Effect from the construction of Nysted Offshore Wind Farm on seals in Rødsand seal sanctuary based on remote video monitoring

Technical report to Energi E2 A/S

Susi Manuela Clermont Edrén[1]
Jonas Teilmann[1]
Rune Dietz[1]
Jacob Carstensen[2]
National Environmental Research Institute (NERI)
[1] *Department of Arctic Environment*
[2] *Department of Marine Ecology*

Ministry of the Environment
Denmark
June 2004

Contents

1 Summary

The scope of this report

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

The seasonal and diurnal presence

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 at the sand bank. The diurnal variation showed the highest presence during the middle of the day.

Diurnal and seasonal patterns estimated by a multinomial model

The distinct seasonal and diurnal patterns of seal occurrence were confirmed by the marginal category probabilities derived from a multinomial model. The diurnal variation corresponded to a overall mean of 6.3 seals around noon decreasing to less than 1 in the early morning and late evening by translating the categories into mean number of seal as above.

Seal presence related to wind speed and directions

Southerly winds around 4-8 m/s increased the number of seals on land. If the wind came from the south (S) there would be a yearly mean of 5.0 seals on land, whereas if the wind was from the north (N) there would only be a yearly mean of 1.5 seals on land. The yearly mean number of seals on land increased from 2.0 seals at 0 m/s, reaching a maximum of 3.4 seals at 6.1 m/s and decreased to 0.2 seals at 20 m/s. Wind speed between 0 and 12 m/s generally resulted in high abundance, whereas strong winds did not favour seals on land.

Boating and construction

There was no change in the disturbance rate during the construction period, probably due to a regulation on boats to pass the sanctuary in adequate distance. This indicates that remote boat traffic and other activities that the seals have experienced previously, although intensified during construction did not affect the number of seals on land.

Effect of the construction period

The number of seals on land increased 12.5% from a yearly mean of 2.79 seals in the baseline period to 3.14 seals in the construction period. Five months had seals observations in both the baseline and the construction period, and four of these had a significant difference in the category probabilities for the two periods. There was a decline in the number of seals on land from April 2002 to April 2003, whereas data from May, June and July all showed increases from 2002 to 2003. August was not significant.

Effect of the ramming

There was, however, a significant decrease in the number of seal on land during the ramming periods, that was carried out during at a single foundation located approximately 10 km SW of the seal sanctuary. The observed reduction of seals varied among months ranging from 8 to 100%. When correcting for other variables in the model the reductions varied between 31 and

61%. The seals may have chosen to stay in the water, swim away or haul out further away from the wind farm than Rødsand.

General presence

The construction work on the wind farm situated approximately 4 km away from the Rødsand seal sanctuary had in general no or little effect on the presence of seals. Even two grey seal pups were recorded during the construction period.

2 Introduction

2.1 Background and purpose

Between 2002 and 2003 a sea based wind farm, "Nysted Offshore Wind Farm", consisting of 72 x 2.2 MW wind turbines, were build by Energy E2, SEAS, DONG and Sydkraft 4 km southwest of the seal sanctuary at Rødsand (south of Lolland).

Part of this work is to asses the extent to which the erection of the wind farm in this area will cause measurable, temporary or permanent, changes in the presence and behaviour of harbour seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) in the Rødsand area.

To monitor the diurnal behaviour continuous monitoring is necessary. This can be done either manually or automatically. To reduce manpower and increase data sampling, a year-round remote video monitoring of the seals hauling out in the sanctuary was installed in March 2002. The present report describes the effect of the constructions period on the seals hauling out in Rødsand seal sanctuary.

2.2 Possible effects on seals from establishment and operation of offshore wind farms

It is possible that some of the activities involved in construction and operation of the wind farm will have a negative impact on the seals in and near the wind farm area. The most significant sources of these effects may be the physical presence and the noise from ships and construction work as well as temporary and even permanent loss of habitats near the wind farm.

In order to study the possible effects from the erection and operation of the wind farm on the seal population a number of investigations have been initiated. The remote video camera system will determine the use of and diurnal activity of the seals in the Rødsand seal sanctuary in relation to the construction and from 1 December 2003 the operation of the wind farm. In addition aerial surveys will determine the use of alternative haulout localities, and the satellite telemetry is documenting the general displacement, habitat selection and use of the wind farm area at sea.

3 Description of the offshore wind farm and seal sites at Rødsand

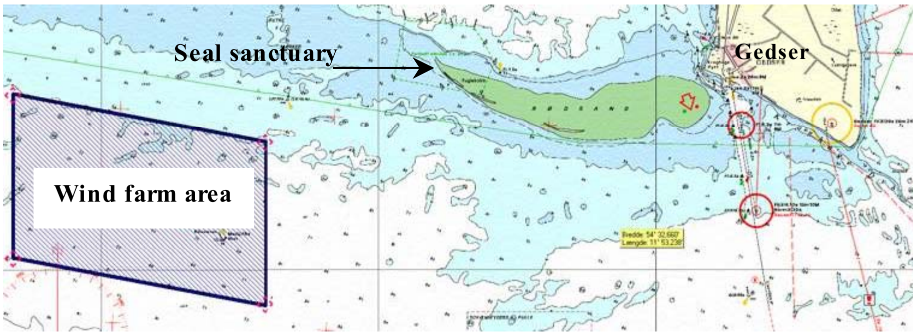

Figure 1. *Map of the wind farm area and the seal sanctuary.*

3.1 The area of the offshore wind farm

Nysted Offshore Wind Farm has been erected in Fehmarn Belt around 10 km south of the city Nysted (Lolland). The water depth of the wind farm is between 5.5 m and approximately 9.5 m. The largest part of the area consists of sand bottom with larger and smaller ridges. In places there are pebbles, gravel or shell. Although there are outcrops of stones >10 cm, no reef-like aggregations have been recorded.

About 2 km north of the wind farm is a shallow (<4m deep) lagoon-like area between Southeast Falster and Southwest Lolland. This area is used by a large number of coastal fishermen mainly using fyke and pound nets. The area also constitutes an ideal habitat for harbour and grey seals, where they go ashore on remote sand banks (Rødsand seal sanctuary) or large scattered stones (Vitten/Skrollen and Flintehorne Odde) away from human disturbance. The wind farm is placed approximately 4 km south-west of the seal sanctuary.

3.2 Seal sites at Rødsand

At the western tip of the Rødsand sandbank (54°35'N, 11°49'E), a seal sanctuary was established in 1978 (Bøgebjerg 1986). The seal sanctuary is protected from all access from 1 March – 30 September in a distance of about 500 m around the western tip of the sand bank (Ministry of the Environment and Energy 1993). The seals prefer the most western tip of the sandbank because currents always keep a deep-water channel very close to the bank where they can rapidly escape. This is the most important haul-out and breeding site for harbour seals in the western Baltic Sea (Teilmann & Heide-Jørgensen 2001). Haul-out sites are important for the breeding, moulting and resting of the seals.

According to fishermen interviewed in the EIA (Dietz et al. 2000) the seals also use the stones around Vitten and Skrollen, near Hyllekrog about 10 km west of the seal reserve. This has now been confirmed by aerial surveys (Teilmann et al. 2004). Throughout the Rødsand lagoon seals are often observed sporadic on rocks and in the water. In the deeper water south of the lagoon fishermen and other users of the area often observe seals, which was confirmed by satellite tracking (Dietz et al. 2000 and 2003b).

The sandbank is flooded in extreme weather and appears to be in a state of constant alteration as a result of currents and sand deposits.

Figure 2. *The sand bank at Rødsand with the seal sanctuary and seals on land in the lower left corner. The bird tower is seen in the middle of the picture.*

4 Materials and methods

4.1 Camera type

The camera system is build by SeeMore Wildlife System Inc., (Alaska, USA, www.seemorewildlife.com). The digital camera system is wireless, solar and wind powered, and designed to operate in extreme foul-weather environments. The cameras are rugged and waterproof (submersible). The cameras have a full Remote-controlled pan, tilt, zoom, auto focus, windshield wiper, squirter, water storage, two-way data transmitters and self diagnostics (Fig. 3). All equipment is designed for remote, 12vdc power.

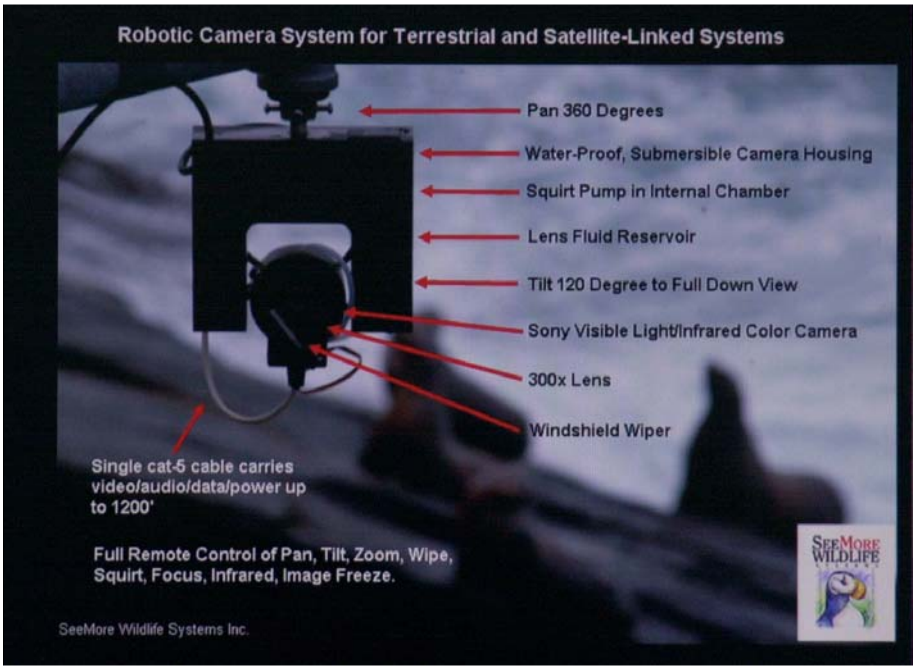

Figure 3. *Camera similar to the ones used at Rødsand (picture from www.seemorewildlife.com).*

The cameras have 360-degree panorama scan and a 120-degree tilt that is remotely controlled over the Internet through specially designed software. This enable us to make regular scans of the surroundings to detect if the seals change haul-out place, zoom in to get detailed counts and species confirmation as well as potentially monitor the cause of disturbances.

4.2 Deployment of cameras

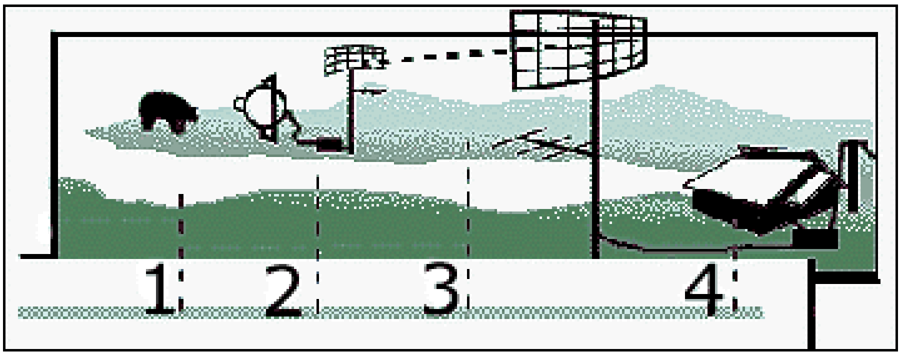

Figure 4. *Schematic illustration of the camera system. 1) Seal sanctuary 2) Tower with cameras, batteries, antennas, etc. 3) Signals are transmitted to and from a receiver in Gedser with the use of microwave. 4) NERI in Roskilde where the camera can be controlled and pictures are analysed (picture from www.seemorewildlife.com).*

Rødsand seal sanctuary is situated about 7 km from the nearest power and phone connection so the system needs to be fully self-supplied and wireless (no. 1 in Fig. 4). Two visible light cameras with 300x telephoto capability are mounted on a 6 m high tower (no. 2 in Fig. 4). The tower was first deployed 900 m from the seals preferred haul-out site, then it was moved to 600 m, and finally to approximately 300 m distance from the seals. The tower is secured to the ground by four stainless steel cases (105x105x53 cm, Fig. 5) filled with sand. Each case weighs around 1 ton. Eight stainless steel wires are mounted 2 m into the ground to minimise vibrations of the tower during strong winds. The cameras are powered by 12vcd batteries connected to two solar panels and a wind generator situated on the top of the tower. With the use of microwave signals the video image is transmitted to a transformer station in Gedser (no. 3 in Fig. 4) where a computer receives the signal and connects it to the Internet. The images from the cameras are full-bandwidth and can be recorded on real-time or time-lapse tapes, or digitised for storage on computer hard disk drives. Live images may also be encoded and streamed onto the Internet for world-wide distribution.

At the moment it is not possible for the public to access live images from the camera, but authorised observers (no. 4 in Fig. 4) can access the remote control program for the cameras and control them from their computer.

Figure 5. *Camera tower at Rødsand Seal Sanctuary with antennas, wind generator, solar panels and battery box.*

4.3 Camera control

The view of the camera was regularly controlled, panned, tilted and zoomed to an optimal view of the animals (see Fig. 6). SeeMore Wildlife improved the software during the monitored period to facilitate operation from the distant location of the tower. Only one camera can be operated at a time. Clicking on the camera buttons on the right (Camera 1 and Camera 2) chooses the camera. Still photos are only stored from the active camera. The camera view can be controlled by the up, down, right, and left bottoms in the middle. The 1 to 10 bottoms on the left are used to zoom in and out in steps. The camera view can also be gradually zoomed by the 'zoom in' and 'zoom out' buttons. Just below the zoom bottoms there is a button for the lens wiper.

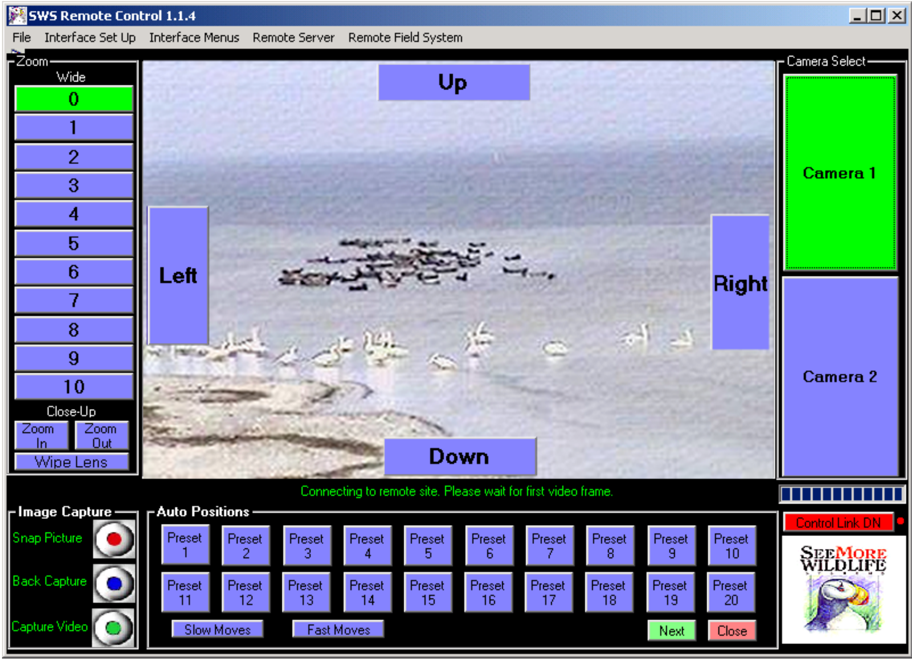

Figure 6. *The remote camera view software from SeeMore Wildlife used for operating the two cameras. The image shows a group of seals resting in shallow water at Rødsand with mute swans in the foreground on May 12, 2003 at 1:24 pm.*

4.4 Data collection and analysis

Live images are digitised to JPEG format and stored every 5 seconds from sunrise to sundown on the computer at the receive station for later analysis. Every morning at 9 a.m. pictures from the past day are transferred through an ADSL link to the computer storage facility at NERI in Roskilde. Here all pictures are being analysed and stored on DVD disks regularly. The software program ThumbsPlus 4.10 is used for handling the pictures. Information from the pictures were extracted and stored on a database in Excel, from where statistical analysis and graphics were produced.

The distance to the seals was too long and the observation angle of the camera was too narrow to obtain high-resolution images of the seals spanning the entire area. It was therefore difficult to count the actual number of seals on the stored images when more than 20 animals are present (Fig. 7a). Online count of seals with the use of the zoom function is much more informative (Fig. 7b) though considerably more time-consuming. From 2004 the exact number of seals will be counted online in selected periods. In this report only the stored images are analysed. The quality of the stored images only allows rough estimates of the number of seals are registered, but the cameras always provide data on whether seals are present or not. Hence, the exact number of seals above 20 could not be determined, therefore the images were categorised into 6 distinct intervals: 0 seals, 1-5 seals, 6-10 seals, 11-15 seals, 16-20 seals, and >20 seals. For efficient processing of the images, only the times of change between categories were recorded.

Hourly observations of the different categories were computed from the recorded time series of category change within the operational periods of the camera. Furthermore, the percentage of time with seals hauled-out over the course of the day was calculated as the sum of periods with seals on land divided by the total period of monitoring. For example, a day with seals present during 6 out of 12 hours corresponded to a 50% haul-out time.

Figure 7. *- Stored images showing the seals haul-out site on the tip of Rødsand seal sanctuary on June 6, 2003 at 14:02. (a) The distance and angle from the camera made it difficult to count seals when lying behind each other. (b) On-line counts with a close zoom on the seals revealed 51 seals this particular day.*

Disturbances of the seals, when a large fraction or all seals suddenly go in the water were also observed and recorded from the images. Seals normally gather in large groups on land. More seals mean more ears and eyes to keep a lookout for danger. If one seal spots a potential danger and reacts to it, it will start a chain reaction causing all or part of the group to flee into the water. With the increased human activity during the construction of the Nysted Offshore Wind Farm we would expect the seals to be more alert and potentially see an increase in the number of disturbances. The disturbance reaction naturally only occurs when there are seals on land and hence, the number of observed disturbances were divided by the time with seals on land to produce comparable data, i.e. a disturbance rate.

4.5 Construction work

The construction of Nysted Offshore Wind Farm was separated into two major phases. The first phase included preparations for the actual construction work, such as excavation for the foundations, digging of cable furrows and a single case of seabed securing with steel sheet piles. The second phase included cabling and the wind turbine construction. Each of the two faces was divided into several activities scheduled as shown in Figure 8. The construction work began in early February 2002 with the digging of the cable furrows for the 33 kV cables to connect the wind turbines. The last wind turbine was mounted July 27th 2003, and the park was in full operation 1 December 2003.

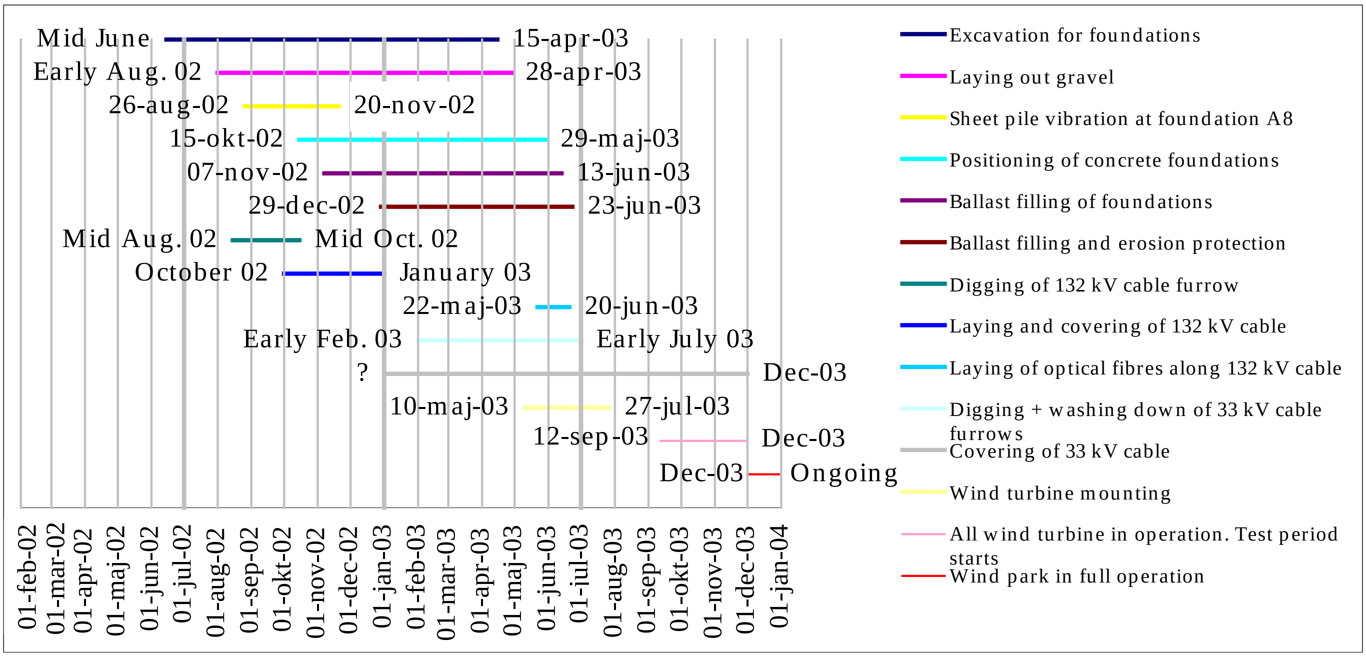

Figure 8. *Time schedule of the construction works at the Nysted Offshore Wind Farm*

The construction works at the Nysted Offshore Wind Farm actually started before the cameras became operational, however, the activities during the first 6 months were less intensive and less noisy and primarily took place in the south-west corner of the wind farm furthest away from the seals. Thus, we believe that the disturbance of the seals was minor until the digging of the 132 kV cable from the park to Nysted (parsing close by the seal sanctuary) and the sheet pile vibration started in mid August 2002. In order to assess the potential impact of the construction works, we decided that images recorded before 16 August 2002 were considered baseline data.

4.6 Wind data

Wind speed and direction were obtained from two partly overlapping time series recorded at Gedser DMI station (data available from March 2002 to November 2002) and at Nysted Offshore Wind Farm (June 2002-December 2003). Both time series had a resolution of 10 minutes or less. The time series from the wind farm included many gaps with missing recordings in the beginning of the time series, and none of the two series covered the entire period with seal haul-out observations. Consequently, a combined wind signal of the two time series had to be constructed. The two time series were compared by calculating mean wind speed and median wind direction for overlapping days of monitoring.

Daily values of wind speed and direction showed large deviations between the two stations for the first part of the time series monitored at the Nysted Offshore Wind Farm (Fig. 9 and 10). Discarding the observations from the first short-term periods of monitoring at the wind farm (red triangles in Fig. 9 and 10) revealed a consistent pattern with almost identical signals. The regression line for wind speed was not different from the identity line, whereas there was an almost constant displacement of 21.5° for wind directions (Fig. 10). A combined wind signal of hourly observations was obtained for the entire study period by averaging wind speed observations and taking the median for wind directions with 21.5° subtracted from the Gedser data. Data from the Nysted Offshore Wind Farm monitored before 8 September 2002 were not used.

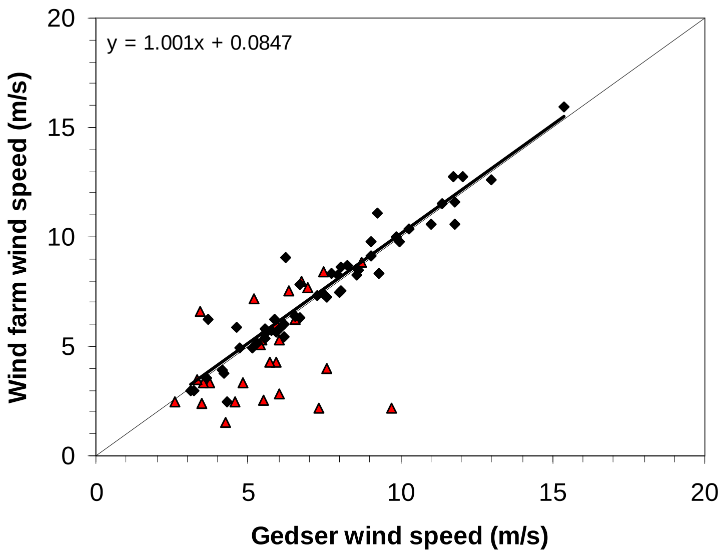

Figure 9. *Daily wind speed compared at the two stations (Nysted Offshore Wind Farm and Gedser). Observations marked by red triangles were from the first period of monitoring at the wind farm and were excluded from the dataset. Regression line for wind speed is shown with a bold line.*

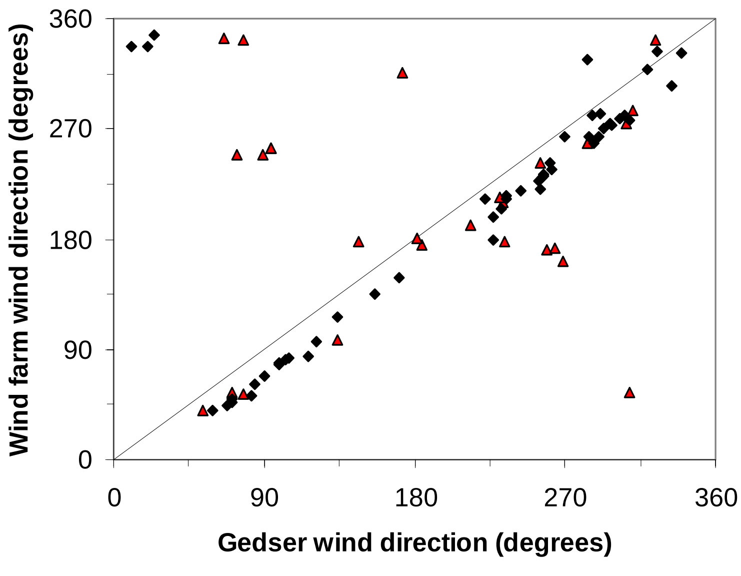

Figure 10. *Daily wind direction compared at the two stations (Nysted Offshore Wind Farm and Gedser). Observations marked by red triangles were from the first period of monitoring at the wind farm and were excluded from the dataset.*

4.7 Statistical analysis

The 6 categories used to describe the number of seals on land can be modelled using the multinomial distribution. Furthermore, the model is an ordinal model since the 6 categories represent a natural order (scale). We shall analyse these data within the framework of generalised linear models (McCullagh and Nelder, 1989).

If (p_{i1}, p_{i2}, ... p_{i6}) are the category probabilities, the cumulative category probabilities

$P_{ir} = \sum_{j=1}^{r} p_{ij}$, r = 1, 2, ... , 5 are modelled as

$$g(P_{ir}) = \mu_r + \mathbf{x}_i' \cdot \boldsymbol{\beta} \quad \text{for } r = 1, 2, \ldots, 5$$

where μ_1, μ_2, μ_3, μ_4, μ_5 are intercept terms that depend only on the categories, $\mathbf{x}_i$ is a vector of covariates that does not include an intercept term, and $\boldsymbol{\beta}$ is a vector of regression parameters related to $\mathbf{x}_i$. The logistic link function was used for *g()*. The parameters were estimated by maximum likelihood regression, and the significance of the difference factors in $\mathbf{x}_i$ was tested by means the likelihood ratio test.

We investigated the following factors assumed to affect the distribution between the different seal categories:

- Seasonal variation by monthly values (*month*).
- Diurnal variation by hourly values (*hour*).
- Baseline versus construction period (*period*).
- Change in seasonal variation between periods (*period×month*)
- Linear response to wind speed (*windspeed*)
- Quadratic response to wind speed (*windspeed×windspeed*)
- Different response to wind direction (*winddir*)

Secondly, we investigated the potential impact of the ramming activity by identifying the seal category observations associated with the time of ramming and included that as a factor in the model:

- Different response for ramming periods (*ramming*)

Marginal means of the transformed cumulative category probabilities, $g(P_{ir})$, were calculated from the parameter estimates, $\boldsymbol{\beta}$, and marginal mean category probabilities, (p_{i1}, p_{i2}, ... p_{i6}), for the different factors included in $\mathbf{x}_i$ were found using the inverse logistic function for back-transformation. Marginal means reflect typical responses of the different factors in the model that are not affected by lack of balance in the data (differences in the number of observations for different months and times of the day).

5 Results

5.1 Placement of the tower

In order not to disturb the seals the tower was initially placed distant (900 m) from the haul-out site and then later moved closer to the seals. At the first location the tower with the two cameras was deployed on 20 March 2002. The great distance and the small angle from the cameras to the seals made it very difficult to count the seals when more than 20 seals were present or when many birds were on land, as they were shading for each other (Fig. 11). The quality of the photos was too poor to extract behavioural information. Therefore the tower was moved to a site approximately 600 m from the haul-out site on 14 August 2002. Eventually the tower was moved to its final destination approximately 300 m from the haul-out site on 9 April 2003. Deposition of sand in the seal sanctuary changes constantly and the distance to the seals therefore varies over the year.

Figure 11. *The image shows the seals preferred haul-out site on the tip of Rødsand seal sanctuary on September 17, 2002 at 15:06. The distance and the angle from the camera made it difficult to count the seals lying behind the black cormorant (Phalacrocorax carbo).*

After having moved the tower to a distance of 300 m from the seals the angle was steep enough to avoid the shading effect (Fig. 12).

Figure 12. *The image shows the seals preferred haul-out site on the tip of Rødsand seal sanctuary on June 13, 2003 at 10:13 after the movement of the camera-tower. The distance to the seals was now 300 m.*

The presence of the tower has not yet proved to have any effect on the seals. The cameras only need little maintenance, as the system is self-contained. The tower is a stationary object, which seem to be accepted by the seals very quickly.

During the moving of the tower with the presence of 10 persons and several boats, the seals stayed on land during the whole process. Compressed water stream created by a small engine compressor showed to be an efficient way of getting the pegs into the ground. This method was faster and reduced the noise relative to hammering the pegs into the ground, and the seals did not react to this procedure. The SeaMore Wildlife Systems are used on other species including stellar sea lions (*Eumetopias jubatus*) and elephant seals (*Mirounga angustirostris*) on very close range.

5.2 New cameras and software

In the beginning too many users were able to control the camera. The cameras were not easy to control and therefore not always left in the right position for the right images to be stored. Therefore a lot of data were lost. On February 5, 2003 two new cameras and software were installed. The new software made it easier to control the cameras and the position could be stored as prefixed positions. A click on a prefixed position would return the camera to one of the stored positions.

5.3 Seal registration

The first images of the seals at Rødsand sanctuary were recorded on 12 April 2002 and the two cameras were in operation to the end of October 2003 with minor gaps in data only. Days with missing images were due to wrong configuration of the camera, misty weather conditions or breakdown of the camera system. There were 421 days with recordings out of 567 days in total during the study period.

Although the camera system is clearly visible, a coalition with a seagull occurred on 10 October 2003 causing damage to the wind generator. Broken parts were replaced on 30 October 2003, but the wind generator was no longer producing energy and the batteries powering the cameras were slowly drained. The wind generator was replaced together with the batteries, since the voltage on the old batteries was too low to be charged by the new wind generator. The cameras were out of function for the months of November and December 2003 and no data is therefore presented for this period.

Data from February 2003 were very limited, because the cameras were out of operation for most of the month and it was not replaced before the end of the month. Results from this month were therefore based on 3-4 days of observations only and therefore more uncertain.

From April 2002 to October 2003 more than 3½ million pictures have been stored from 421 days, providing us with a large database of information on the seal's use of the seal sanctuary.

5.4 Seal presence at Rødsand

The seasonal presence

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 (Fig. 13). The diurnal variation showed the highest presence during the middle of the day, whereas mornings and evenings had a generally lower presence of seals. This pattern was particularly pronounced from March to June (Fig. 13). The seasonal and diurnal variations were similar for the two years considering that many of the presence estimates were based on a few days' observations.

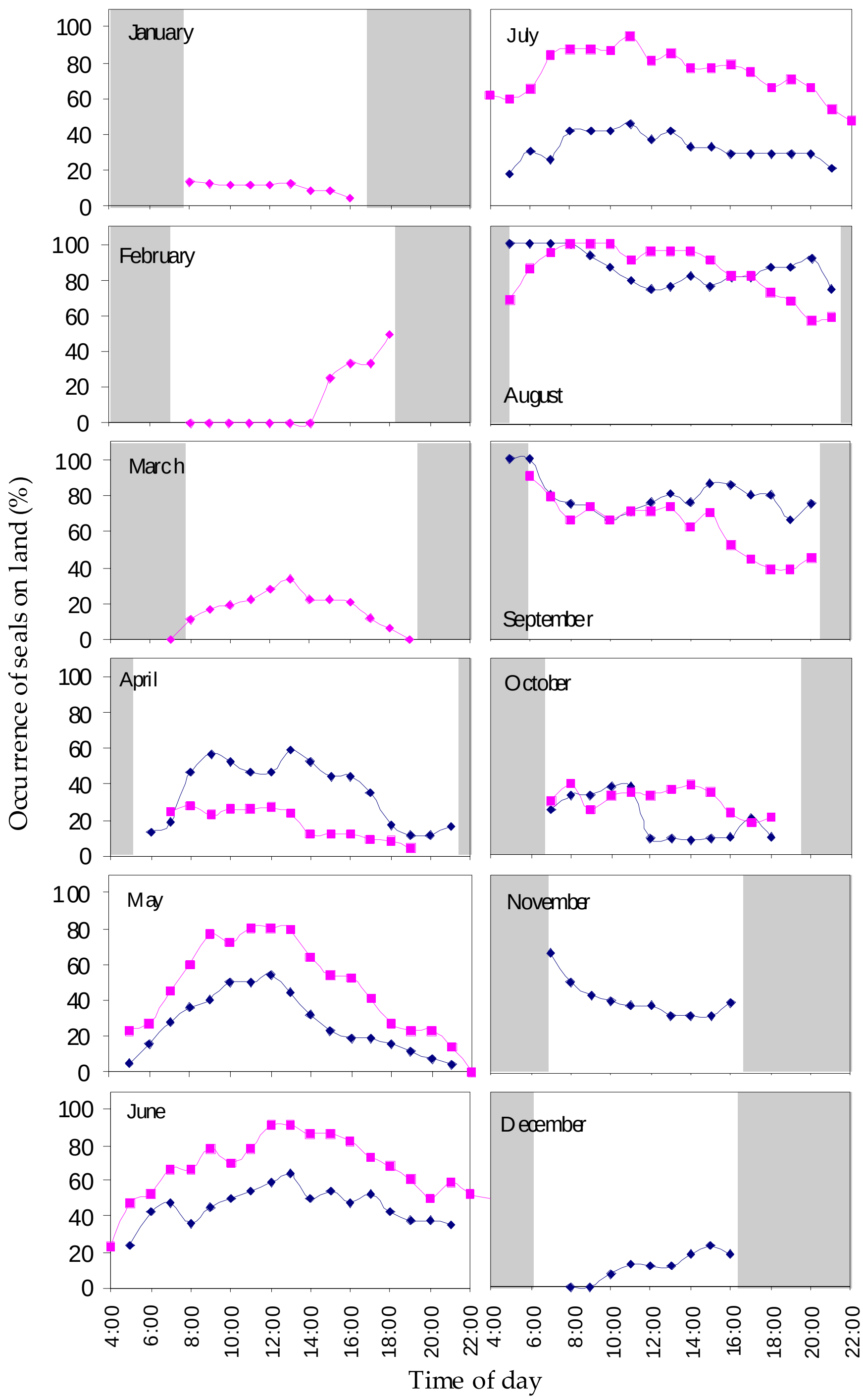

Figure 13. Diurnal variations in the presence of seals on land at Rødsand seal sanctuary for the different months found by averaging. Shaded areas represent hours where the seal could not be counted due to darkness. Data from 2002 (dark blue) and 2003 (pink).

Multinomial model

The hourly data of the seal categories resulted in 4748 observations, partitioned into 2389 observations without any seals (~50%), 280 observations of 1-5 seals (~6%), 293 observations of 6-10 seals (~6%), 350 observations of 11-15 seals (~7%), 283 observations of 16-20 seals (~6%) and 1153 observations with >20 seals (~24%). These observations were described by 20 levels of hour (4-23), 12 levels of month (January – December), 2 levels of period (baseline, construction), 8 levels of wind direction (N, NE, E, SE, S, SW, W, NW). Differences in the seasonal variation between the baseline and construction period could only be carried out for those months that had observations in both periods (April-August). The wind speed was modelled as a quantitative factor with ranges from 0.1 to 19.6 m/s.

All factors included in the model (see section 4.8) were highly significant (all: P<0.0001). This should, of course, be seen in the light of the many observations that allowed identification of small differences. Assuming the categories to be associated with a mean number of seals of 0, 3 (1-5 seals), 8 (6-10 seals), 13 (11-15 seals), 18 (16-20 seals) and 25 (>20 seals), the change from baseline to the construction period corresponded to a 12.5% increase from a yearly mean of 2.79 seals in the baseline period to 3.14 seals in the construction period. The other factors of the model induced larger variations than the change from baseline to the construction period.

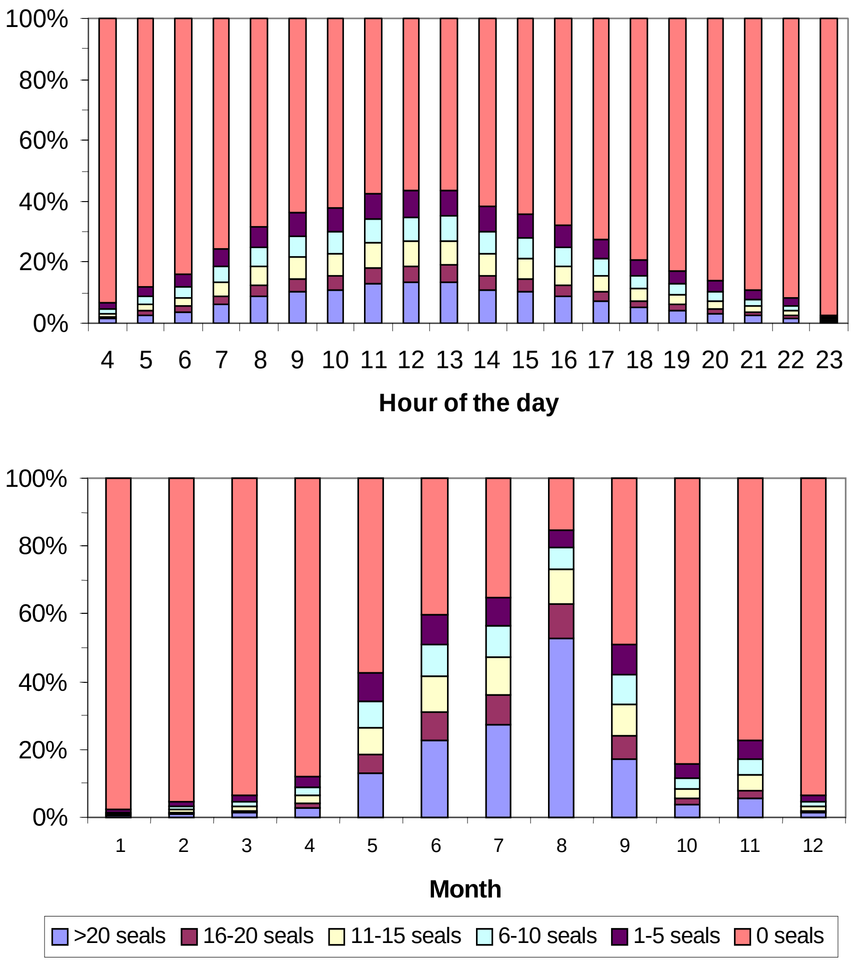

Figure 14. *Estimated distributions for the 6 seal categories during the day (top) and the year (bottom). The category probabilities were calculated as marginal means from a multinomial model.*

The distinct seasonal and diurnal patterns of seal occurrence (Fig. 13) were confirmed by the marginal category probabilities derived from the multinomial model for the 6 distinct categories (Fig. 14). The diurnal variation describe the mean category probabilities over the entire year with equally weighted wind directions and for a mean wind speed of 6.3 m/s. Similarly, the seasonal variation describe the mean category probabilities over the entire day (from 4 to 23) with equally weighted wind directions and a mean wind speed of 6.3 m/s. The diurnal variation corresponded to a mean of 6.3

seals around noon decreasing to less than 1 in the early morning and late evening by translating the categories into mean number of seals as above. Monthly means ranged from 0.25 seals in January to 17.0 seals in August (note that these mean values are minimum numbers as the >20 category was set to 25 seals). The maximum number of seals on land in August corresponded to the moulting season of the seals.

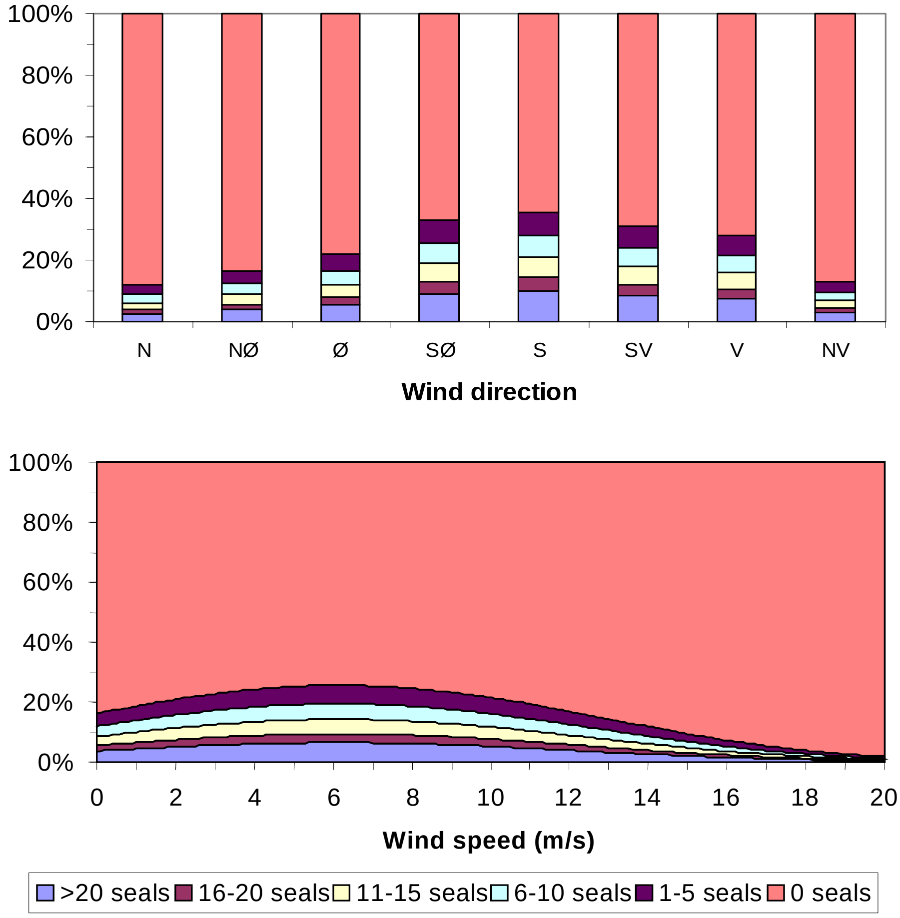

Figure 15. *Estimated distributions for the 6 seal categories for different wind direction (top) and wind speed (bottom). The category probabilities were calculated as marginal means from a multinomial model describing yearly conditions for all hours between 4 and 23.*

Southerly winds around 4-8 m/s increased the number of seals on land (Fig. 15). If the wind came from the south (S) there would be a yearly mean of 5.0 seals on land, whereas if the wind was from the north (N) there would only be a yearly mean of 1.5 seals on land. The yearly mean number of seals on land increased from 2.0 seals at 0 m/s, reaching a maximum of 3.4 seals at 6.1 m/s and decreased to 0.2 seals at 20 m/s. Wind speed between 0 and 12 m/s generally resulted in high abundance, whereas strong winds did not favour seals on land.

The small increase in the seal category probabilities from baseline to the construction period was not equal for all the months (the interaction effect *period×month* was significant). Five months had seals observations in both the baseline and the construction period, and four of these had a significant difference in the category probabilities for the two periods (Fig. 16). There was a decline in the number of seals on land from 3.4 seals in April 2002 to 1.9 seals in April 2003, whereas data from May, June and July all showed increases from 2002 to 2003 (3.2 increasing to 7.3 for May, 4.8 to 11.0 for June, and 3.3 to 12.3 for July). The small increase from 17.6 seals in first half of August 2002 to 18.3 seals on land in second half of August 2002 and August 2003 was not significant.

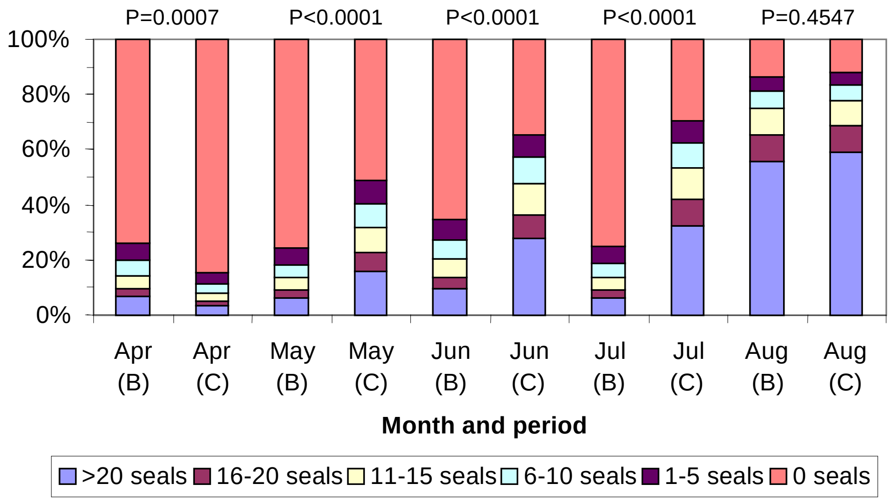

Figure 16. *Estimated distributions for the 6 seal categories for months with camera in operation during baseline (B) and the construction period (C). The category probabilities were calculated as marginal means from a multinomial model. P-values above the columns give the probability that the distributions are identical for the two months.*

5.5 Ramming

Ramming/vibration activities were carried out at a single foundation (A8) located approximately 10 km from the seal sanctuary. Seal category probabilities were significantly different (P<0.0001) during the periods of ramming when all other sources of variation were taken into account. There was a decrease in the number of seals on land during ramming/vibration periods (Fig. 17). It was not possible to test for month-specific effects of ramming periods, since most of the ramming data were from September 2002.

Ramming periods were associated with a decline from 18.0 seals to 12.5 seals in August (30.6% reduction), from 9.3 seals to 4.6 seals in September (50.5% reduction), from 2.3 to 0.9 seals in October (60.9% reduction), and from 3.6 seals to 1.5 seals in November (58.3% reduction). These modelled changes were determined from the observations taking other factors such as wind, month and time of the day into account. However, the actual decreases were less than modelled in August (from 13.6 seals to 12.1 seals; 11.0% reduction) and in September (from 9.5 seals to 8.7; 8.4% reduction), whereas the decrease was substantially larger in November (from 13.2 seals to 0.0 seals; 100% reduction). In fact, for the 25 hourly camera observations during ramming periods in November, no seals were observed on land.

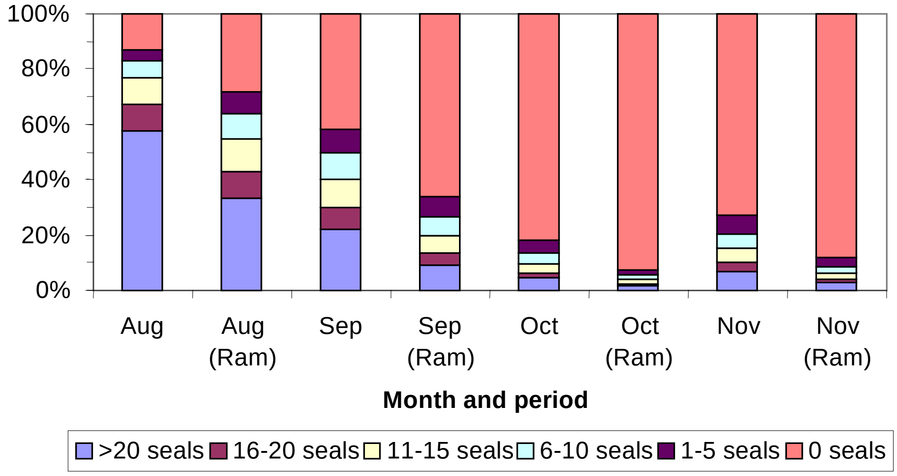

Figure 17. *Estimated distributions for the 6 seal categories for periods during the four month with ramming activities (Ram) compared to periods without ramming activities in 2002. The category probabilities were calculated as marginal means from a multinomial model.*

5.6 Seal disturbances

The presence and the actual number of seals increased in the summer months, as did the number of recorded disturbances (Fig. 18). The number of disturbances appeared to be higher in 2003 than in 2002 in general, but if the number of disturbances per month is divided by the actual recorded time with seals on land there is no difference (Fig. 19). The mean rate of disturbances was 0.104 h^{-1} in the baseline and 0.110 h^{-1} in the construction period and these were not statistically different (two sample t-test w. equal variances, df=19, p=0.84).

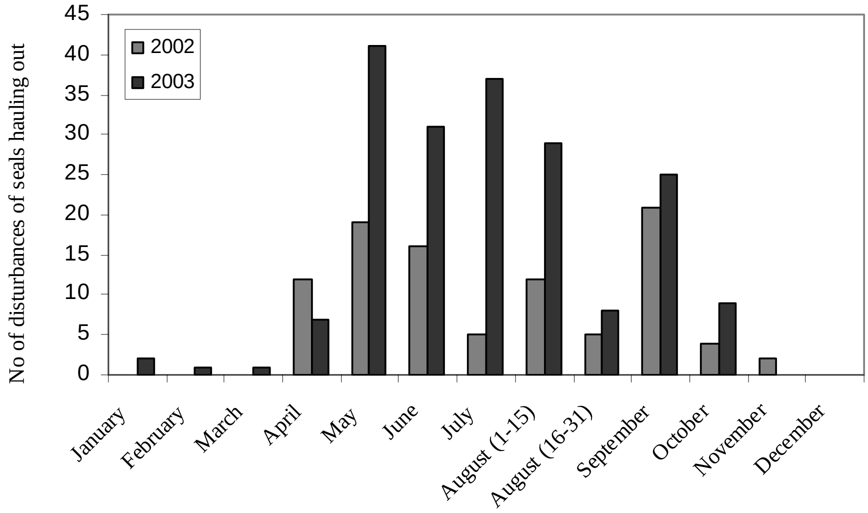

Figure 18. *Disturbances of seals hauling out in Rødsand seal sanctuary. Data was not available before April 12, 2002 when the video recording of seals started. The cameras were out of operation in November and December 2003.*

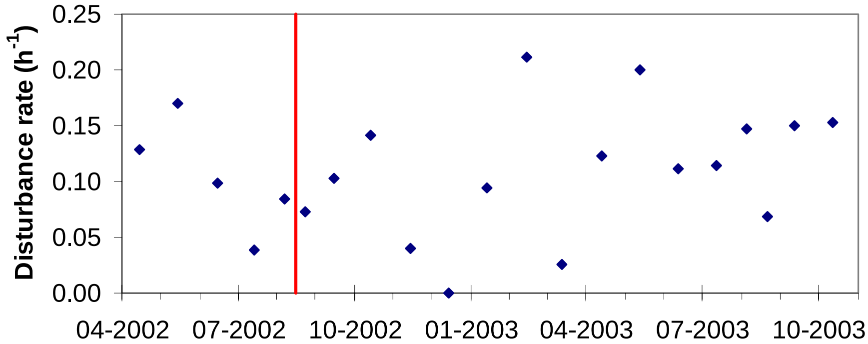

Figure 19. *The number of disturbances relative to the time with seals on land for each month with August 2002 split in two parts. The red line marks the change from baseline to the construction period.*

6 Discussion

Modelling seal presence relative to season, diurnal pattern, period and wind

The large amount of hourly observations spanning almost two years naturally included many different sources of variation. We have proposed to model categories of seals on land using 5 main factors (month, hour, period, wind speed, wind direction) that all were found to be significant. Any residual variation was assumed random. There may be other important factors affecting the number of seals on land for which we have no complete dataset (meteorological data other than wind, human disturbances, etc.), but if such unmonitored factors do not systematic interact with any of the applied factors the model results remain valid. Harders (2003) investigated the number of seals and their attention attitude at Rødsand sanctuary for two months in the summer of 2001 in relation to a wide range of meteorological variables and indicators for human activity near the seals. She found that seasonal and diurnal variation as well as wind speed and direction were the only significant factors affecting the seals, and her results corresponded extremely well to those obtained in the present study. This corroborates the assumption that there are no other important factors influencing the seals at Rødsand besides those already included in the model. The estimated seasonal variation is also in accordance with that found from aerial counts during 2002 and 2003 (Teilmann et al. 2003 and 2004).

Presence of seals during the construction period

There was no general decrease in the number of seals on land from baseline to the construction period, in fact, there was a 12.5% increase in the category probability for seals on land. We believe that this is mainly due to an increase in the Rødsand population of seals from 2002 to 2003. It was anticipated that the seal epidemic (summer of 2002) would have substantially reduced the number of seals during the construction period. In management area 4 that covers the southern Sjælland and the islands of Lolland and Falster 109 dead seals was 193TMM Silver in 2002 (Dietz et al. 2003a). This mortality correspond to about 11% of the population size in the area, however, aerial surveys of population sizes in the region found that there was a decrease of 44% from 2001 (extrapolated from surveys in 2000) to 2002. This discrepancy may be explained by either an unusual haul out behaviour due to the decease or that only a part of the dead seals were found. From 2002 to 2003 an increase of 17% were found in management area 4 (Teilmann et al.2004). The small increase in the video-recorded seal population combined with the potential negative impact of the seal epidemic suggests that there is no overall impact from the construction of the Nysted Offshore Wind Farm.

Effect of the ramming

There was, however, a significant decrease in the number of seals on land from the ramming of a single foundation that took place approximately 10 km SW of the seal sanctuary. 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. Most of the ramming periods took place in September 2002 with calm winds mainly from SE and S. Edrén (et al. 2003) found no difference in seal number during ramming, however, the statistical test used in this report was inadequate for a proper test.

During the ramming/vibration an underwater seal scrammer and porpoise pingers were used to scare the animals away from the site before the actual ramming/vibration started. It is not possible to determine if the reaction to the ramming was due to the scarring devices or the ramming/vibration. The noise from the ramming/vibration activities may have been audible to the seals at Rødsand, both on land and in the water, while the scarring devices would only be audible under water. Noise from the ramming/vibration activities travels further through water than in air. The seals that happen to be in the water during ramming/vibration may have stayed in the water, or may have swum away from the sound, possibly to other haul-out sites further away from the wind farm area than Rødsand.

Boating and construction

The decrease in seal numbers during ramming periods could also be due to increased boat activity during these specific ramming periods. The increased activity during the construction period should led to more external disturbances from boats. However, there was no change in the disturbance rate despite an increased activity level, probably due to a regulation on boats to pass the sanctuary in adequate distance. This indicates that, despite intensified activity, remote boat traffic and other activities that was known to the seals, did not affect the number of seals on land significantly. Harders (2003) similarly found no effect from distant human disturbances.

7 Conclusion

Feasability of the video registration

The video registration of the seals at Rødsand seal sanctuary has provided high-resolution data for analysing the possible effects of the construction of the Nysted Offshore Wind Farm on the seals. Even with the problems in the starting phase of the video registration, we conclude that the temporal amount of data achieved by this method exceed the data that can be cost realistically collected by an observer. We believe that the stationery camera tower have posed no disturbance to the seals, as no reaction from the seals was observed during installation and two subsequent movements of the camera tower.

The seasonal and diurnal presence

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 at the sand bank. The diurnal variation showed the highest presence during the middle of the day.

Diurnal and seasonal patterns estimated by a multinomial model

The distinct seasonal and diurnal patterns of seal occurrence were confirmed by the marginal category probabilities derived from the multinomial model. The diurnal variation corresponded to a mean of 6.3 seals around noon decreasing to less than 1 in the early morning and late evening by translating the categories into mean number of seals.

Seal presence related to wind speed and directions

Southerly winds around 4-8 m/s increased the number of seals on land. If the wind came from the south (S) there would be a yearly mean of 5.0 seals on land, whereas if the wind was from the north (N) there would only be a yearly mean of 1.5 seals on land. The yearly mean number of seals on land increased from 2.0 seals at 0 m/s, reaching a maximum of 3.4 seals at 6.1 m/s and decreased to 0.2 seals at 20 m/s. Wind speed between 0 and 12 m/s generally resulted in high abundance, whereas strong winds did not favour seals on land.

Effect of the construction period

The number of seals on land increased 12.5% from a yearly mean of 2.79 seals in the baseline period to 3.14 seals in the construction period. Five months had seals observations in both the baseline and the construction period, and four of these had a significant difference in the category probabilities for the two periods. There was a decline in the number of seals on land 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.

There was no change in the disturbance rate (seals fleeing into the water) during the construction period, probably due to a regulation on boats to pass south of the sanctuary in adequate distance. This indicates that remote boat traffic did not affect the number of seals on land significantly.

The construction of the wind farm situated approximately 4 km away from the seal sanctuary had in general no or only little effect on the presence of seals on land. Even two events of grey seal breeding were recorded during the construction period, which is the first time for decades.

Effect of the ramming

There was, however, a significant decrease in the number of seal on land during the ramming periods, that was carried out during at a single foundation located approximately 10 km SW of the seal sanctuary. The observed reduction of seals varied among months ranging from 8 to 100%. When correcting for other variables in the model the reductions varied between 31 and 61%. The seals may have stayed in the water, which is a safer environment to them or, been swimming away from the area or chosen other haulout sites further away from Rødsand during this period.

8 Recommendations

Video monitoring is an efficient tool for monitoring possible effects from human activities at haulout sites. This monitoring should be continued during the operation of the wind farm to evaluate the potential effect of the seals on land. It is recommended to include the very detailed baseline data obtained from manual observations from the bird tower (Harders 2003). By conducting detailed online video counts of the seals during June-August and compare with the data from Harders (2003), a much more powerful statistical test can be applied to test for potential effects on the seals, than presented in this report.

We recommend that the camera views be made available to the public as live on-line images over the Internet or as playback of downloaded interesting activity sequences.

9 Referencer

Bøgebjerg, E. 1986. Spættet sæl (*Phoca vitulina*) i Danmark 1976–1984. Danske Vildtundersøgelser hæfte 42, Vildtbiologisk Station: 38 pp.

Dietz, R, J. Teilmann & O.D. Henriksen 2000. EIA study of offshore wind farm at Rødsand. Technical report about seals – Juli 2000. SEAS Distribution A.m.b.A. Vind Energi Center, Slagterivej 25 DK-4690 Haslev. Available at: http://www.nystedhavmoellepark.dk/frames.asp

Dietz, R., J. Teilmann, T. D. Rasmussen, S. M. C. Edrén & O. D. Henriksen 2003a. Sældøden i Danmark 2002, Status over indsamling, omfang og prøvetagning af spættet sæl (*Phoca vitulina*). Danmarks Miljøundersøgelser. Arbejdsrapport fra DMU nr. 177: 23 pp. http://www.dmu.dk/1_viden/2_Publikationer/3_arbrapporter/rapporter/AR177.pdf

Dietz, R., J. Teilmann, O.D. Henriksen & K. Laidre 2003b. 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, http://www.dmu.dk/1_Viden/2_Publikationer/3_Fagrapporter/default.asp - fr429: 44 pp.

Edrén, S.M.C., J. Teilmann, R. Dietz, O.D. Henriksen, & J. Carstensen 2003. Remote video registration of seals at the Rødsand seal sanctuary - Technical improvements and feasibility for detecting effects from the Nysted Offshore Wind Farm. National Environmental Research Institute Research Note No. 187: 28 pp. http://www.dmu.dk/1_viden/2_Publikationer/3_arbrapporter/rapporter/AR187.pdf

Harders, P.B. 2003. Haul out, disturbance and diet of harbour seals (*phoca vitulina*) and grey seals (*Halichoerus grypus*) at Rødsand. M.Sc. thesis (in Danish). Institute of Biology, University of Southern Denmark and Dept. of Arctic Environment, National Environmental Research Institute.

McCullagh P & J. A. Nelder 1989. Generalized Linear Models. Second Edition. Chapman & Hall/CRC, Boca Raton, Florida. 511 pp. Ministry of the Environment and Energy 1993. Bekendtgørelse om Rødsand Vildtreservat. Miljøministeriets bekendtgørelse af 20. September 1993. Miljøministeriet J.nr. D 1100-0045: 2 pp.

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. Danmarks Miljøundersøgelser.

Teilmann, J., R. Dietz, S. M. C. Edrén, O. D. Henriksen & J. Carstensen 2003. Aerial surveys of seals at Rødsand seal sanctuary and adjacent haul-out sites. National Environmental Research Institute Research Note No. 188: 32 pp. http://www.dmu.dk/1_viden/2_Publikationer/3_arbrapporter/rapporter/AR188.pdf

Teilmann, J., J. Carsentsen, R. Dietz & S. M. C. Edrén 2004. Effect on seals at Rødsand seal sanctuary from the construction of Nysted Offshore Wind Farm based on aerial surveys. Technical report to Energy E2 A/S. Available at: http://www.nystedhavmoellepark.dk/frames.asp