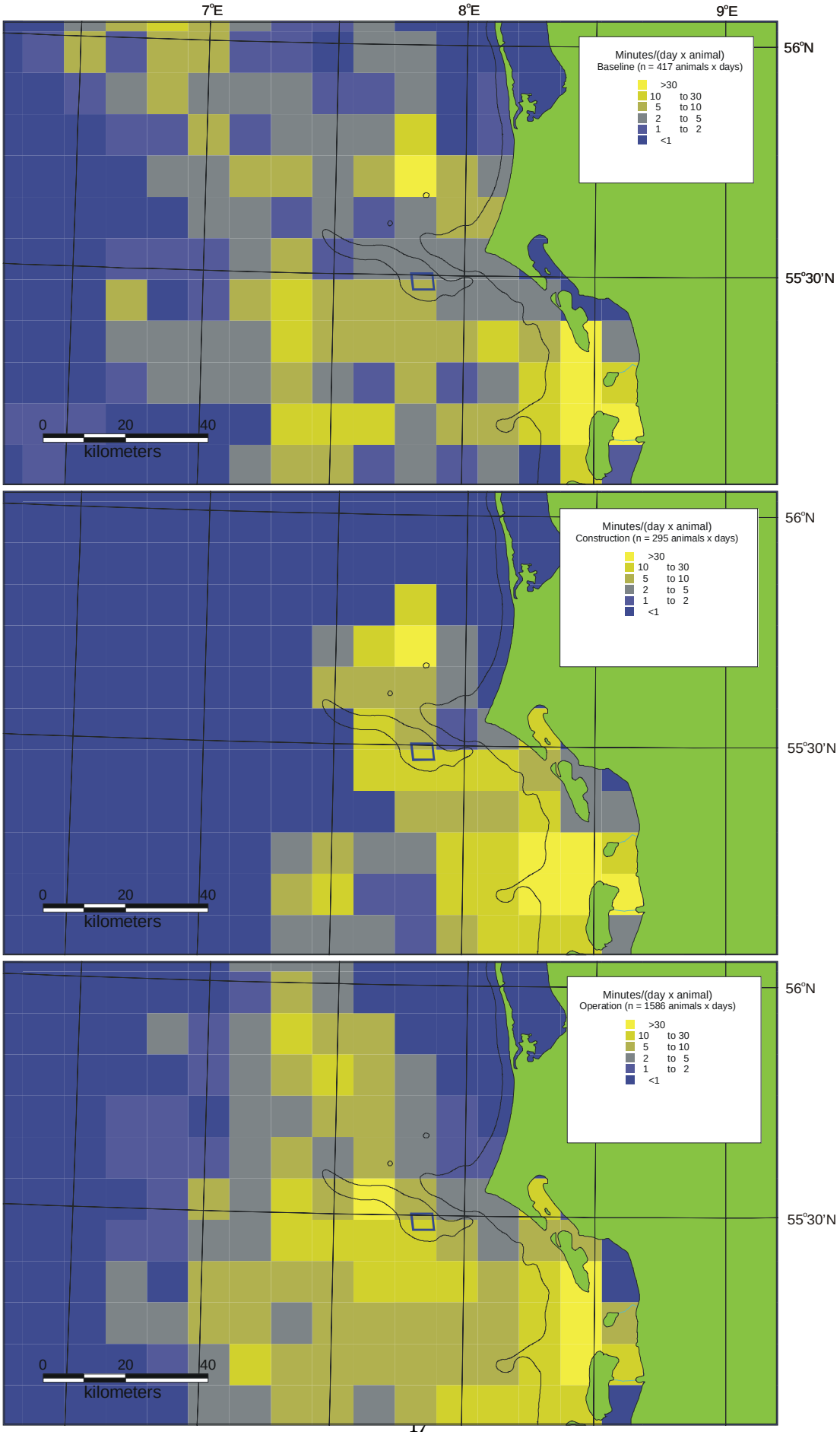
7°E
8°E
9°E
56°N
55°30'N
Minutes/(day x animal)
Baseline (n = 417 animals x days)
>30
10 to 30
5 to 10
2 to 5
1 to 2
<1
0
20
40
kilometers
56°N
55°30'N
Minutes/(day x animal)
Construction (n = 295 animals x days)
>30
10 to 30
5 to 10
2 to 5
1 to 2
<1
0
20
40
kilometers
56°N
55°30'N
Minutes/(day x animal)
Operation (n = 1586 animals x days)
>30
10 to 30
5 to 10
2 to 5
1 to 2
<1
0
20
40
kilometers

***Figure 13.*** *Analysis of time spent in 10x10 km squares, based on linear interpolated tracks between filtered Argos positions. Each value represents the average time (in minutes) spent per day per seal in each of the 10x10 km squares. Analysis was performed separately for positions from baseline (upper), construction (center) and operational period (lower).*

## 5.5 Ship surveys at Horns Reef

Ship surveys were conducted to count harbour porpoises but also seals were observed. Seals were seen consistently on almost all surveys, but always in low numbers, only in few cases more than 10 per day. Determination of species is difficult at sea, and especially young grey seals can easily be mistaken for harbour seals. However, as no adult grey seals were observed, it is assumed that all observations are harbour seals. Due to the low number of sightings and large variation in observations from survey to survey, no statistical test of differences in distribution has been attempted and the maps are presented as a supplement only.

During baseline surveys seal sightings were scattered over the survey area, but also with gaps in some areas without sightings. This is in contrast to surveys during construction and operation, where seals were observed in almost all of the well-surveyed squares. The highest number of seals per unit effort was observed during construction, with lower numbers during operation. This is likely to be fully or partly explained by the development of the seal population in general. In autumn 2002 (i.e. following completion of most surveys that year) there was an outbreak of phocine distemper virus, which killed approximately half of the population and although the population recovered well in the following years, the population is still not up to the level it was in summer 2002.

Visual observations of seals from ship surveys, show that seals were observed inside the wind farm area in numbers not readily different from the surrounding waters. An exception from this was the construction period in spring and summer 2002, where very fewer seals were observed inside and in the immediate surroundings of the wind farm. Furthermore, no observations were made inside the wind farm area on days with pile drivings. Seals were most likely staying away from the construction site due to the very high levels of underwater noise generated by the pile driving operations and the associated mitigation.

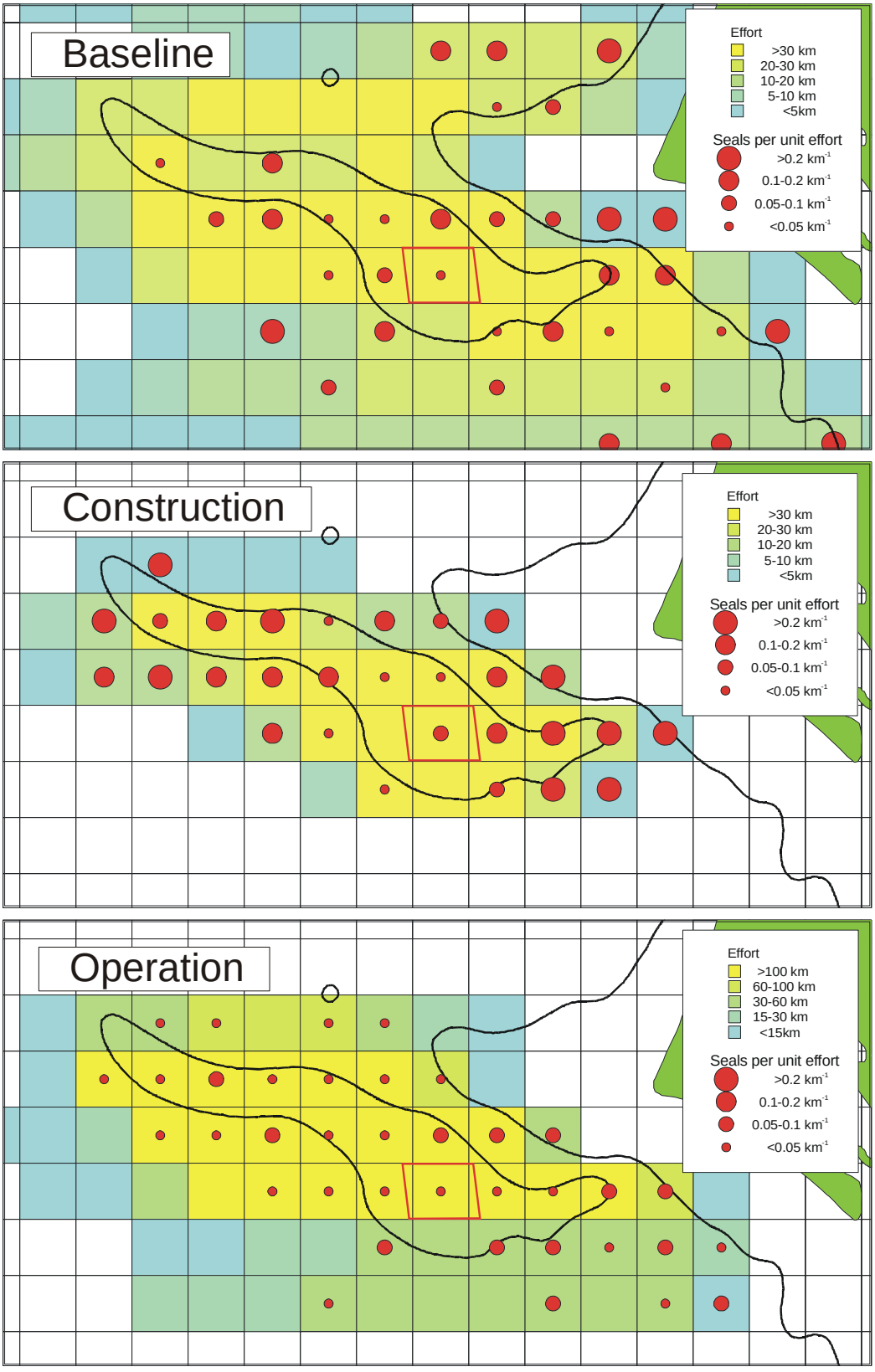


***Figure 14.*** *Harbour seal sightings normalized by effort (kilometers of trackline sailed in each 4x4 km square) at the baseline, construction and operation periods. Note that effort scales differ. Solid black line indicate 10 m depth contour. Wind farm area is indicated by the red trapezoid.*

# 6 Conclusion

The two wind farms are located in very different settings, with Horns Rev placed very exposed in the North Sea and Nysted in a more sheltered location in the Western Baltic. Conditions for seals are also very different in the two areas. The seals around Horns Rev are at the northernmost edge of the distribution range of a very large seal population in the International Wadden Sea. The seals at Nysted are part of a considerably smaller and more isolated population, resident in the area. From the telemetry studies it appears that the active space used for foraging by the seals at Horns Rev is considerably larger than at Nysted. These factors together make the seals at Nysted more vulnerable to disturbances than the seals at Horns Reef. Nevertheless, there seems to be little difference in the way the two groups of seals were affected by the construction and operation of the wind farm.

The seal epidemic in 2002 killed about 20-50% of the Danish harbour seal populations. However, the affected populations in Denmark recovered close to the theoretical maximum rate of increase (about 12%/year) for harbour seals. Also the number of grey seals increased during the study period which coincides with an increase in the Baltic grey seal population. This indicates that the wind farms had no or very limited effect on the population size.

The only negative effects on seals were detected during the pile driving. At Nysted Offshore Wind Farm fewer seals were present on land when pile driving took place. Ship surveys observations at Horns Rev Offshore Wind Farm supports this observation, as no seals were observed in the wind farm during pile driving.

Through the satellite telemetry data we can conclude that both wind farms is part of the foraging areas for harbour seals from Rømø and Rødsand. On the other side it is also clear that the areas utilised by the seals consist of a much larger continuous area of importance, centred on Horns Reef and Rødsand seals sanctuary.

During the most comprehensive study on the effect of wind farms on seals, state of the art technology has been used. This has given us tremendous amounts of data and wealth of new information about the behaviour of both harbour and grey seals and reactions to wind farms. However, the very limited change in behaviour detected, lead to the question if the seals could be affected positively or negatively on a smaller scale. For example if seals are attracted to the foundations where an artificial reef with possibly higher fish abundance is formed or if the noise from the active turbines scares the seals away. The difficulties in following seals with high accuracy inside the wind farm prevented us from monitoring small scale behaviour.

**List of major findings in the studies of harbour porpoises:**

1) Fewer seals were observed on land during pile driving at Nysted.
2) There were indications of a disturbance from pile driving operations at both wind farms
3) No changes in abundance were observed during construction at neither sites.
4) No effects were documented from the operating wind farms.

# 7 References


Dietz, R, J. Teilmann & O.D. Henriksen 2000. EIA study of offshore wind farm at Rødsand. Technical report about seals. Miljø- og Energiministeriet, National Environmental Research Institute: 46 pp. http://www.nystedhavmoellepark.dk/upload/pdf/Seals-UK.pdf

Dietz, R., J. Teilmann, O.D. Henriksen & K. Laidre 2003. Movements of seals from Rødsand seal sanctuary monitored by satellite telemetry. Relative importance of the Nysted Offshore Wind Farm area to the seals. National environmental Research Institute Technical Report No. 429: 44 pp. http://www.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/FR429.pdf

Edrén, S.M.C., Teilmann, J., Carstensen, J., Harders, P. & Dietz, R. 2005. Effect of Nysted Offshore Wind Farm on seals in Rødsand seal sanctuary - based on remote video monitoring and visual observations. Report request. Commissioned by ENERGI E2 A/S. National Environmental Research Institute: 52 pp. http://www.nystedhavmoellepark.dk/upload/pdf/SealsVideo_2004.pdf

Härkönen, T., Dietz, R., Reijnders, P., Teilmann, J., Harding, K., Hall, A., Brasseur, S., Siebert, U, Goodman, S.J., Jepson, P.D., Rasmussen, T.D. & Thompson, P. 2006a. A review of the 1988 and 2002 phocine distemper virus epidemics in European harbour seals. Diseases of Aquatic Organisms 68: 115-130.

Härkönen, T., Brasseur, S., Teilmann, J., Vincent, C., Dietz, R., Abt, K., Reijnders, P., Thompson, P., Harding, K., Hall, A. (In press). Status of grey seals along mainland Europe from the Southwestern Baltic to France. NAMMCO Scientific Publications.

Jepsen, P. 2005. Forvaltningsplan for spættet sæl (*Phoca vitulina*) og gråsæl (*Halichoerus grypus*) i Danmark. Udgivet af Miljøministeriet, Skov- og Naturstyrelsen 2005. J.nr. SN 2001-361-0004. Available at: http://www.skovognatur.dk/Udgivelser/2005/Forvaltningsplansael.htm

Nørgaard, N. 1996. Haul-out behaviour, movenemts, foraging strategies and population estimates of harbour seals (*Phoca vitulina*) in the Danish Wadden Sea. 1996. Zoology, University of Aarhus.

Olsen, M.T. 2006. Genetic analysis of harbour seal (*Phoca vitulina*) population structure and dispersal patterns in Danish and western Swedish waters. Master study from University of Copenhagen.

Teilmann, J. & M.P. Heide-Jørgensen 2001. Tællinger af spættet sæl og gråsæl 2000, Østersøen, Kattegat og Limfjorden. *In*: Laursen, K. Overvågning af fugle og sæler 1999-2000. Faglig rapport fra DMU 350: 84-91. http://www.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/FR350.pdf

Teilmann, J., Carstensen, J., Dietz, R. & Edrén, S.M.C. 2005. Aerial monitoring of seals during construction and operation of Nysted Offshore Wind Farm. Report request. Commissioned by ENERGI E2 A/S. National Environmental Research Institute: 35 pp.
http://www.nystedhavmoellepark.dk/upload/pdf/Seals_2004.pdf

Tougaard, S., Skov, H. & Kinze, C.C. 2000. Environmental Impact Assessment. Investigation of marine mammals in relation to the establishment of a marine wind farm on Horns Reef. Report to ELSAMprojekt. http://www.hornsrev.dk/Miljoeforhold/miljoerapporter/Baggrundsrapport_12.pdf