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Movements of seals from Rødsand seal sanctuary monitored by satellite telemetry

Relative importance of the Nysted Offshore Wind Farm area to the seals

NERI Technical Report No. 429

Tom side

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Data sheet

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Abstract:

This report documents the capture and tagging of ten harbour and grey seals from the Rødsand seal sanctuary, Southeast Denmark prior to the construction of the Nysted Offshore Wind Farm. Harbour seals remained within 50 km of the tagging site year-round, while grey seals made extensive movements up to 850 km away from Rødsand to Sweden, Germany, Estonia and Latvia. The average Kernel home range (95% fixed Kernel) of the harbour seals was 394 km^2 ranging from 237 to 709 km^2, whereas the corresponding Kernel home range was 130 times larger for grey seals namely 51,221 km^2 ranging from 4,160 to 119,583 km^2. All the tagged harbour seals stayed year-round in the Rødsand area, whereas, the grey seals on average only remained in the area for 17.8% (range: 2.6 - 58.3%) of the monitored time.

Keywords:	Harbour seal, grey seal, satellite tracking, offshore wind farms, movements, home range, dive behaviour
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Contents

1 Summary

Introduction

This report documents the capture and tagging of ten harbour and grey seals from the Rødsand seal sanctuary, Southeast Denmark. The investigation provides information on site fidelity, migration and Kernel home range of the seals prior to the construction of the wind farm. It also serves as a baseline study for future determination of changes in habitat selection by seals during and after construction of the wind farm.

Movements and Kernel home ranges

Geographic locations were obtained both from land and at sea. The track-lines together with the Kernel home ranges are presented individually for four harbour seals and six grey seals. From these figures it is clear that the harbour seals remained within 50 km of the tagging site year-round, while grey seals made extensive movements up to 850 km away from Rødsand to Sweden, Germany, Estonia and Latvia. These differences in dispersal patterns were reflected in the calculated Kernel home ranges, where seals that dispersed farther from the tagging site had large estimates of area use (or home range). The average Kernel home range (95% fixed Kernel) of the harbour seals was 394 km^2 ranging from 237 to 709 km^2, whereas the corresponding Kernel home range was 130 times larger for grey seals namely 51,221 km^2 ranging from 4,160 to 119,583 km^2 for five out of the six grey seals. Although only few (seven) positions were obtained within the wind farm area, the calculated Kernel home range of all four harbour seals and four out of six tagged grey seals extended into the wind farm area. All the tagged harbour seals stayed year-round in the Rødsand area, whereas, the grey seals on average only remained in the area for 17.8% (range: 2.6 - 58.3%) of the monitored time.

These findings imply that the Rødsand locality is more important for harbour seals than for grey seals. Grey seals appear to have alternative feeding and haul out sites for the major portion of the year. Therefore disturbances near Rødsand, especially during late winter and early spring, when the grey seals probably leave the area to breed and mate in the Baltic Sea, will have higher impact on harbour seals compared to grey seals.

Haul-out and dive data

Haul-out and dive data were only sampled from a pregnant harbour seal and a subadult female grey seal. The grey seal spent about 40% of its time on land while the harbour seal spent only 22% of the time on land. Both spent 17-18% of time at the surface (0-2 m). The grey seal frequented areas with greater depths than the harbour seal, which stayed locally in the shallow waters near Rødsand. The average dive depth for the grey seal was 44 m (range: 12-82 m) and 9 m (range: 6-12 m) for the harbour seal. Although the harbour seal exploited an area with much shallower water it made significantly longer dives. The grey seal dived almost 10 vertical km per day, while the harbour seal only dived 3.5 vertical km per day. The adult female harbour seal only hauled-out from sunrise until early evening with up to 60% of the time on land during late morning. The subadult

female grey seal hauled-out during all hours of the day but also peaked around late morning and midnight with almost 40% of the time on land.

A number of recommendations are made for future additional work. Hence, satellite telemetry (including dive recorders) and GPS/GSM technique should be continued during and after the planned construction work, to obtain information on the effects of the construction activity and presence of the wind farm. Improved capturing techniques should be used, as the seals at Rødsand are very nervous compared to other areas. The tagging should preferably be conducted in September and use the obtained moulting information to improve data collection.

2 Introduction

2.1 Background and purpose

The Danish government has introduced several action plans with the goal of reducing the annual emissions of CO_2 to half of 1998 levels by 2030. In order to help achieve this, the amount of energy produced from renewable energy sources, including offshore wind farms, is to be increased. The former Ministry of the Environment and Energy has issued Energi E2 and SEAS a commission to construct a wind farm, "Nysted Offshore Wind Farm", close to Rødsand (south of Lolland). The wind farm will consist of seventy-two 2,2 MW turbines. The initial construction work on the foundations started in the end of June 2002, and the wind farm is planned to be in operation in the fall 2003.

An EIA study was carried out in 2000 following the guidelines jointly drawn up by the Danish Energy Agency and the National Forest and Nature Agency (Dietz et al. 2000). Part of this task is to assess the extent to which the construction of the wind farm in this area will cause measurable, temporary or permanent, changes in the local population of harbour seals (*Phoca vitulina)* and grey seals (*Halichoerus grypus*).

In June 2001 National Environmental Research Institute (NERI) reported a feasibility study on the use of satellite telemetry as a tool to investigate potential effects of the wind farm on the seal population on Rødsand (Dietz et al. 2001a). The present report includes data from ten seals tagged near Rødsand between 2000 and 2002. The data presented represent the baseline situation before the construction of the wind farm started.

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

It is possible that some of the activities involved in the 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 disturbances may be the physical presence of the wind turbines and the noise from ships and construction work. These disturbances can potentially lead to temporary or even permanent loss of habitats near the wind farm.

In order to study the possible effects from the construction and operation of the wind farm on the seal population a number of investigations were initiated. Aerial surveys determined the use of alternative haul-out localities, a web-cam monitored the use of and diurnal activity at the Rødsand seal sanctuary, while the satellite telemetry study monitored the general movements, habitat selection and use of the wind farm area.

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

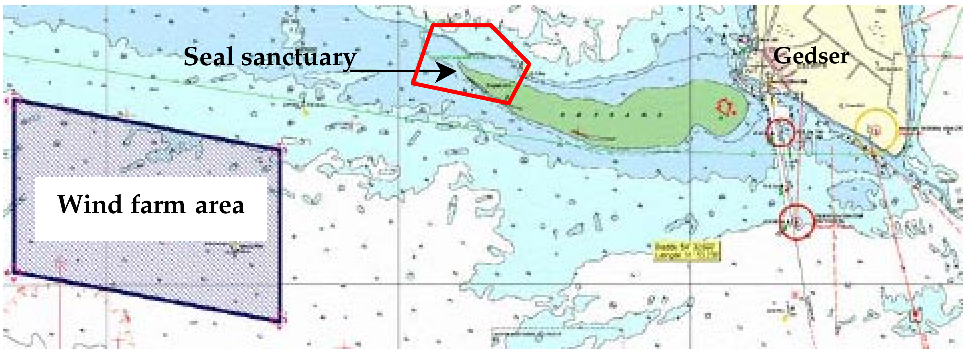

Figure 1. *Map of the wind farm area and the seal sanctuary.*

3.1 The area around the Nysted Offshore Wind Farm

Nysted Offshore Wind Farm will be placed in Femer Belt about 10 km south of the city Nysted (Lolland). The water depth in the wind farm area is between 5.5 m and 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 larger than 10 cm, no reef-like aggregations are known.

About 2 km north of the wind farm is a shallow (less than 4 m deep) lagoon-like area between Southeast Falster and Southwest Lolland. This area is used by a large number of coastal fishermen mainly using fish traps 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 stone reefs (Vitten, Skrollen and Flintehorne Odde) away from human disturbance. The wind farm will be placed 4 km southwest 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 public access from 1 March – 30 September in a distance of about 500 m around the western tip of the sandbank (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 open very close to the bank, through which 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 sanctuary. This has now been confirmed by aerial surveys and during this study (see later). Throughout the Rødsand lagoon seals are often observed sporadic on rocks and in the water. Seals are often seen in the deeper water south of the lagoon (Dietz et al. 2000).

The sandbank in the seal sanctuary (Fig. 2) is flooded in extreme weather and is in a state of constant alteration as a result of currents and sand deposits.

Figure 2. *The seal sanctuary at Rødsand taken during an aerial count in April 2002 (Photo: Rune Dietz).*

4 Objectives

The objectives of the present study are:

- To provide information on site fidelity, migration and Kernel home range of harbour and grey seals prior to the construction of the wind farm.

- To determine the potential vulnerability of the two seal species to the construction and operation of the wind farm.

- To provide information on haul-out and diving behaviour.

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5 Materials and methods

5.1 Biological measures

During tagging operation, the seals species, sex, length and weight were recorded. In addition hair samples were taken for future genetic identification of the seals.

5.2 Satellite telemetry

5.2.1 Principle of satellite transmitters (PTTs)

The Service Argos System is on board five NOAA satellites. These satellites are sun synchronous polar orbiting satellites, which in total will make 14 orbits per day (24 h). The satellites travel in an altitude of 850 km and are in "view" of the satellite transmitter (PTT) for 9-12 minutes per passage. Hence the satellite coverage is latitude dependent, with the best coverage around the poles. The system is based on the "Doppler Shift Principle", and the accuracy of the position is dependent of the number of consecutive transmissions, received within a satellite pass and the time between them. The data are downloaded from the satellite to a ground station. The PTT is a sealed unit produced by a company certified by Service Argos. PTTs used for marine mammals have a "saltwater-switch" or conductivity sensor, which allows the unit to transmit 250 ms after the animal has surfaced and the micro current between the two saltwater-switch-poles are broken. Each transmission takes between 360 and 960 ms. The PTT transmits every 45 s, the so-called "repetition rate". Hence the repetition rate and when the animal is diving are limiting the number of transmissions received by the satellite. In order to save energy and extent the lifetime of the transmitters the PTTs are programmed to transmit a certain number of hours or transmissions per day or only on certain days – the so-called "duty cycle"

5.2.2 Netting of the seals

Ten seals were caught in nets between 16 November 2000 and 12 April 2002.

Two rows of approximately 250 m floating gillnets were set in the seal sanctuary approximately 25 and 35 m from the shore just outside the slope where the depths falls from 1 to 4 m. Both monofilament and twisted nylon with mesh sizes of 20x20 cm were used. Both black and transparent green nets were used. All nets were floating with very little weight in the lead line, which made it easy for the entangled seals to reach the surface and breath. During the first two attempts in November and December 2000 nets of 2 m height were used. During these attempts seals were often observed diving under the nets. In the consecutive attempt net height was increased to 4 m to prevent the seals from swimming underneath. In general the seals were obviously used to the presence of nets and hence a considerable effort was required to catch the first 9 seals by this method. The last tagged seal was caught actively by surrounding the seals with a net set from a boat. This method has proven successful in the German and Danish Wadden Sea. However, the seals at Rødsand were scared by the approaching boats, which reduced the efficiency of this method. Furthermore, unlike the Wadden Sea, the seals at Rødsand can escape to both sides of the sandbank and the shallow area makes it difficult to manoeuvre a boat.

5.2.3 Handling of the seals

***Figure 3**. Two harbour seals tagged at Rødsand illustrating the two ways of restraining the animals while tagging (Photos: Rune Dietz and Jonas Teilmann).*

After the seals were caught in the nets they were either dragged up on shore or lifted into the boat where they were fixed in a net cradle mounted between two bars. The seal was transported to the shore, where the net was removed from the body of the seal. The seal was fixed on a specially designed plywood plate with eight mounting straps (Fig. 3) or in a wooden cradle. Holes were cut in the cradle net to allow for attaching the transmitter and for freeze branding.

5.2.4 Transmitter type

Ten seals were tagged using three different types of satellite transmitters. Different transmitter types were tested to elucidate which transmitter gave the best performance when mounted on the head of seals (see Dietz et al. 2001). In previously studies transmitters were mounted on the back of the seals (e.g. Teilmann et al. 1999), but size reduction of the transmitters have now made headmounts possible which enhances the chance of receiving positions while the seal is swimming. The tags were all designed for the present study in co-operation with the manufacturers, with respect to shape, transmitter type and battery size/type. They measured 7-10 cm in length, 3-4.5 cm width, and 2-4 cm in height and weighed between 150 and 200 g in air (Fig. 4).

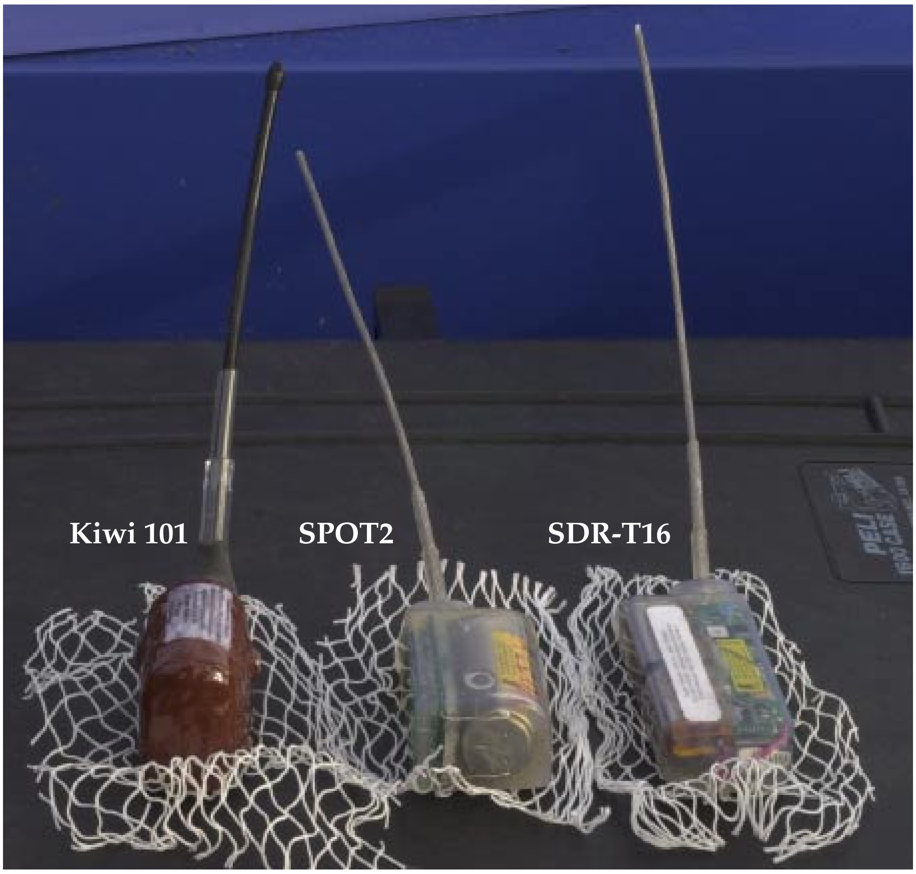

Figure 4. *The three types of transmitters used in this study (Photo: Rune Dietz).*

*Table 1. Specifications of the nine transmitters deployed on ten seals. 10337 were deployed twice. *This seal drowned in a pound net set by a fisherman east of Gedser peninsula (Fig. 11).*

Id no.	Transmit-termodel	Duty cycle	Daily uplinks	Expected lifetime	Observed lifetime
24286	Kiwi-101	3d on/3d off	no limit	140 days	116 days
10337a	SPOT2	1d on/1d off	1.000/day	180 days	(12*) days
10337b	SPOT2	on every day	1.000/day	78 days	63 days
17759	SPOT2	on every day	260/day	346 days	224 days
17562	SPOT2	on every day	260/day	346 days	157 days
17765	SPOT2	on every day	666/day	135 days	39 days
17567	SPOT2	on every day	260/day	346 days	238 days
17773	SPOT2	on every day	700/day	129 days	77 days
10334	SDR-T16	2d on/2d off	500/day	50 days	21 days
10335	SDR-T16	2d on/2d off	500/day	50 days	59 days

The tags were programmed differently and dependent of this the expected lifetime varied (Table 1). Sirtrack produced the Kiwi-101 tag and Wildlife Computers produced the seven SPOT2 tags. Both types contained one C-cell battery and provided no haul-out and dive data. The two SDR-T16 produced by Wildlife Computers were powered by two M1-cells and provided both dive and haul-out information.

5.2.5 Attachment of the transmitter

The fur on the head of the seal was cleaned with acetone and the transmitter was glued to the fur (Fig. 5) with two-component epoxy glue (Araldite 2012). The glue hardened after approximately 10 minutes depending on air temperature. A yearling harbour seals (# 17562) was so small, that the transmitter had to be mounted on its back.

***Figure 5.** A grey seal (#10334) with a transmitter glued to the fur on the head (Photo: Rune Dietz).*

5.2.6 Data collection and analysis

Data on movements, diving behaviour and transmitter status were collected via the Argos Location Service Plus system (Toulouse, France; Harris et al. 1990) and received on-line over the Internet and on CD-ROMs. The software Satpak 3.0 (Wildlife Computers) was used for validating dive data received from Argos and transforming data into a spreadsheet format. Excel 97 was used for statistical analysis and graph presentations.

Argos divides the derived location quality (LC) into six classes LC B, LC A, LC 0, LC 1, LC 2 and LC 3, for which the average of the latitude and longitude 68th percentile errors predicted by Argos are as follows. LC 3: 150 m; LC 2: 350 m; LC 1: 1,000 m; LC 0, A, and B have no assigned precision. Results from four grey seals tagged in captivity with satellite transmitters (PTT 100; Microwave Telemetry Inc., Columbia, MD) have recently been published (Vincent et al. 2002). The following accuracy on latitude/longitude were obtained: LC 3: 15 m/295 m; LC 2: 259 m/485 m; LC 1: 49 4m/1,021 m; LC 0: 2,271 m/3,308 m, LC A: 762 m/1,244 m and LC B: 4,596 m/7,214 m.

The SAS-program Argos_Filter V5.0 (Prepared by Dave Douglas, USGS, Alaska Science Center, Alaska, USA) was used to choose the most plausible locations.

The program identifies implausible locations based on two different filtering methods: 1) A user-defined distance that is used as a threshold for determining locational redundancy; and 2) distance, angle and rate measurements that attempt to identify implausible locations based on the fact that most suspicious ARGOS locations cause the animal to incorrectly move a substantial distance and then return (subsequent location is more correct), resulting in a tracking-path that goes 'out-and-back' (and/or further validated by unrealistic movement rates, depending on the temporal frequency of the locations). This program produces three kinds of output, one for each of the filtering strategies: 1) Minimum-redundant-distance (MRD); and 2) distance-angle-rate (DAR). Finally, a third more-experimental output is produced that 'adds' selected DAR locations to the MRD results, only when the DAR locations conform to directional movement as defined by 'anchoring' all MRD locations. ArcView was used for mapping the movements and Kernel home range of the tagged seals.

Two seals had a pressure (depth) transducer that sampled depth every 10 sec. Dive data for these two tags were stored in histograms summarising dive data for 6-hour periods and then relay them to the satellite during the following 24 hours. Three types of 6-hour histograms were sampled: 1) Maximum depth for each dive, 2) duration of each dive, and 3) time spent in each depth interval (TAD). Data from these three categories were sampled and stored in 14 user-defined intervals, shown in Table 2. The pressure transducer had a resolution of +/- 1 meter and an accuracy of +/- 1% of the depth reading.

Table 2. The 14 user defined intervals used for sampling data of maximum dive depth (1), duration of each dive (2) and time spent in each depth interval (3)

Interval	Type 1 Max. depth	Type 2 Duration	Type 3 "TAD"
1	0-5 meters	0-1 minutes	haulout
2	6-10 meters	1-2 minutes	0-2 meters
3	11-15 meters	2-3 minutes	3-5 meters
4	16-20 meters	3-4 minutes	6-10 meters
5	21-25 meters	4-5 minutes	11-15 meters
6	26-30 meters	5-6 minutes	16-20 meters
7	31-35 meters	6-7 minutes	21-25 meters
8	36-40 meters	7-8 minutes	26-30 meters
9	41-45 meters	8-9 minutes	31-35 meters
10	45-50 meters	9-10 minutes	36-40 meters
11	51-55 meters	10-11 minutes	41-45 meters
12	>55 meter	11-12 minutes	46-50 meters
13		12-13 minutes	51-55 meters
14		> 13 minutes	> 55 meters

Two other types of information were transmitted in separate messages; Status messages and Timelines. The status messages included the maximum dive depth during the previous 24 hours, information on dry (on land) or wet (at sea) readings from the saltwater switch, the time spent on land (in 6-hours intervals) and status of the sensors and battery performance. Timelines, representing 24 hours, are divided into 72 intervals of 20 minutes. Each 20 minute period determines whether the seal was on land or in the water for more than 50% of the time.

5.3 Kernel home range

The Kernel Home range method consists of placing a kernel (a probability density) over each position in the set of observations. A regular grid is superimposed on the data, and an estimate of the density is obtained at each grid intersection, using information from the entire sample. The estimated density at each intersection is essentially the average of the densities of all the kernels that overlap the point. Observations that are close to the point of evaluation will contribute more to the estimate that the ones that are far from it. Thus, the density estimate will be high in areas with many observations, and low in areas with few. Several Kernel methods are available. The "fixed kernel" method is used in this study as recommended by Seaman & Powell (1996) since this gives area estimates with the lowest error.

Kernel home ranges were made using the "Animal Movement" extension in ArcView. The geoprocessing wizard in ArcView was used to subtract land for the Kernel home range polygon to get exact area estimates of the 95%, 75% and 50% Kernel home range probability in the water only. The 95% probability means that there is a 95% chance that the seal will be within this area at any time. Only one location per day is included in the Kernel home range analysis, as many consecutive locations on some days would bias the results.

Kernel home ranges were calculated for each individual seal (95, 75 and 50%) as well as a pooled "meta-home range" for all seals of the same species. The meta-home range was representative of relative area use by either harbour or grey seals, as all locations for each individual were pooled for the estimate.

5.4 Other marking of the seals

For long-term identification beyond the lifetime of the satellite transmitters, the seals were also freeze branded. For this purpose 7 cm high bronze numbers frozen down to –172 °C for at least 5 minutes in liquid nitrogen were used. The bronze numbers were pressed against the skin of the seal for 25 seconds on each side just behind the shoulders (Fig. 6). After 3-4 weeks the digits becomes fully visible, as the hair at the branded patch is lost due to the destruction of hair follicles. The freeze branding marks will be visible for at least 13 years according to Härkönen et al. (1999).

Some seals were also marked with plastic cattle ear tags (Roto-tags) in the hind flippers (see Table 3). This method has been used in many other seal studies as a long-term identification mark, e.g. in ringed seals in Greenland where seals were recaptured up to six years later (Kapel et al. 1998).

Some seals were also equipped with transponders (Trovan Passive Integrated Transponder System; PIT tags) used for domestic animals like dogs and cats (see Table 3). The transponders were placed in the blubber over the left shoulder and will be permanently embedded in the tissue. By scanning recaptured or dead seals this method may provide information on the seals over a longer time frame.

Figure 6. *A harbour seal freeze branded during the tagging operation (Photo: Pernille Bondo Harders).*

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6 Results

6.1 The tagged seals

Four harbour seals and six grey seals were tagged during this study. The four harbour seals were tagged between April 2001 and April 2002 and covered all age groups including yearling, subadult and adult. Three subadult and three adult grey seals with an even sex distribution were tagged between November 2000 and March 2002 (see Table 3 for details).

Table 3. *Information on species, transmitter number, tagging date, sex, age group, length, weight, freeze branding number, Rototag number and transponder number of the ten seals tagged between November 2000 and April 2002.*

Species & Id no.	Tagging date	Sex	Age group	Std. length (cm)	Weight (kg)	Freeze #	Roto-tag #	Trans-ponder #
Harbour seal								
10337b	21.4.2001	Male	Subadult	121	54	4	-	-
10335	22.4.2001	Female	Adult	148	100	5	-	-
17562	24.9.2001	Male	Yearling	90	25	8	8	-
17773	12.4.2002	Male	Subadult	107	43,5	10	27	00-060F-3910
Grey seals								
10337a	16.11.2000	Male	Subadult	130	49	1	-	-
24286	17.11.2000	Male	Subadult	135+	71	2	-	-
10334	20.4.2001	Female	Subadult	133	66	3	-	-
17567	18.9.2001	Male	Adult	162	110	6	-	00-060F-759F
17759	18.9.2001	Female	Adult	152	110	7	-	00-060D-5DEC
17765	20.3.2002	Female	Adult	150	74	9	13	00-060F-9FF7

6.2 Satellite telemetry

6.2.1 Data obtained

Information on the number of extracted locations of the tagged seals is compiled in Table 4. A total of 3,078 positions were extracted and analysed. Although only four harbour seals were tagged, more locations were obtained for the species than from the six grey seals. From the four harbour seals 1,727 positions (4.9 positions/day) was obtained, whereas only 1,351 positions were obtained from the six grey seals (2.1 positions/day). When comparing the number of transmissions per day in relation to the number of reliable locations received, harbour seals required fewer transmissions (mean=164) compared to grey seals (mean=210) to provide a location. This is probably due to behavioural differences between the two species.

Table 4. *Information on transmitter longevity and number of locations obtained from the ten seals tagged during this study. *An American drift buoy accidentally transmitted strong signals with the same ID-number, so only 71 days' locations have been received (see section 6.2.3).*

	Date of deployment	Date of last position	Days of contact	Extracted positions	Positions per day
Harbour seal			**356**	**1,727**	**4.9**
10337b	21.4.2001	22.6.2001	63	746	11.8
10335	22.4.2001	15.6.2001	59	38	0.6
17562	24.9.2001	27.2.2002	157	566	3.6
17773	12.4.2002	27.6.2002	77	377	4.9
Grey seal			**650**	**1,351**	**2.1**
10337a	16.11.2000	27.11.2000	12	27	2.3
24286	17.11.2000	12.3.2001	116	391	3.4
10334	20.4.2001	14.5.2001	21	27	1.3
17567	18.9.2001	13.5.2002	238*	107	1.5
17759	18.9.2001	29.4.2002	224	631	2.8
17765	20.3.2002	27.4.2002	39	168	4.3
All			**1,002**	**3,078**	**3.1**

6.2.1.1 Duration of contact

Most of the transmitters stopped transmitting earlier than predicted. 24286 and 10335 probably ran out of battery, 17562 stopped for unknown reasons, while 10337a drowned in fishing gear (Table 1). The remaining six seals probably moulted their fur and lost the tag. The peak moulting season for the grey seals are in June but it is likely that the moult starts earlier. Based on the date of last contact we suggest that when grey seals carry a tag, the fur under the tag will start loosening and the tag will fall off during late April - mid May. The peak moulting season for harbour seals are in August. However, three out of four tags were lost during the last ten days of June, suggesting that the fur started to loose at this time. Future transmitter programming can take the average moulting dates into account and hence optimise the performance of the tags.

6.2.2 Seasonal coverage

The four harbour seals combined were monitored nine month of the year. As only one harbour seal (#17562) was caught in September, this animal was the only one providing information during fall and winter. No harbour seals were tracked during March, but three individuals were tracked during April through June. The six grey seals were likewise monitored nine month of the year from September through May (Table 5).

Table 5. Seasonal distribution of extracted locations received from the tagged seals monitored between November 2000 through June 2002.

	Month										
Id.-no.	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May.**	**Jun.**	**Grand total**
Harbour seals	35	141	133	109	82	66		176	590	395	1,727
10337B								90	363	293	746
10335								2	25	11	38
17562	35	141	133	109	82	66					566
17773								84	202	91	377
Grey seals	**40**	**158**	**194**	**237**	**231**	**117**	**107**	**227**	**40**		**1,351**
10337A			27								27
24286			55	86	109	87	54				391
10334								10	17		27
17567	23	53						8	23		107
17759	17	105	112	151	122	30	35	59			631
17765							18	150			168
Grand Total	**75**	**299**	**327**	**346**	**313**	**183**	**107**	**403**	**630**	**395**	**3,078**

6.2.3 Movements

Harbour seal #10337b

The first harbour seal was captured on 21 April 2001. This was a subadult male (#10337b) from which positions were obtained until 22 June 2001. Within this period it remained quite stationary around the Rødsand seal sanctuary but visited the stone reef Vitten at least five times. Four trips were recorded along the east coast of Falster. Three of these trips went to the coast along Marielyst and one extended north of Ulslev (54E45′N). Only one location (0.13%) was obtained within the wind farm area, but five tracklines passed through the wind farm area. Only the northeastern quarter part of the wind farm area was included in 95% Kernel home range area (Fig. 7).

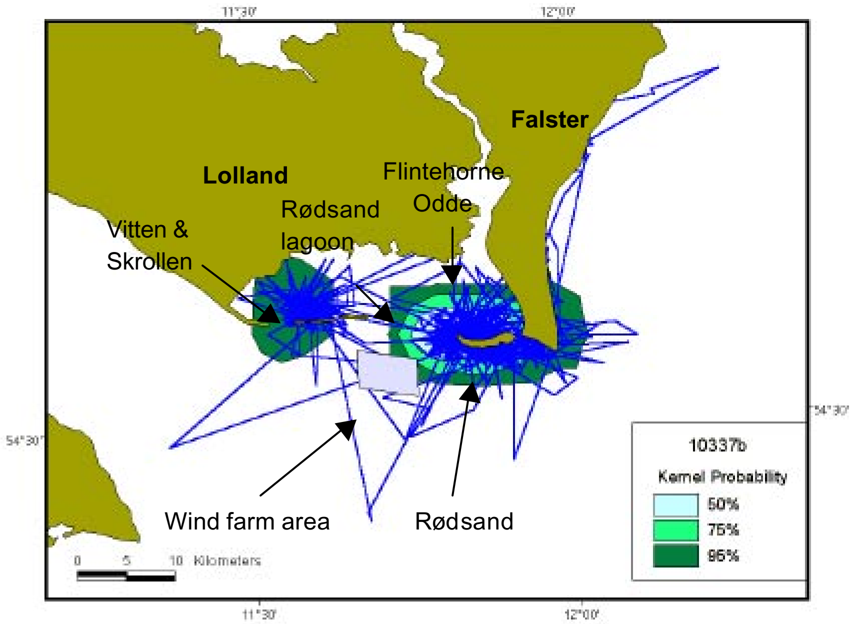

__Figure 7.__ The movements and Kernel home range of a subadult male harbour seal (#10337b) tracked from 21 April to 22 June 2001.

Harbour seal #10335

The second harbour seal was tagged on 22 April 2001 and was monitored until 15 June 2002. This adult female harbour seal (#10335) was probably pregnant, and did not move far away from the seal sanctuary area, where it was likely to give birth in June. No locations or tracklines passed through the wind farm area. Only the north-eastern corner of the wind farm area was included in 95% Kernel home range area (Fig. 8).

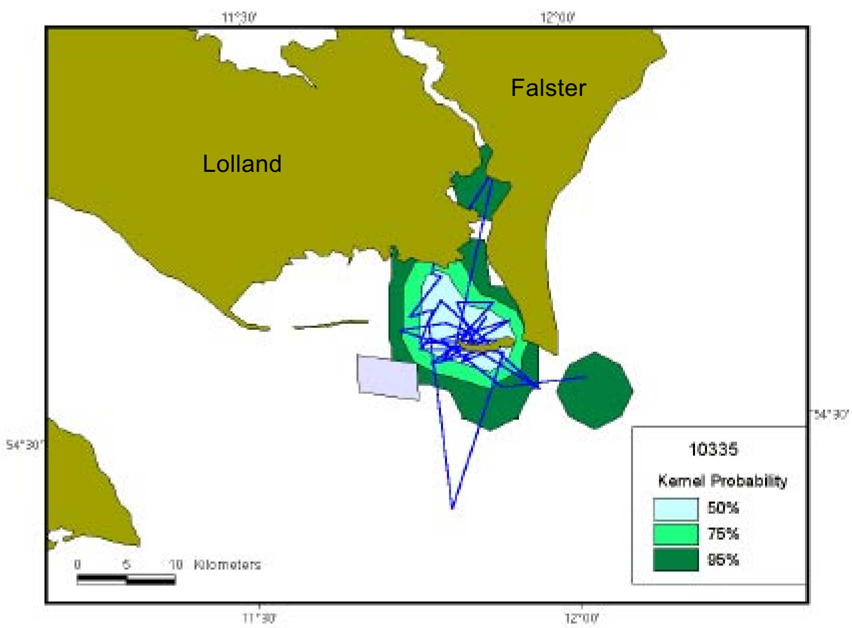

__Figure 8.__ The movements and Kernel home range of an adult probably pregnant harbour seal (#10335) tracked from 22 April to 15 June 2001.

Harbour seal #17562

The third harbour seal (#17562) was a yearling (born the same year) male tagged on 24 September 2001. It was monitored until 27 February when the transmitter prematurely stopped. This seal used a substantial proportion of its time south of Rødsand (Fig. 9). It made three trips to the western part of Lolland and three trips down to Mecklenburg Bay in Germany. The seal also frequented the stone reef at Flintehorne Odde and the southern part of Guldborg Sund up to Bredningen. However, this seal did not frequent the haul out site at Vitten. The calculated Kernel home range extended north to Nykøbing Falster. Five locations (0.88%) were obtained within the wind farm area, and numerous tracklines passed through the wind farm area. The wind farm area was centred within the 95% and partly within the 75% probability range of the calculated Kernel home ranges. This seal died during the seal epizootic in late summer 2002. It was found on Femern, 40 km south-west of Rødsand and recognised due to the freeze brand and Rototag number (no details available yet).

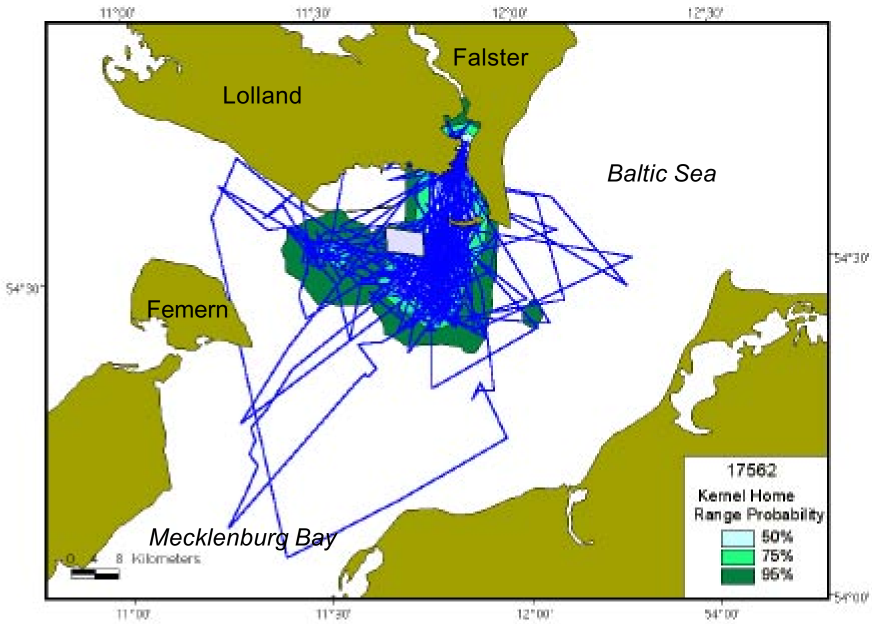

Figure 9. *The movements and Kernel home range of a yearling harbour seal (#17562) tracked from 24 September 2001 to 27 February 2002.*

Harbour seal #17773

The last harbour seal (#17773) was a subadult male that was tagged on 12 April 2002 and tracked until the transmitter was lost in the moulting season the 27 June. This seal more or less only used the lagoon north of Rødsand and like the yearling seal, it frequented the haul-out site at Flintehorne Odde and the southern part of Guldborg Sund up to Bredningen (Fig. 10). One location (0.27%) was obtained within the wind farm area. Most of the wind farm area was within the 95% probability range of the Kernel home range calculation.

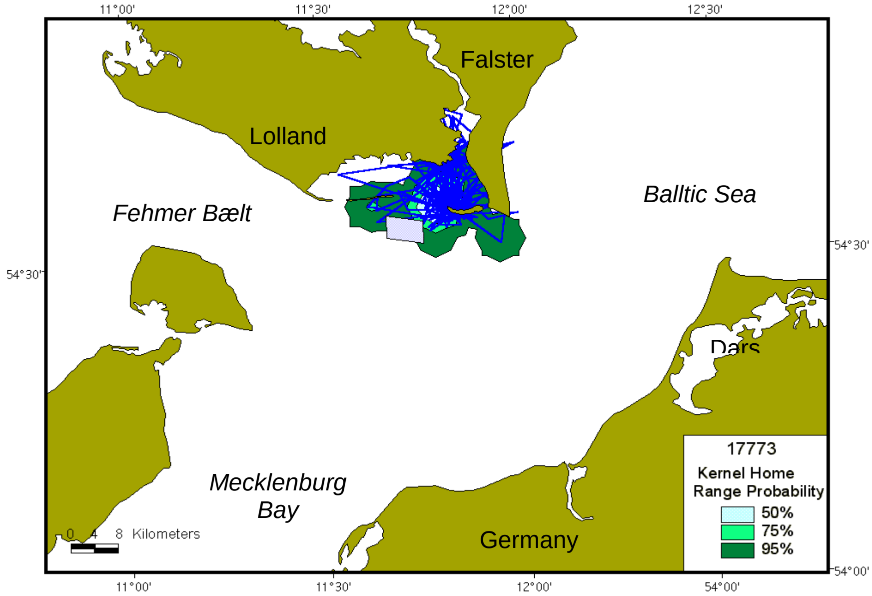

Figure 10. The movements and Kernel home range of a subadult harbour seal (#17773) tracked from 12 April to 27 June 2002.

Grey seal #10337a

During this study six grey seals were tracked. The first grey seal, a young male, (#10337a) was tracked from 16 November to 27 November 2000.

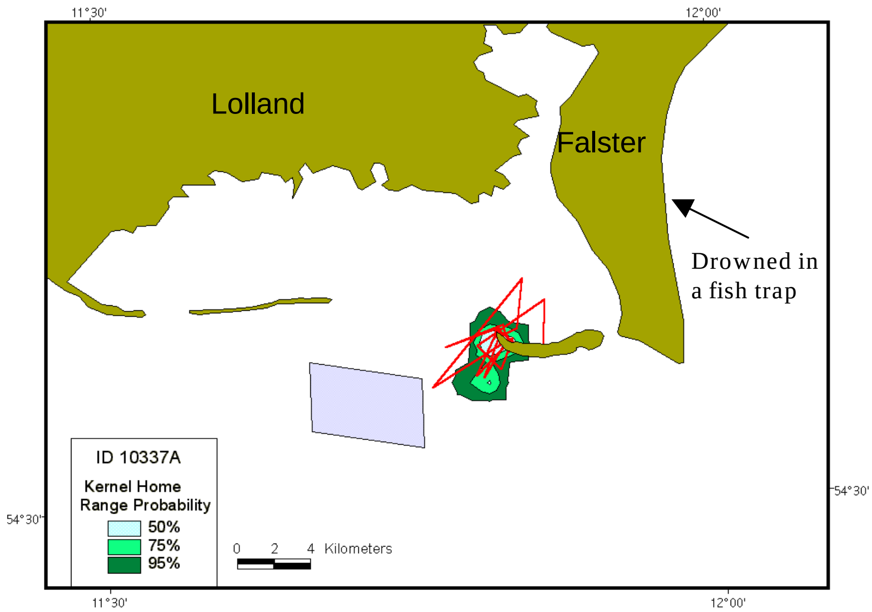

Figure 11. The movements and Kernel home range of a young male grey seal (#10337a) tracked from 16 November to 27 November 2000.

The seal stayed most of the time near the tagging locality. Thereafter it moved to the eastern side of Falster, where it drowned in a fish trap inside a pound net east of Gedser peninsula (see arrow in Fig. 11).

No positions were obtained within the wind farm area nor was the wind farm area included in the predicted Kernel home range. For information on the dead seal see section 6.4.

Grey seal #24286

The second grey seal, also a young male (#24286) tagged on 17 November 2000 and tracked until 12 March 2001 only stayed for a few days in the Rødsand area. Then it moved north-east and passed Møn on 19 November, and continued to Øresund, where it arrived on 24 November (Fig. 12). It moved between the Swedish grey and harbour seal locality Måkläppan and the Danish island Saltholm. It stayed close to this region until the transmitter probably ran out of battery 12 March 2001. Within this period it took a single trip east to the Baltic from 19-26 December and passed Bøgestrømmen, a Danish seal locality where only harbour seals have previously been observed (Teilmann & Heide-Jørgensen 2001), from 29 to 30 December 2000. During the rest of the winter it stayed within the triangle between Amager, Saltholm and Måkläppan. The southern part of Saltholm is a well-known seal locality for both harbour and grey seals only 5 km east of Copenhagen (Teilmann 1992). This spot turned out to have a similar importance to the seal as Måkläppan. An interesting feature is that the Øresund bridge and tunnel is placed between Saltholm and Måkläppan only a few hundred meters from the southern tip of Saltholm. Apparently this did not affect the seal.

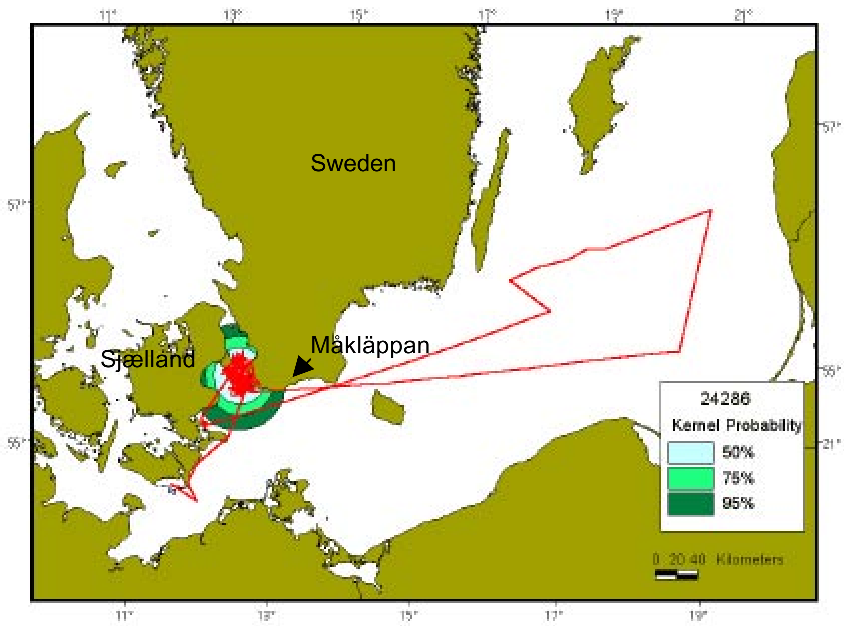

Figure 12. *Movements and Kernel home range of a young male grey seal (#24286) tracked from 17 November 2000 to 12 March 2001.*

Grey seal #10334

The third tagged grey seal (#10334) was a subadult female, which was tracked from 20 April to 14 May 2001. After the tagging the grey seal stayed in the Rødsand area at least one day. Then it migrated into the Baltic along the Swedish eastcoast (Fig. 13). During this movement it passed a number of seal haul-out sites in the Swedish archipelago. Among these was Utklippan southeast of Karlskrona (18 April) and the skerries south and east of Öland, where it passed 29 April 2001. After one day at this haul-out site it moved northward to the archipelago east of Arkö where it arrived on 2 May and stayed there until 11 May. This area contains the two grey seal sanctuaries Svartbådan and Stångskärsrev, where admittance is prohibited year-round. The last position was obtained from the eastern archipelago outside Estonia, where contact was lost on 14 May 2001. The Kernel home range of this animal was large, probably due to both a large dispersal distance and a relatively low number of locations received during that time. The wind farm area is included in the 95% probability area due to the high rate of movements and rather few locations obtained from this animal.

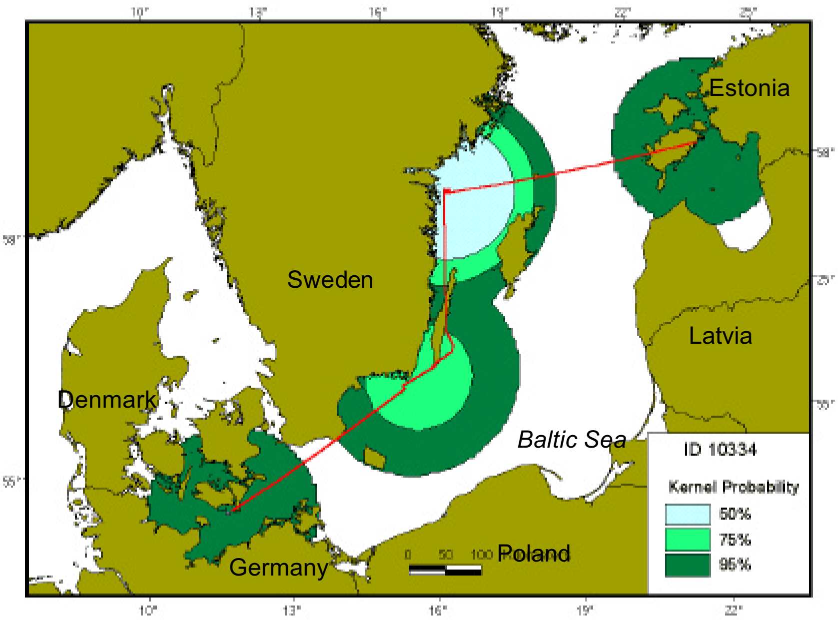

Figure 13. *The migration route and the Kernel home range of a young female grey seal (#10334) tracked from 20 April to 14 May 2001.*

Grey seal #17567

The fourth tagged grey seal (#17567) was an adult male, which was tracked from 18 September 2001 to 13 May 2002. Within this period it conducted a similar migration pattern as #10334 from Rødsand to the area east of Arkö (Fig. 14). No positions were obtained from the period between 16 October to 2 of April 2002, as an American drift buoy by mistake used the Argos ID-number assigned to the seal and overruled the seal data. The seal stayed at Rødsand from 18 September to 16 October 2001 and the next position was obtained is the protected areas Svartbådan and Stångskärsrev east of Arkö on 2 April 2002. It stayed in this area until contact was lost on 13 May 2002. No timing and routing from this movement could be extracted due to the overruled uplinks of the seal transmitter. The Kernel home range of this animal was also quite extensive. The wind farm area is included even in the 50% probability area due to the high rate of movements made by this animal.

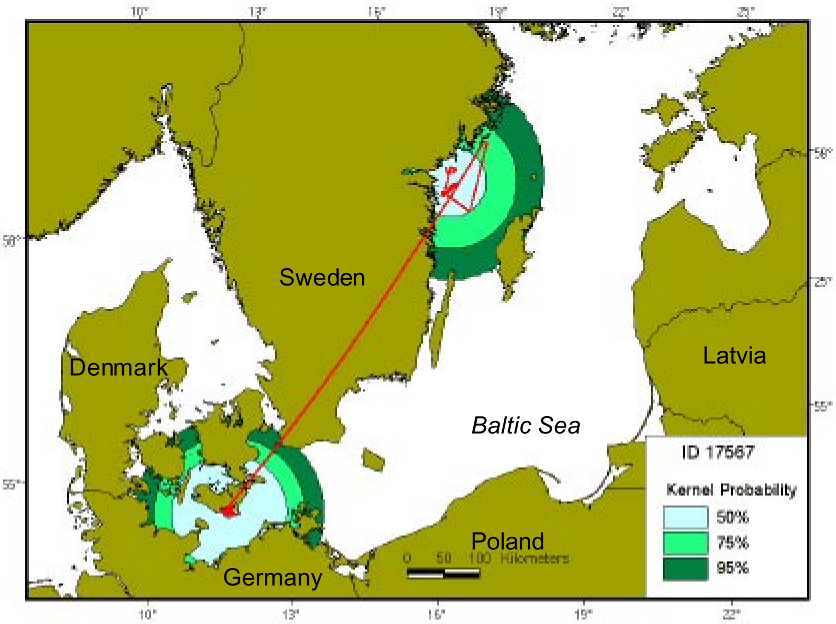

Figure 14. *The migration route and the Kernel home range of an adult male grey seal (#17567) tracked from 18 September 2001 to 13 May 2002.*

Grey seal #17759

The fifth tagged grey seal (#17759) was an adult female, which was tracked from 18 September 2001 to 29 April 2002. It stayed in the Rødsand area until 2 February. Within the next two days it passed Rügen in Germany, then migrated to Allirahu outside the Gulf of Riga, where it arrived on 17 February 2002 (Fig. 15). Within 15 days it hence travelled a distance of approximately 820 km to this Estonian seal location known to be inhabited by more than 500 grey seals (Jüssi & Jüssi 2001). At this location it probably gave birth to a pub, as an Estonian scientist observed a seal with a transmitter on the head in a breeding area with a pub in mid February (Mart Jüssi pers. comm.). The seal stayed at Allirahu until 10 March where it started a 30 days trip back to Rødsand, where it returned on 10 April. On 13 March it passed north of Latvia and from 16-25 March it stayed northwest of Latvia. On 8 April it was west of Bornholm, a day later west of Rügen and it arrived at Rødsand the 10 April. The slower trip back could have been due to company with its pub. During the seal catch 12 April it was resighted on land at Rødsand 12 April apparently in good condition, but no pub was seen. One location (0.16%) was obtained within the wind farm area. The wind farm area is included in both the 50, 75 and 95% probability areas for this animal.

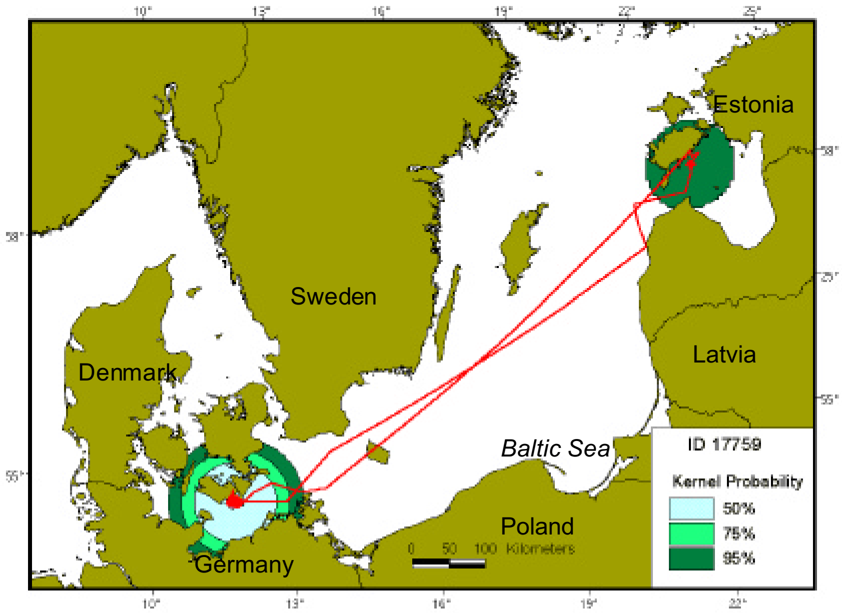

Figure 15. The migration route and Kernel home range of an adult female grey seal (#17759) tracked from 18 September 2001 to 29 April 2002.

Grey seal #17765

The last tagged grey seal (#17765) was also an adult female, tagged on 20 March. Already the following day this seal headed towards Estonia like # 17759. It passed north of Bornholm on 24 March and arrived in the Gulf of Riga on 27 March (Fig. 16). The distance from Bornholm to the Gulf of Riga was 635 km travelled in only three days. This grey seal chose two different haul out sites at Laevarahu and Selgrahu east of Saaremaa and north of Hiiumaa, each occupied by 200 to 400 grey seals (Jüssi & Jüssi 2001). It remained in the area at least until 27 April, when contact was lost. The wind farm area is included in the 95% probability area due to the high rate of movements made by this animal.

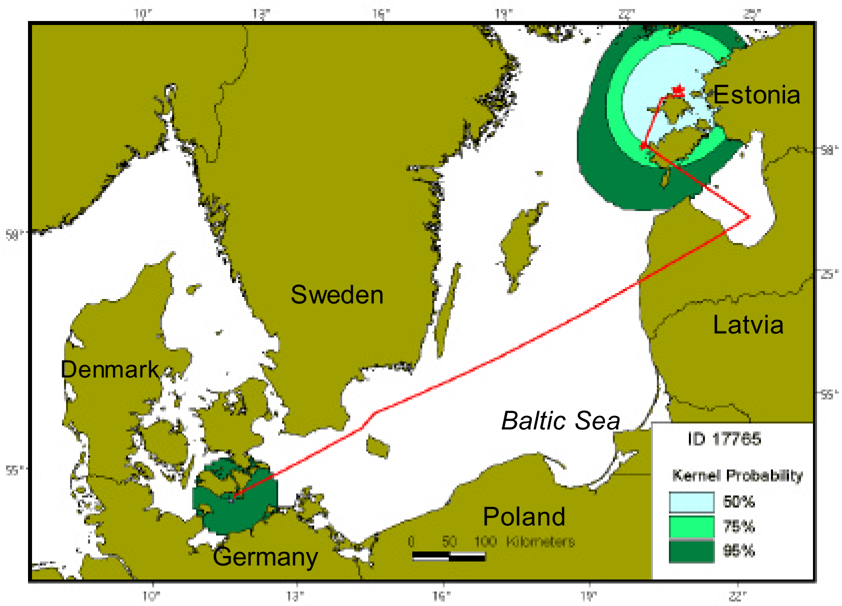

Figure 16. The migration route and the Kernel home range of an adult female grey seal (#17765) tracked from 20 March to 27 April 2002.

6.2.4 Use of the wind farm area

The results show that harbour seals stay within the area of the lagoon and surroundings and that this area is of great importance throughout the year (Fig. 18). As shown on Figure 17 the grey seals used areas far beyond the local wind farm area. The results suggest that adult female grey seals leave the Rødsand area in February/March to breed in the archipelago of Estonia in the northeastern Baltic. Also some of the males and subadult females migrate to the Baltic. They seem to prefer the archipelago of the Swedish coast around Stockholm.

Only seven locations were obtained inside the wind farm area, six of these were from three different harbour seals and one was from a grey seal. The six locations within the wind farm area came from a yearling (n=4; #17562) and two subadult (# 17773 and #10337b) male harbour seals, which constituted 0.71, 0.27 and 0.13% of the obtained positions, respectively. Of the total of 1727 locations obtained from harbour seals only 0.35% were inside the wind farm area (Fig. 18). The single position from the grey seals made up 0.074% of all tagged grey seals and 0.16% of that particular seal (#17759). Although only few locations were received from the wind farm area the estimated Kernel home ranges included the wind farm area for most (8/10) seals, which show that the area may be frequented but is probably not of major importance.

The size of the wind farm area is about 24 km^2 (SEAS 2000). This area represents 10.8% of the average 95% Kernel home range of all the harbour seals and 3.4 – 10.1 % of the individual harbour seals. For the grey seals the wind park area represents 0.047% of the average 95% Kernel home range of all the grey seals and 0.020 – 0.58% of five individual grey seals. The one grey seal that was caught in a fish trap shortly after the tagging had a Kernel home range that was only 54.2 % of the wind farm area, but the short longevity is not considered representative. The wind farm area constitutes hence a relatively high percentage (10.8%) of the 95% Kernel home range of the harbour seals, whereas the wind farm area is of minor importance to the grey seals compared to the total Kernel home range of these seals. However, the importance may be more significant in certain periods of the year (see Fig. 19).

As the transmitter has to be out of the water several times during a satellite passage to obtain a location, the question arise as to, whether the method is actually biased towards fewer positions at sea compared to the land observations. It is evident that the location densities are higher closer to the known haul-out sites at Rødsand, Vitten and Flintehorne Odde.

6.2.5 Kernel home ranges

From the Kernel home ranges for the individual seals presented above, it is obvious that the harbour seals were considerably more stationary than the grey seals. The overall 95% probability Kernel home range for harbour seals was 394 km^2 (Table 6; Fig. 18), whereas the corresponding figure for grey seals was 130 times larger namely 51,221 km^2 (Fig. 17).

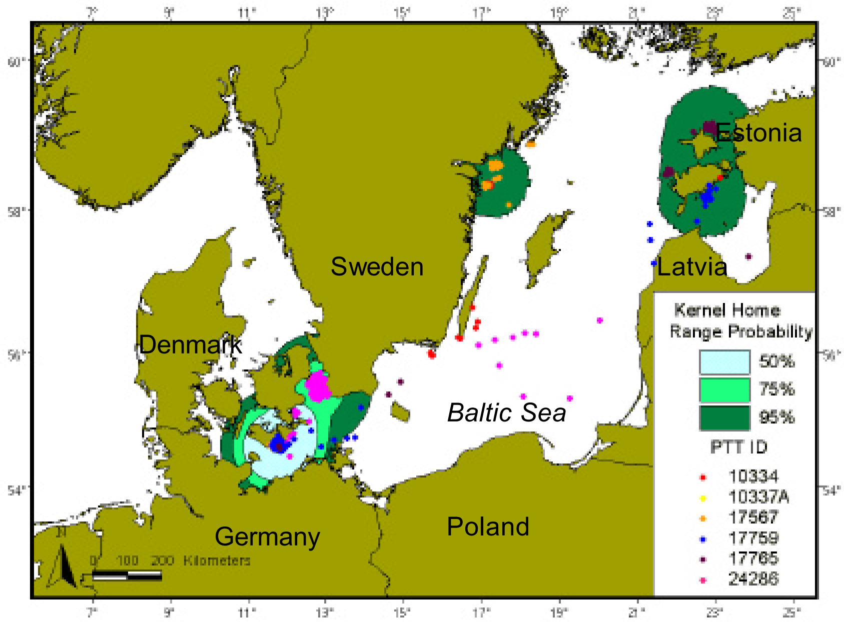

Figure 17. *Locations obtained from all six tagged grey seals. The Kernel home range is calculated from the combined dataset from all grey seals.*

Table 6 shows that the individual 95% Kernel home ranges of harbour seals varied from 313 to 709 km^2 whereas the corresponding figures (#10337A not included) were 4,160 to 119,583 km^2 for grey seals. This implies that the Rødsand area is important to harbour seals year round whereas grey seals frequent the area for shorter or longer periods. Land counts presented in the EIA (Dietz et al. 2000) suggest that the grey seals leave the Rødsand area during the breeding and mating season in February/March, which is also supported by one of the tagged adult females (#17759). Therefore disturbances near Rødsand must be expected to have a higher impact on harbour seals during the late winter – early spring period compared to grey seals.

Table 6. *Kernel home range estimates for 95, 75 and 50% probabilities for the 10 tagged seals given in km^2. The figures are accounting for land, which is not included in the estimates.*

ID	95%	75%	50%
Meta-home range harbour seals	**394**	**102**	**48**
10337B	237	87	45
10335	270	116	59
17562	709	333	142
17773	313	72	26
Meta-home range grey seals	**51,221**	**16,446**	**9,020**
10337A	13	5	2
24286	4,160	3,133	1,583
10334	119,583	34,799	15,232
17567	50,822	33,414	18,407
17759	24,946	11,616	7,244
17765	49,629	21,816	12,615
Grey seal h.r./harbour seal h.r.	**231**	**161**	**188**

The Kernel home range data are likely to reflect the area, where the seals are searching for food. Theoretically the Kernel home range data could be used to extrapolate guidelines for the transport routes for personnel and ships during the construction phase in order to obtain minimum disturbance during the operation. However, the substantial variability among individuals makes such an approach problematic, and a higher resolution with possible diurnal patterns would need to be explored as well.

Although only few positions were obtained within the wind farm area, the calculated Kernel home range areas for the harbour seals and four of the tagged grey seals extended into the wind farm area. In addition the actual zone of acoustic effect extends beyond the actual wind farm area as illustrated by Henriksen (2001). This indicates that animals might be affected outside the actual wind farm area. Whether the animal behaviour will actually be affected by the construction and operation of the turbines must be monitored in new studies during and after construction.

The overall Kernel home range of harbour seals showed two areas of importance to the harbour seals (Fig. 18). The most important was the eastern part of the Rødsand lagoon area and into the southern part of Guldborg Sund as well as an area south of the sanctuary. The other area was east of the wind farm area and south of Hyllekrog. It is striking that the harbour seals do not use the eastern part of the lagoon very much, this could be an artefact of the small sample size or possibly because the ship route to Nysted posses some kind of barrier to the seals. Most grey seals in the vicinity of Rødsand were obtained north and northwest of the seal sanctuary (Fig. 19). The monitored grey seals seldom frequented Vitten and only two locations were obtained in Guldborg Sund.

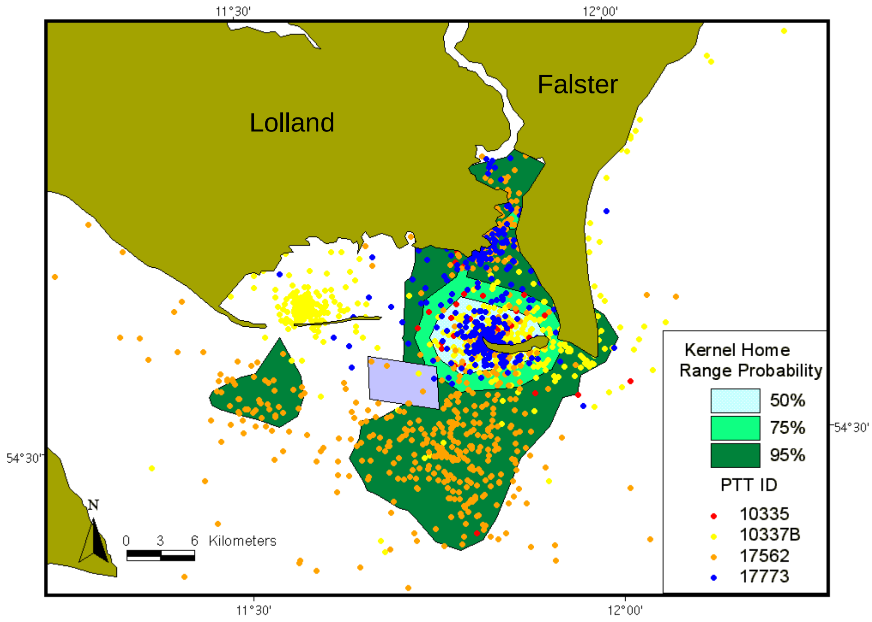

Figure 18. Locations obtained from the four harbour seals around the wind farm area.

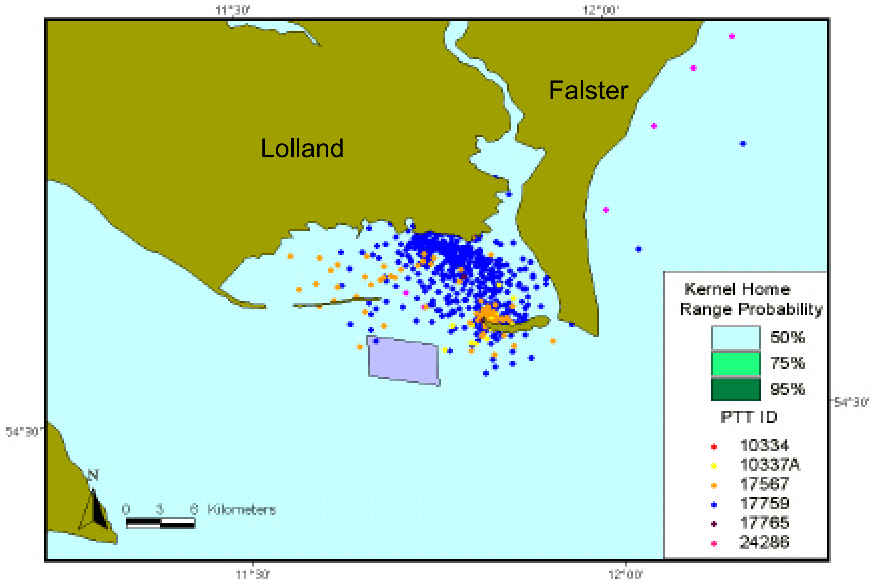

Figure 19. *Locations obtained from the six grey seals around the wind farm area. Note that the 50% Kernel home range area covers the whole map.*

6.2.6 Positions at sea versus positions on land

Only two of the transmitters attached to a female grey seal (#10334) and an adult female harbour seal (#10335) provided data on whether the locations were transmitted from land or at sea. Of all locations from these two seals 44% locations were obtained from land and 56% from the sea. As the two seals spend between 22 and 40% of their time on land (see section 6.2.7), locations received from land seem to be over represented. Unfortunately the data set from the two seals is very small and the limited data set does not allow definite conclusion about the relative number of locations received on land and at sea.

From the land observations it becomes obvious that only the seal sanctuary at Rødsand and the skerries east of Arkö were of haul-out importance for the two seals in the monitored period. An important finding is also that it is possible to obtain locations at sea although fewer good quality locations were obtained. Based on the two maps it seems that the grey seal #10334 did spend all its time in the water until it reached the skerries east of Arkö except for a short stop at Utklippan.

6.2.7 Diving behaviour of the seals

The time spent on land and in various depth categories was sampled by the two SDR-T16 transmitters placed on seal #10334 and #10335. Figure 20 shows that the grey seal (#10334) spent about 40% of its time on land while the harbour seal (#10335) was only 22% of the time on land. They both spent 17-18% of their time at the surface (0-2 m). Due to the depth of the area frequented by the grey seal, it was able to dive deeper than the harbour seal, which stayed locally in the shallow waters near Rødsand. Recordings of the maximum dive depth per 24 hrs showed that the deepest depth for the grey seal was 82 m (range=12-82 m, mean=44 m, n=10) and 12 m (range=6-12 m, mean=9 m, n=14) for the harbour seal.

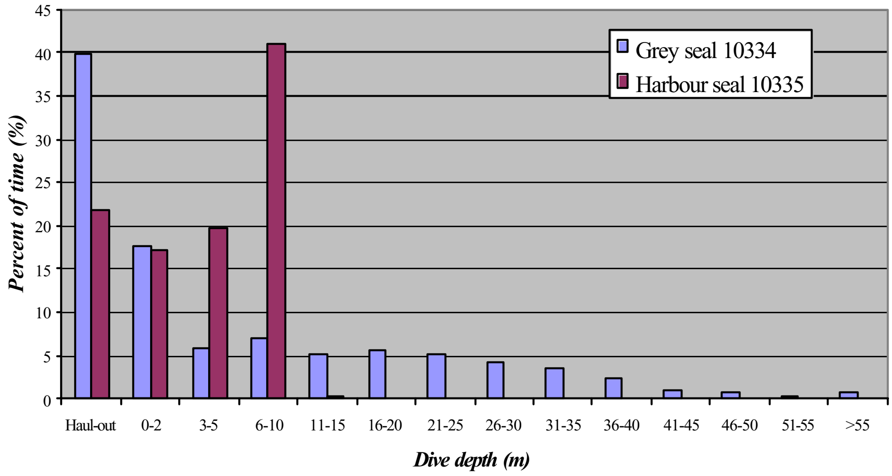

Figure 20. *Time spend hauled out (on land) and at various depth categories.*

The frequency distribution of the dive durations has a similar pattern for the two seals (Fig. 21). They both made many short duration dives (0-1 minutes) most likely when resting or travelling at the surface. Fewer dives were made in the 1-2 minutes category while the number of dives peaks at the 2-4 and 3-5 minutes categories for the grey and the harbour seal, respectively. Very few dives exceeded 8 minutes for the grey seal and 10 minutes for the harbour seal. However, both seals made dives lasting more than 13 minutes. Although, the harbour seal exploited a much shallower area its dives generally lasted longer.

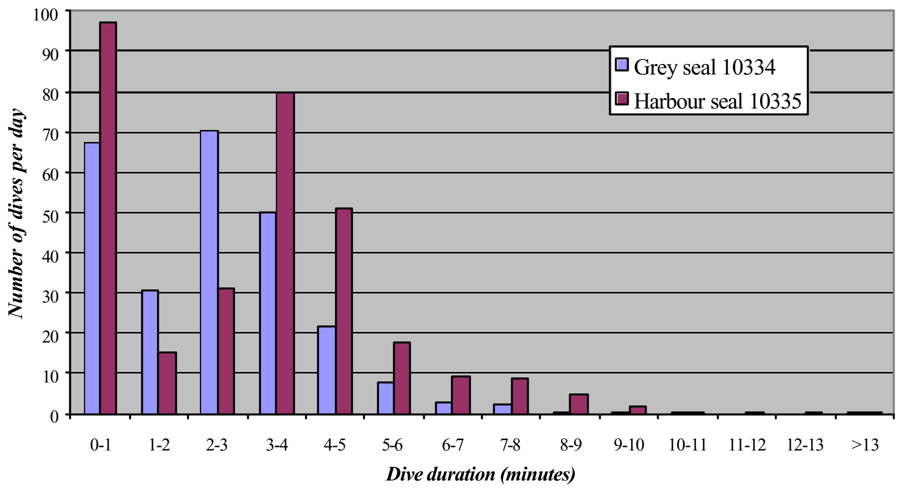

Figure 21. *Number of dives per day within specified dive duration intervals.*

The distribution of dive depths (Fig. 22) shows a similar pattern as in Figure 20. The harbour seal made 163 and 175 dives per day in the two first categories (0-5 and 6-10 m), while the grey seal only made about 80 and 30 dives per day in the same two categories. Instead the dive depth of the grey seal showed a peak around 16-25 m. On average the grey seal dove 339 times per day while the harbour seal dove 348 times per day. When multiplying each dive with the mean depth the grey seal dove almost 10 vertical km (including both ascent and descent) per day, while the corresponding figure for the harbour seal was only 3.5 km per day.

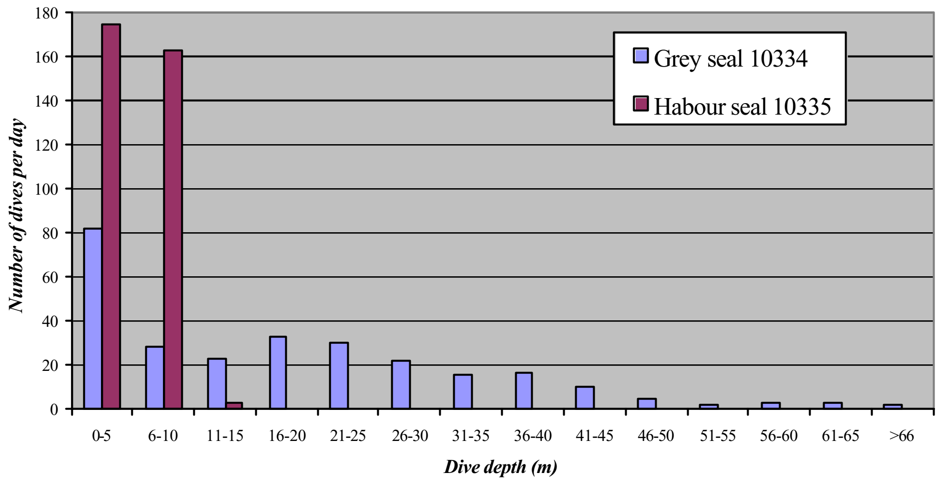

Figure 22. *Distribution of dive depth of individual dives.*

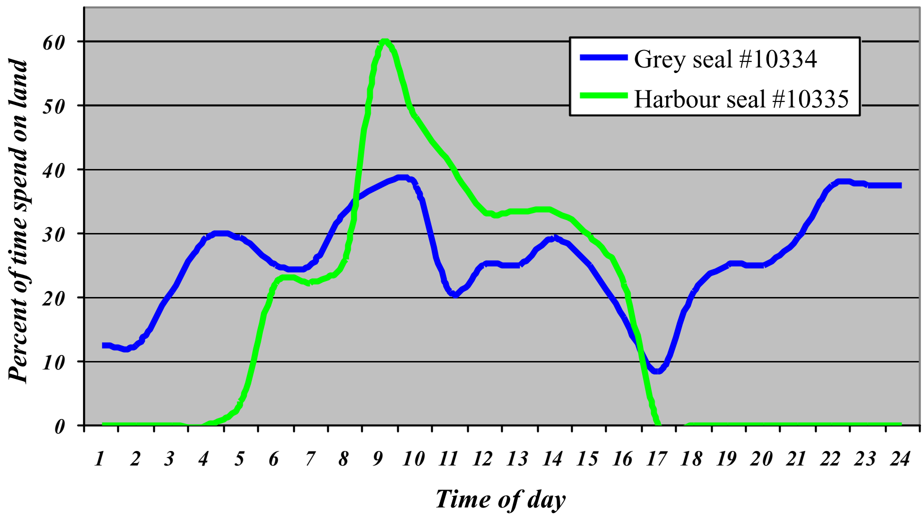

Figure 23. *Diurnal haul-out behaviour of two seals with dive sensors.*

Figure 23 indicates that the adult female harbour seal only hauled out from sunrise until early evening with up to 60% of the time on land around 10 o'clock. The subadult female grey seal hauled out during all hours of the day but with a peak also around 10 o'clock and in late evening with almost 40% of the time on land.

As the data set on diving behaviour is limited to only two individuals from two different species further data has to be collected before general conclusions can be made. However, the results represent the first data on diving and haul-out behaviour of seals in Denmark and exemplify the kind of data that can be obtained using dive recorders.

6.3 Other types of marking

During the handling of the animals, they were given a freeze brand number, and some also got a Roto-tag and a PIT tag. These methods have the potential to provide long term information on the movements and site fidelity of the animals. So far only seal #17562 has been identified using the freeze number. This seal died (PDV positive) during the seal epizootic in late summer 2002 and was found on the beach on Femern in Germany, 40 km south-west of Rødsand. This type of information is important in evaluating the long-term movements of the seals and the effect of the tagging on the animals. The grey seal #10337a caught in the fish trap two weeks after tagging had not yet developed a response to the freeze brand.

6.4 Reactions to the transmitters

The first tagged grey seal #10337a was caught in the fish trap inside a pound net (see above for details). The seal had herrings ranging between 16 to 22 cm in length in its stomach, which suggest that the seal was actively feeding when it was caught. In the intestine otoliths from five herrings (fish size: 17.1-18.9 cm) and two cods (fish size: 6.2-8.1 cm) were found. Within the two weeks of instrumentation the seal had obtained a weight of 55 kg, which is 6 kg more than when it was tagged. Furthermore no infections or other signs of irritation were found on the skin under the tag (see also section 6.3). A sweep of samples was obtained for future analysis of e.g. genetics and contaminants. The harbour seal #17562 found in Germany during the seal epizootic in late summer 2002 was inspected by a German veterinarian (U. Siebert pers. comm.) indicates that the seal had moulted since the transmitter was lost and that there were nothing unusual to see on the head, where the transmitter had been. This seal had increased its weight from 25 to 31.2 kg (low due to PDV) and its length from 90 to 121 cm.

One of the tagged harbour seals (#10337b) was also instrumented with a camera for three hours to monitor the behaviour and reactions after the tagging (in co-operation with National Geographic, see Dietz et al. 2001 for further details). Within the first hour of recording the seal made some rapid turns, which could be a reaction to the visual recognition of the transmitter on the water subsurface reflection or because it tried to get rid of the tags. This reaction however, rapidly ceased. Within an hour the tagged seal met another harbour seal and followed it for approximately 30 minutes. In addition the seal soon started searching for fish, especially around stones. The behaviour was hence considered to be normal less than an hour after the tagging.

Based on these informations we conclude that satellite tags on the head of the seals did not negatively affect the feeding behaviour of the seals.

Tom side

7 Discussion

7.1 Kernel home ranges

The Kernel home range calculations for grey seals (common estimate: 51,221 km^2; range: 4,160 to 119,583 km^2, #10337A not included due to premature failure) revealed that the tagged seals moved considerably farther than the harbour seals (common estimate: 394 km^2 range: 237 to 709 km^2). Note however, grey seals satellite tagged in the northern Baltic Sea did not exhibit the same long distance movement found in the present study (Sjöberg & Ball 2000). Using the same methods, the Kernel home ranges (95% fixed Kernel) for Baltic seals ranged from 1,088 to 6,400 km^2. No comparable figures were available for harbour seals in the Baltic or adjacent waters. However, foraging trips for harbour seals from Scotland were estimated in the range of 4.3 to 55.0 km (Thompson et al. 1998). Thompson et al. (1998) found that female harbour seals around Scotland conducted significantly shorter feeding trips than males. In the present study the yearling harbour seal moved more around than e.g. the pregnant female, but more data are required to describe the general pattern. Extensive migrations were observed both for subadult and adult grey seals. For the adult animals these movements were in some cases linked to breeding and probably also mating behaviour. Tagging of more animals would improve the knowledge on general behavioural patterns of both harbour and grey seals.

7.2 Local use of the wind farm area

Even though few positions were obtained in the wind farm area eight out of ten animals were likely to use this area from time to time.

All harbour seals had the whole or part of the wind farm area included in their 95% Kernel home ranges but only three seals were actually documented to have been in the area, and their presence was relatively seldom, as these observations made up only 0.41% (range: 0.00-0.88%) of all locations. The importance for the grey seals was even lower due to their large Kernel home ranges generated by their extensive movements between alternative haul-out sites in other parts of Denmark as well as Sweden, Estonia and Latvia (Fig. 24). 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% (range: 0.00-0.16%) of all locations. The fact that the grey seals move between a number of sites means, that the grey seals may chose or rely more heavily on alternative areas. The observed migration into the Baltic during the breeding period can be interpreted in two ways. Either it can be 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 (i.e. Danish localities) in the outskirts of their distribution range.

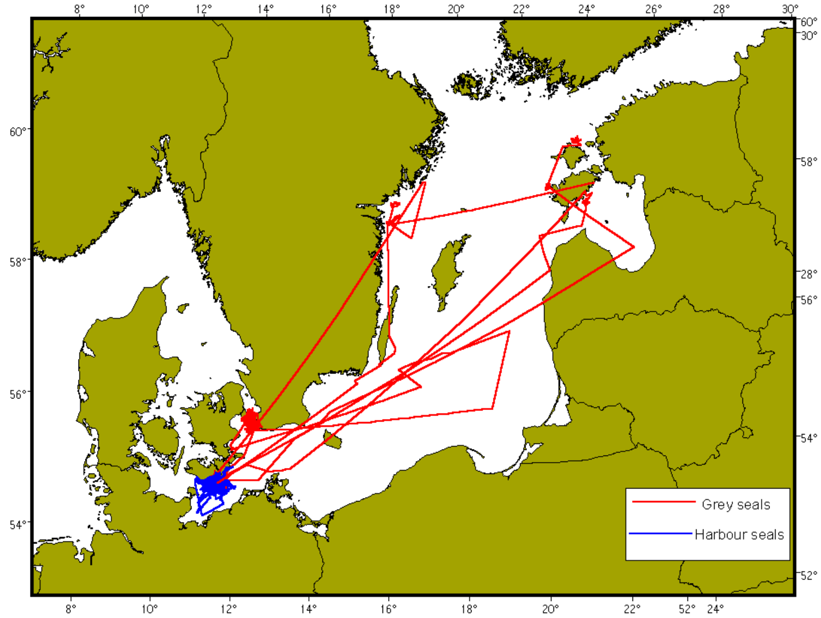

Figure 24. *Movements of all harbour seals (blue lines) and all grey seals (red lines) observed in this study.*

7.3 Method evaluation

In general satellite telemetry proved to be a very strong tool to study the movements and evaluate the importance of the wind farm area to the seals. A substantial number of positions were obtained even though a better seasonal coverage could have been obtained if all seals had been caught in September. Satellite telemetry is particularly powerful for monitoring long-range migrations. Higher resolution on a local scale may be obtained by use of the recently developed GPS/GSM technique. A number of "force majeure" problems like the death of a seal and an American drift buoy reduced the data amount. The moulting reduced the summer coverage, as the tags were lost. In future studies the loss of transmitters due to moulting observed in this study can be used to obtain more information in the active period.

As the transmitter has to be out of the water several times during a satellite passage to obtain a location, the method was probably biased towards fewer positions at sea compared to the land observations. It is evident that the densities of locations are higher close to the haul-out sites at Rødsand, Vitten and Flintehorne Odde, although a substantial number of "at sea locations" were also obtained. This shows that the transmitter mounting on the head was a good platform for receiving locations while the seal was swimming. Upon evaluation of the effect of the tagging, we concluded the seals showed normal behaviour with the transmitters being attached to their fur and that no effect on the skin was observed.

7.4 Recommendations for future work

- Satellite telemetry should be continued during and after the planned construction work. By comparing the baseline data from this report the effects on habitat selection of the construction activity and presence of the wind farm can be observed.
- Techniques with even higher resolution i.e. more precise and larger number of positions per day would further improve the accuracy in describing the movements and habitat selection of the seals. The new GPS/GSM technique recently developed in a co-operation between SEAS, Logic I/O and NERI may meet this requirement.
- The effort should aim at monitoring ten seals (both grey and harbour seals like in the baseline study) per year with optimal seasonal coverage.
- Deployments should preferably be conducted in September to improve the yearly data coverage.
- Additional data on the haul-out and dive behaviour will improve information on diurnal and feeding patterns in the study area.
- New capturing techniques should be used to improve the capturing efficiency of the nervous seals at Rødsand.
- Future programming of transmitters should benefit from the present moulting information to maximise information received.

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This report documents the capture and tagging of ten harbour and grey seals from the Rødsand seal sanctuary, Southeast Denmark prior to the construction of the Nysted Offshore Wind Farm. Harbour seals remained within 50 km of the tagging site year-round, while grey seals made extensive movements up to 850 km away from Rødsand to Sweden, Germany, Estonia and Latvia. The average Kernel home range (95% fixed Kernel) of the harbour seals was 394 km^2 ranging from 237 to 709 km^2, whereas the corresponding Kernel home range was 130 times larger for grey seals namely 51,221 km^2 ranging from 4,160 to 119,583 km^2. All the tagged harbour seals stayed year-round in the Rødsand area, whereas, the grey seals on average only remained in the area for 17.8% (range: 2.6 - 58.3%) of the monitored time.

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