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

Report request
Commissioned by Vattenfall A/S
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Ib Krag Petersen
Anthony D. Fox

Data sheet

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Summary

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Dansk resumé

I denne rapport præsenteres analyser af nyligt observerede ændringer i vandfugles fordeling omkring Horns Rev 1 vindmølleparken. Der lægges i rapporten særlig vægt på analyser af fordelingen af sortand.

Undersøgelser af vandfugles antal og fordeling på Horns Rev blev indledt i 1999. Som del af et demonstrationsprojekt omkring havbaserede vindmølleparkers miljømæssige konsekvenser blev der i perioden fra 1999 til 2005 gennemført i alt 34 optællinger af vandfugle. I perioden fra november 2005 til maj 2006 blev yderligere seks optællinger gennemført, disse i relation til en VVM-redegørelse for Horns Rev 2 vindmølleparken.

Resultater fra ovennævnte demonstrationsprojekt konkluderede at fordelingen af lommer og sortand var negativt påvirket af mølleparkens tilstedeværelse.

I slutningen af 2006 og i januar 2007 rapporterede vedligeholdelsesmandskab og helikopterpiloter, der arbejdede med mølleparken, observationer af stigende antal sortænder indenfor selve mølleparkens område. På denne baggrund blev yderligere fire optællinger af fugle i området planlagt til gennemførelse fra januar til april 2007.

Optællingsdata fra januar, februar, marts og april 2007 viste at sortand var den langt hyppigst forekommende fugleart i området, med i alt 356,635 observerede ænder. Sølvmåge (7.661), Ederfugl (5.674) og lommer (511) var andre hyppigt forekommende arter/artsgrupper i området.

Der blev observeret en stor forandring i sortændernes fordeling indenfor undersøgelsesområdet i perioden fra 1999 til 2007, forårsaget af andre forhold end vindmølleparkens tilstedeværelse. Dette gjorde en sammenligning af fordelingen af sortænder før og efter mølleparkens opførelse umulig. Derfor blev analyserne, der anvendtes i denne rapport baseret på data fra 2004 til 2007.

Ved tre af de fire gennemførte optællinger i 2007 blev der observeret flere sortænder i møllepark-området end der blev observeret ved tidligere optællinger. Den 25. januar blev 2.112 sortænder observeret i parken, den 15. februar 4.624, den 3. marts 1.359 mens der den 1. april kun blev observeret 35 sort-ænder i parken.

En analyse af antallet af observerede sortænder pr. km for seks 2x2 km kvadrater indenfor mølleparkens område, sammenlignet med tilsvarende værdier for 14 2x2 km kvadrater nærmest mølleparken, viste at der ikke var signifikante forskelle imellem mølleparken og naboområdet for de tre optællinger i januar, februar og marts. Data fra april viste derimod signifikant færre sortænder i mølleparken end i det omgivende areal. En tilsvarende analyse, baseret på det samlede data sæt for de fire optællinger i 2007, viste ingen signifikant forskel imellem tætheder i mølleparken og det omgivende areal.

Der blev foretaget en kumulativ afstands frekvens analyse baseret på 500 meter intervaller fra mølleparkens center punkt ud til en afstand af 6 km fra dette. Dette blev gennemført for årene 2004 til 2007. Resultaterne viste at der igennem denne periode sås en gradvist større andel af fuglene i selve mølleparkens område, med signifikante forskelle imellem alle år.

En analyse af andelen af sortænder indenfor en radius af 3 km fra mølleparkens centrum, set i relation til antallet indenfor en 6 km radius fra denne, viste en dramatisk ændring i perioden, med lidt over 10% af fuglene i parkens område i 2004, til 50% af fuglene i mølleparkens område i 2007.

På den baggrund konkluderes det at sortænder kan forekomme i høje tætheder i nyligt etablerede havvindmølleparker. Forekomsten af tætheder i mølleparken, der svarer til tæthederne i de omgivende arealer, kan dog have en tidsmæssig forsinkelse, således at sortænderne først forekommer i havmølleparken nogle år efter etableringen. Vi kan dog ikke helt udelukke at ændringerne skyldes ændringer i fuglenes fødegrundlag.

Idet sortænder praktisk taget ikke sås på selve Horns Rev under optællingerne af fugle i perioden op til mølleparkens etablering er det vanskeligt at vurdere hvor mange sortænder området kunne rumme i 2007 hvis mølleparken ikke var tilstede. Anvendelse af værktøjer til rumlig modellering af fuglenes tætheder kunne muligvis belyse om de fundne tætheder af sortand i mølleparken repræsenterer 100% af hvad der kunne forventes hvis mølleparken ikke var anlagt. En sådan analyse ligger ud over rammerne for nærværende rapport.

Fladedækkende tæthedsberegninger for sortand fra de fire optællinger, foretaget i 2007, vil blive præsenteret i en efterfølgende rapport.

Lommer, der ved tidligere undersøgelser viste sig at undgå møllerne, sås i 2007 ikke i mølleparken og dennes nære omgivelser, og har således ikke ændret deres fordeling (adfærd) i forhold til mølleparken.

1 Introduction

1.1 Background

In February 1998 it was decided to look at possibilities to establish an offshore wind farm at Horns Rev, in this report mentioned as the Horns Rev 1 wind farm. The wind farm should be a large-scale demonstration facility in order to obtain knowledge concerning technical, economic and environmental issues in relation to further development of offshore wind farms in Danish waters. In the approval it was specified that the environmental impact assessment programme should include before and after studies with the aim of detecting any potential impacts.

As part of this programme the ornithological impact of the wind farm has been investigated. Two subjects were addressed, namely the potential change in habitat utilisation by certain bird species and collision risk between birds and turbines. Results from these investigations have been reported in an ornithological impact assessment (Noer et al. 2000) and annual reports during the proceeding study period (Christensen et al. 2001, 2002, 2003, 2004, Christensen & Hounisen 2004, 2005, Petersen et al. 2004, Petersen 2005, Petersen et al. 2006). In the present report the issue of changes in habitat utilisation is addressed.

The southern part of the Danish North Sea constitutes major staging and wintering grounds for huge numbers of water- and seabirds (Tasker et al. 1987, Laursen & Frikke 1987, Laursen et al. 1997). Therefore, in 1999 investigations of bird numbers and distribution in the Horns Rev area was initiated. Up until 2005 a total of 34 aerial surveys, carried out both before, during and after the construction of the wind farm, made the background for analyses of impact from the wind farm on bird distributions (Petersen et al. 2006).

In 2005 DONG Energy A/S initiated the EIA process in relation to the Horns Rev 2 wind farm. Investigations of bird distributions was part of that EIA, and between November 2005 and May 2006 a total of six aerial surveys were conducted, covering largely the same area as that of the Horns Rev 1 investigations (Christensen et al. 2006).

One conclusion from the investigations of impacts on bird from the wind turbines was that Common Scoter *Melanitta nigra* avoided the wind farm area, albeit many birds in the surrounding sea (Petersen et al. 2006). In January 2007 helicopter pilots noted many Common Scoters in the wind farm area.

1.2 Scope of the investigation

With the primary aim to clarify whether Common Scoters now utilise the areas between the turbines to a higher extent than they did in the previous period of the operational phase of the Horns Rev 1 wind farm, Vattenfall A/S commissioned NERI to conduct four aerial surveys of birds at Horns Rev from January until April 2007. The results of these investigations are presented in this report.

2 Methods

2.1 Selection of study area

The study area was designed to cover the area of the Horns Rev 1 wind farm site as well as an area almost identical to the study area used during similar surveys around Horns Rev 1 from 1999 until 2005 (Petersen et al. 2006). The westernmost transect lines were prolonged approximately 5 km north of the northern waypoint of the survey lines of previous surveys, while shortened in the southern parts. The survey area constituted a total of 1,750 km² (Fig. 1).

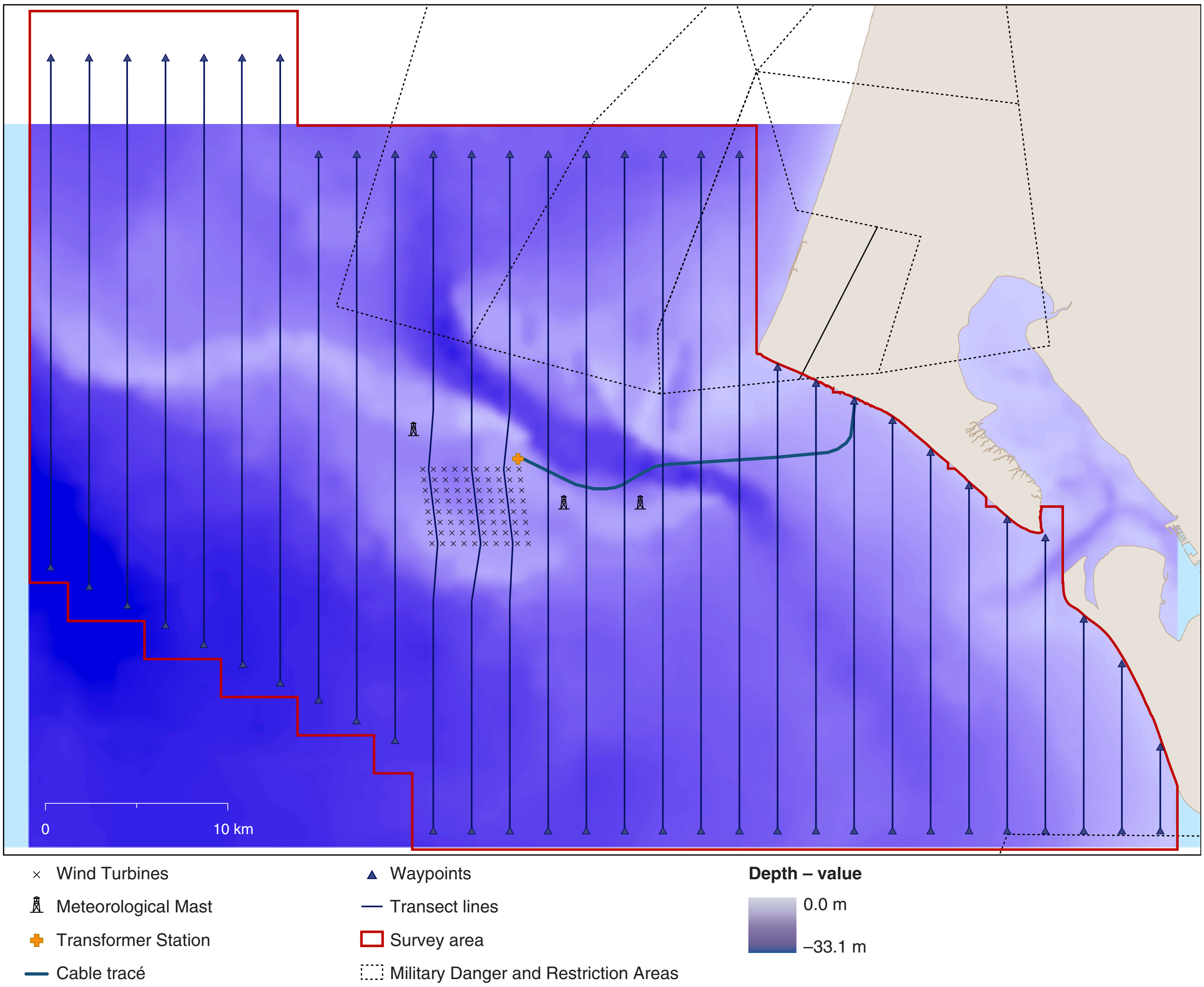


Figure 1. The study area, showing the total survey area (outlined in red) and survey transect net (grey lines). The wind turbines, transformer station, cable tracé and meteorological masts are shown. Also shown are military restriction areas. The bathymetry of the area is indicated.

2.2 Survey method

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

The surveys were conducted along pre-defined transect lines. Coordinates of transect end-points were entered into the GPS of the aircraft for navigation. A total of 30 transect lines, with a total track length of 803 km was established as parallel, north-south oriented lines at two km intervals (see Fig. 1).

During the surveys, two observers covered each side of the aircraft. Only experienced observers familiar with species identification were used. All observations were continuously recorded on dictaphones, giving information on species, number, behaviour, transect band and time. The behaviour of the observed birds included the activities: sitting (on the water), diving, flushing or flying.

Observations were related to transect bands, which were determined by using an inclinometer (predetermined angles of 10º and 25º below the horizontal measured abeam flight direction), and thus included three bands on each side of the aircraft. Beneath the aircraft, a band of 44 m on each side of the flight track could not be observed. Transect widths during the aerial surveys are shown in Fig. 2.

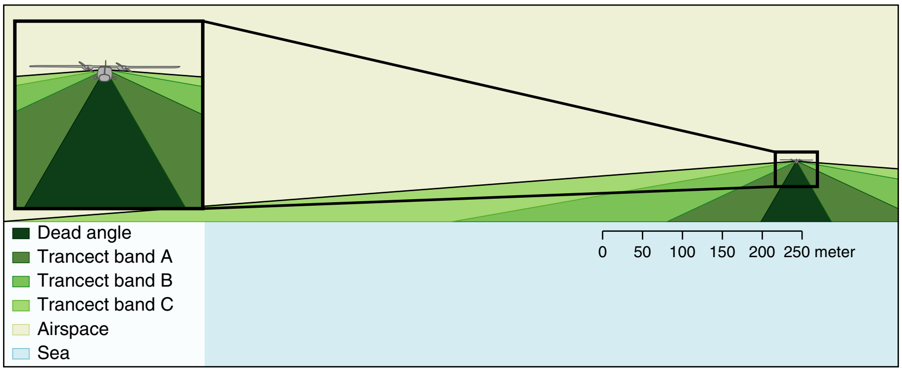


Figure 2. Head-on schematic diagram to scale of the aerial survey aircraft on transect, showing the flight altitude above the sea surface, showing the "dead angle" immediately below the aircraft that cannot be viewed by observers. The coloured angles illustrate the distances out from track line that define the transect bands. Inset shows the close up detail.

During the aerial surveys a computer logged flight track data from a differential GPS at five second intervals. Each record contained longitude, latitude, altitude and time. Accuracy of GPS longitude and latitude was normally considered to be within 2 m. In the very rare situations where the GPS failed during track-logging, positions of each bird observation were calculated from the known time of passage at the way points that were used for navigation and from the cruising speed of the aircraft. In these cases the spatial accuracy of the observation data is somewhat reduced.

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

As the survey results are highly sensitive to weather conditions, surveys were not carried out when wind speed exceeded 6 m/s, because detectability of birds on the sea surface was severely reduced. Low visibility or glare also reduced detectability. In cases of severe glare, observations from one side of the aircraft were temporarily discontinued. Military activity prevented full coverage of the northeastern part of the study area on some surveys (cf. Fig. 1).

2.2.1 Species identification

It was known in advance that several pairs of birds or groups of bird species closely resembling each other occur in the study area. These comprise red- and black-throated diver *Gavia stellate/arctica*, Guillemot *Uria aalge* and Razorbill *Alca torda* and Arctic *Sterna pardisaea* and common tern *S. hirundo*. All of these species can only be discriminated at close range and under good visual conditions, and generally the knowledge of the species composition of these groups can only be considered approximate.

With respect to the problem in question, however, there is no *a priori* reason to expect that impacts from a wind farm should differ between similar species. Moreover, designing a realistic monitoring programme that can demonstrate differential impacts between, e.g., red- and black-throated divers would be nearly impossible. The extra effort expended in differentiating these species is unlikely to be worth the investment, since it is not expected there would be any difference between species response to the wind farm. For this reason, the similar species are considered as grouped data throughout the report.

2.3 Data analyses

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

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

Methods used previously during the base-line study are only presented briefly here. For more details see Noer et al. (2000), Christensen et al. (2001, 2002).

To assess the numbers of birds of the different species that would be susceptible to potential disturbance effects from the wind turbines, and to assess the importance of wind farm area and the adjacent waters, we describe bird preference for the wind farm area and different adjacent zones of potential impact relative to their preference for the whole study area (Fig. 3). For these zones the preference of the most numerously occurring species was calculated using Jacobs selectivity index (Jacobs 1974).

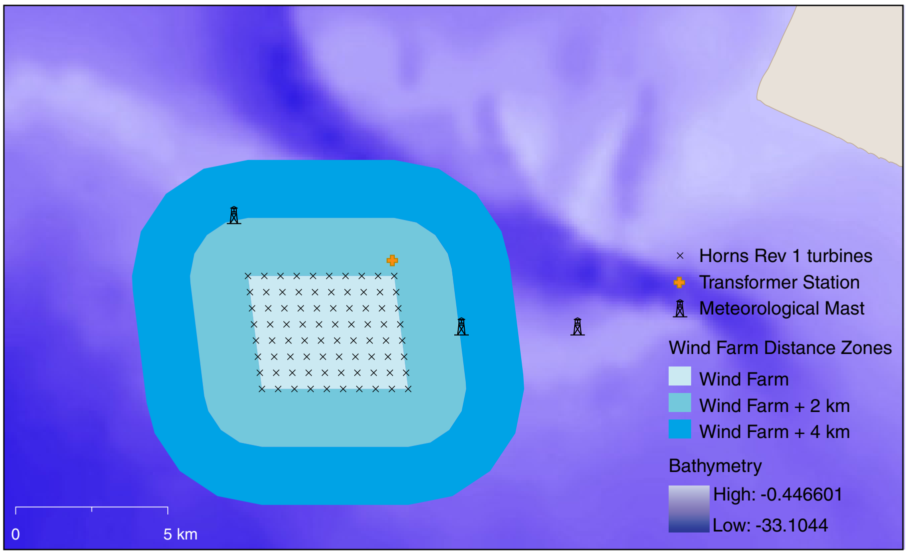


Figure 3. The Horns Rev 1 wind farm site with the extent of the 2 and 4 km buffer zones around the wind farm indicated.

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

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

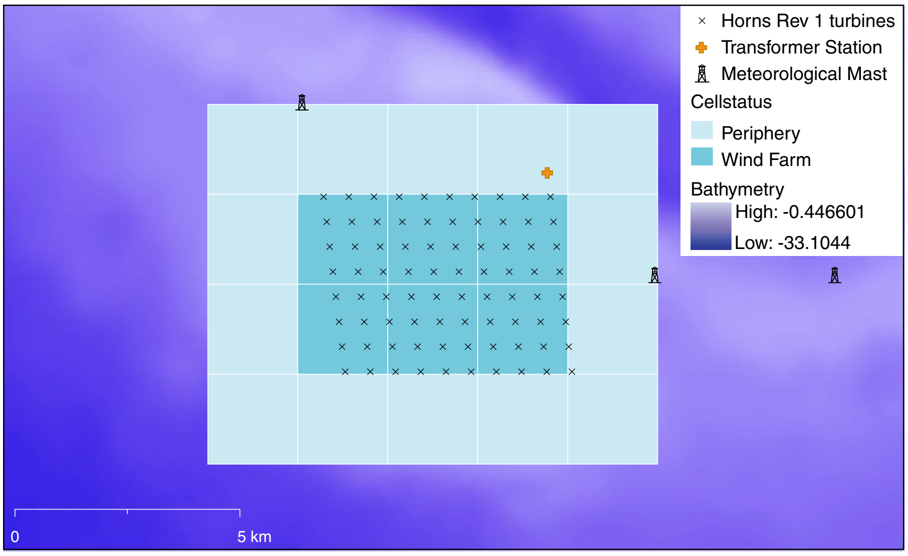
where r = the proportion of birds in the area of interest compared to the birds in the whole study area, and p = the proportion of the transect length in the area of interest compared to the total transect length in the whole study area. The difference between the two proportions is tested as the difference between the observed number of birds in the area of interest and the number expected in this area, estimated from the share of the length of transect in relation to transect length in the total area (one-sample χ^2-test).

To assess the minimum detectable change in bird numbers within and close to the wind farm area, we applied a χ^2 two-sample test to the numbers recorded within the wind farm area and within the wind farm and +2 and +4 km zones during the base-line years compared against varying reductions and increases. Similarly χ^2 two–sample tests were used to elucidate potential disturbance effects during the period of construction compared to the base-line. In cases when bird numbers were too small to allow a χ^2-tests, Fisher's exact test was applied (SAS Institute 1999-2001). In all χ^2-tests a Yates correction was used to make a continuity adjustment.

Because of the special interest in the reactions of common scoter to the Horns Rev 1 wind farm, extra attention is paid to this species. Specifically, we test the hypotheses (i) that by 2007, the frequency of encounter of common scoter (per unit count effort within 2 km x 2 km squares) within the Horns Rev wind farm do not differ from those immediately outside and (ii) that using the available data from 2007 and from 2004-2006 inclusive (three post-construction years) the proportion of birds occurring inside the Horns Rev 1 wind farm have shown a consistent increase since the time of construction. For optimal comparison between data from different years we selected surveys carried out in January to April (included).

We tested (i) by calculating the encounter rate of common scoters within 2x2 km grid squares from the results of the four surveys presented here. The area of the wind farm was defined within 6 of these squares (the impact area) and the mean number of birds counted per km of survey flown within these grid squares was compared with that from the 14 2x2 km grid squares immediately surrounding the wind farm (Fig. 4). The differences for each month were tested to assess statistically significant differences within and outwith the wind farm using standard student's t-tests corrected for unequal variances.

Figure 4. The Horns Rev 1 wind farm site with 2x2 km grid squares covering the wind farm site (6 grid squares) and the immediate surrounding of the wind farm (14 grid squares).



We tested (ii) by calculating the distance of every single flock of common scoters encountered from the exact midpoint of the wind farm out to 6 km from this midpoint. This circle radius 6 km encloses an area of Horns Rev 1 with more or less similar water depth along the reef, but also represents a distance twice that of the length from the centre of the wind farm to the outermost turbine (i.e. the maximum influence on scoter distribution from their construction). We then compared the cumulative frequency distributions of (a) flocks (i.e. individual clusters of birds) and (b) total number of common scoters between years since 2004, to see if we could detect changes in their distribution over time. If common scoters were moderating their behavioural response to the turbines over time, we would expect that the frequency distributions showed significant differences between years, with greater proportions occurring within the wind farm as time progressed. We tested for between year differences in cumulative frequency distributions using two-sample Kolgomorov-Smirnov tests and fitted simple regression models to the percentage of common scoter flocks and individuals occurring within the area influenced by the turbines over the years 2004-2007.

2.4 Quality control

All observations of birds during the aerial surveys were recorded on a dictaphone. During subsequent transcription unusual data were underlined or commented to make a later exclusion of erroneous data possible.

After being computerised into databases, all records were checked once again to identify errors during this procedure.

The present report is subject to the following quality control:

- Internal scientific review by a senior researcher
- Internal editorial and linguistic revision
- Internal proof-reading
- Layout followed by proof-reading
- Approval by project managers.

3 Results

3.1 Survey coverage

In the period from January to April 2007 a total of four aerial surveys were conducted at Horns Rev, one survey in each of these months. The survey coverage during the individual surveys was varying, mainly due to weather conditions or exclusion from active military restriction areas. In January and February three transect lines were omitted due to lack of sufficient day light for the survey. The surveyed transect lines are illustrated along with bird distributions for individual surveys in the species account below.

The overall survey coverage for the cumulated surveys reflected the variable coverage for the individual surveys (Fig. 5). During the individual surveys the observers covered the surveyed transect lines without single sided gaps. The slightly enhanced coverage seen in the wind farm area was caused by the fact that transect lines followed mid lines between rows of turbines, and thus slightly longer than the straight line. The length of the surveyed transect lines during each of the four surveys is given in Table 1.

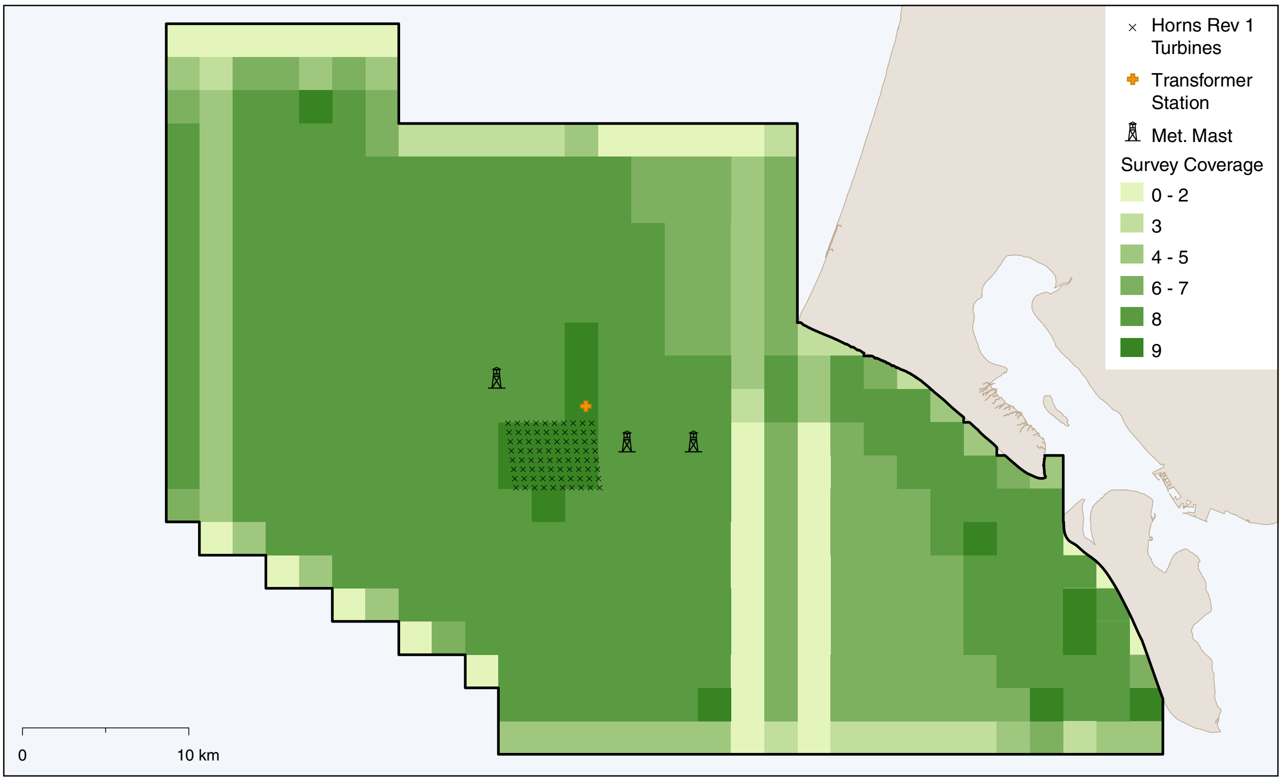


Figure 5. Transect length survey effort (in km) per 2 x 2 km grid squares in the study area, summed for four surveys performed in 2007. See text for details.

Table 1. The length of surveyed transect line during each of four aerial surveys at Horns Rev, January to April 2007. The cumulated transect length was calculated, correcting for effort.

Date	Length (Km)
25 JAN 2007	1,440
15 FEB 2007	1,356
3 MAR 2007	1,368
1 APR 2007	1,611

3.2 Waterbird distributions at Horns Rev, January to April 2007

A total of 26 bird species or species groups were recorded during the four aerial surveys (Table 2).

In this chapter the distribution of eight waterbird species or species groups are presented. Most species are selected because of the presence of high numbers in the study area. Others, such as Little Gull, were selected because of their conservation status. Some bird species or groups were omitted from this chapter despite presence in the study area in relatively high numbers. This was true for Oystercatcher, being strictly a coastal bird and therefore irrelevant to the wind farm area.

Table 2. The total numbers of bird observations during four aerial surveys at Horns Rev, January to April 2007. The summed numbers (Total) may represent resightings between individual surveys, whereas no resightings are expected within the same survey.

Species	Total	25 JAN 2007	15 FEB 2007	3 MAR 2007	1 APR 2007
Diver sp.	292	157	36	15	84
Red-throated Diver	216	52	55	14	95
Black-throated Diver	3	1	1		1
Gannet	34		1		33
Cormorant	1			1	
Greylag Goose	20				20
Wigeon	35				35
Long-tailed Duck	8	3	4	1	
Eider	5,674	1,911	2,608	750	405
Common Scoter	356,635	106,113	133,262	87,890	29,370
Velvet Scoter	358	77	123	20	138
Red-breasted Merganser	2		2		
Oystercatcher	456	354	1	9	92
Common Gull	111	2	106	3	
Herring Gull	7,661	3,038	2,313	246	2,064
Lesser Black-backed Gull	2				2
Great Black-backed Gull	87	6	56	4	21
Black-headed Gull	5			5	
Little Gull	116	12	12	13	79
Kittiwake	33	26	1	2	4
Gull sp.	579	6	567		6
Arctic Tern	2				2
Sandwich Tern	1			1	
Razorbill	17		17		
Razorbill/Guillemot	198	67	120	10	1
Guillemot	17	3	12	2	

Divers and alcids (Razorbill/Guillemot) are treated here as two groups of species, despite the fact that more than 40% of the divers were identified as Red-throated Diver.

All numbers presented here are numbers of observed individuals. No attempts have been made to estimate total numbers in this report. When indicating total numbers of individuals in this report, summed for the four surveys, it should be borne in mind that bird species wintering in the study area may well have been resighted between surveys. The total numbers therefore indicate the total number of encounters of individuals. Resightings of individuals within the same survey is not expected to occur.

3.3 Species account

3.3.1 Red- and black-throated diver *(Gavia stellata/arctica)*

A total of 511 divers were recorded during the four surveys, with most birds observed on 25 January (210) and 1 April (180). Most birds identified to species were Red-throated Divers (42%), with only 1% identified as Black-throated Diver and most birds were recorded as unidentified Diver sp. (57%) (Table 2).

The distribution of the divers varied considerably between surveys. On 25 January a concentration was recorded on the southern fringe of the western part of the Horns Rev sand bar, and with high numbers of encounters in the northwestern part of the study area (Fig. 6A). On 15 February concentrations of divers was recorded on medium water depth south of the Horns Rev 1 wind farm as well as in a relatively restricted area of the northwestern parts of the study area (Fig. 6B). On 3 March the relatively few birds were recorded in the northwestern parts of the study area (Fig. 6C). On 1 April the highest concentrations were recorded in a restricted area in the northwestern parts of the study area, with scattered observations south of the Horns Rev sand bar and off the coast of Skallingen and Fanø (Fig. 6D).

No divers were recorded within the Horns Rev 1 wind farm area, and the closest observation was observed at a distance of 1.6 km from the wind farm area. Divers avoided the area of the wind farm and its 2 and 4 km zones, with D-values of -1.00, -0.79 and -0.32 respectively for the wind farm and when including the 2 and 4 km zones (Table 3).

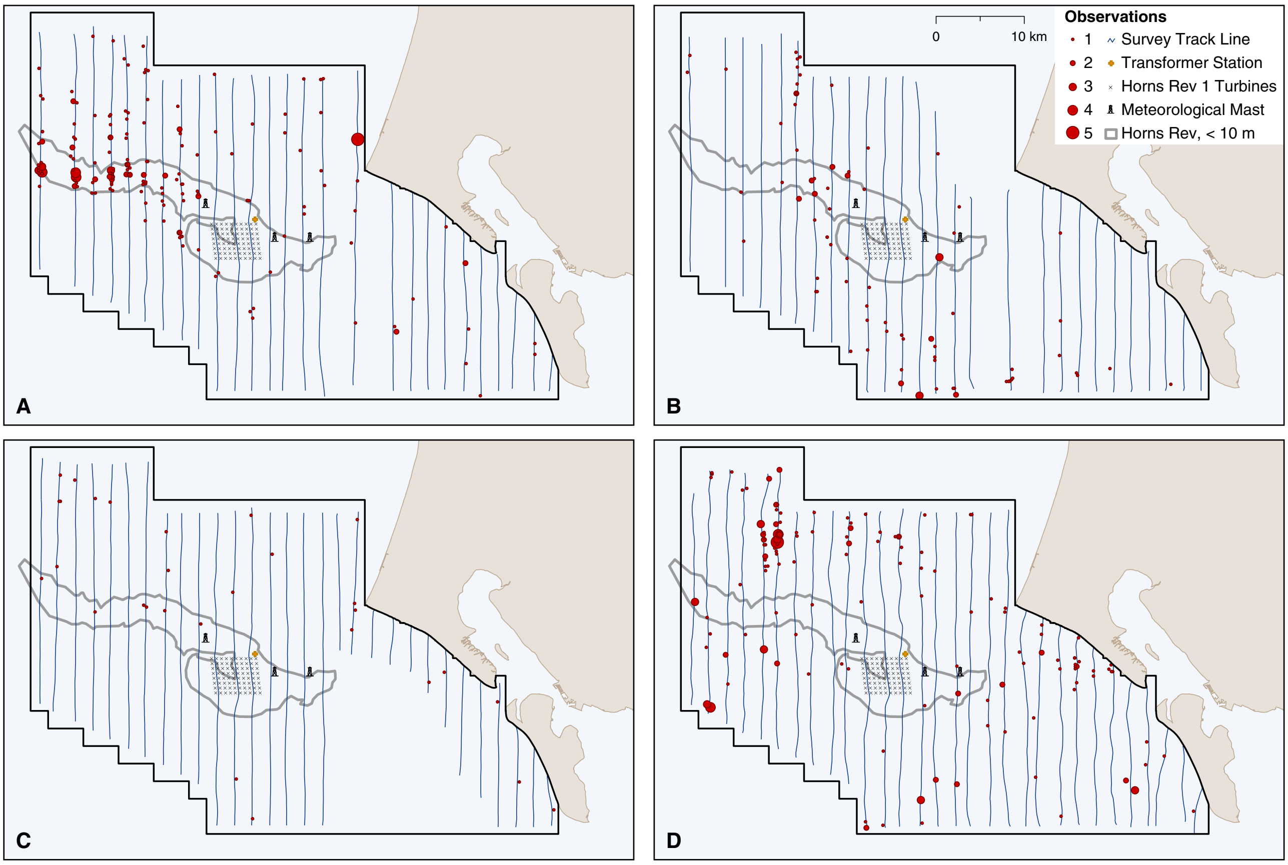


Figure 6. Distribution map of 210 divers observations in the study area, 25 January 2007 (A), of 92 divers observations in the study area, 15 February 2007 (B), 29 divers observations in the study area, 3 March 2007 (C) and of 180 divers observations in the study area, 1 April 2007 (D). Turbine positions and the extension of the reef with water depth of less than 10 m are shown. Thin blue lines identify track lines.

Table 3. Percentage of birds (number of individuals) encountered in the Horns Rev wind farm area (MA) based on 4 aerial surveys, as compared to the entire survey area, and in wind farm area plus zones of 2 and 4 km radius from the wind farm site (MA+2 and MA+4). Also shown are the total numbers of birds for each species/species group recorded throughout the surveys from the total study area (N). For each species and area, the Jacobs Index value (D) is given which varies between -1 (complete avoidance) and 1 (complete selection). The last column for each species category and area is the probability that these encounter rates differ from those of the entire area, based on one sample χ^2-tests. Values (P) are probabilities using standard statistical notation, n.s. represents P > 0.05, * P<0.05, ** P<0.01, *** P<0.001.

Species	MA	D for MA+0	P	MA+2	D for MA+2	P	MA+4	D for MA+4	P	N
Diver sp.	0.00	-1.00	**	0.59	-0.79	***	5.48	-0.32	**	511
Eider	0.00	-1.00	***	0.00	-1.00	***	0.00	-1.00	***	5674
Common Scoter	2.11	0.13	***	7.06	0.20	***	11.09	0.05	***	356635
Herring Gull	0.13	-0.85	***	0.47	-0.83	***	1.14	-0.82	***	7661
Little Gull	0.86	-0.31	n.s.	3.45	-0.18	n.s.	9.48	-0.04	n.s.	116
Auk/Guillemot	0.00	-1.00	n.s.	0.00	-1.00	n.s.	0.86	-0.86	***	232
% of total survey coverage	1.63			4.86			10.19			

3.3.2 Gannet (*Sula bassana*)

Of the total 34 Gannets observed during the four surveys all except one was seen on 1 April. The last bird was recorded on 15 February (Table 2). Gannets were mainly recorded in the western parts of the study area, both south and north of the Horns Rev sand bar.

3.3.3 Eider (*Somateria mollissima*)

A total of 5,674 Eiders were recorded in the study area. Most birds were recorded on 15 February (2,608) and 25 January (1,911) (Table 2). The numbers decreased during the last two surveys, where many Eiders have supposedly migrated into the Baltic.

There was little variation in distribution of the Eiders between the individual surveys. Almost all birds were seen on shallow water close to the coast of Skallingen and Fanø (Fig. 7A-D).

No Eiders were recorded in the Horns Rev 1 wind farm area, and only one Eider was seen in the general reef area. Thus, Jacobs Index D-values for all three zones were -1.00 (Table 3).

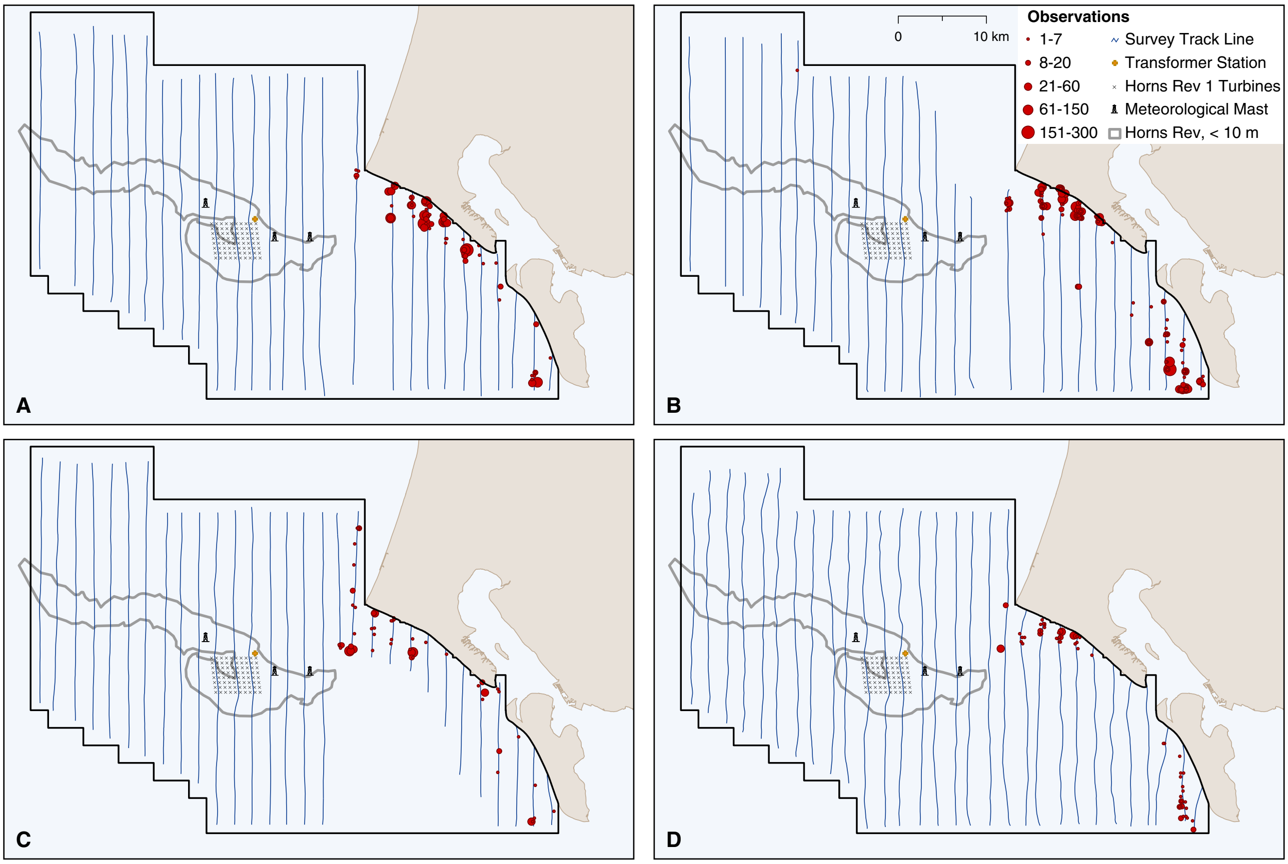


Figure 7. Distribution map of 1,911 Eiders observations in the study area, 25 January 2007 (A), of 2,608 Eiders observations in the study area, 15 February 2007 (B), of 750 Eiders observations in the study area, 3 March 2007 (C) and of 405 Eiders observations in the study area, 1 April 2007 (D). Turbine positions and the extension of the reef with water depth of less than 10 m are shown. Thin blue lines identify track lines.

3.3.4 Common scoter (*Melanitta nigra*)

With 356,635 observed birds during the four aerial surveys Common Scoter was the single most numerous species in the study area. Most birds were recorded on 15 February (133,262) and 25 January (106,113). On 3 March a number of Common Scoters have been missed due to very low fog, preventing the coverage of the southern parts of transects south of Skallingen. With the 87,890 birds recorded that day, the total numbers of Common Scoters in the study area could well have been similar to that of the previous two surveys. On 1 April the numbers had dropped to

29,370 birds, most likely reflecting the migration of Common Scoters into the Baltic (Table 2).

The distribution of the Common Scoters varied little between surveys. Most birds were recorded off the coast of Skallingen and Fanø, but with an increasing proportion of the birds found in the Horns Rev area as the season progressed. The waters off Skallingen and Fanø held 81, 64 and 21% of the total number of birds in the study area on 25 January, 15 February and 1 April respectively. The figure for 3 March has been omitted because of lacking coverage in parts of the coastal waters.

At Horns Rev most Common Scoters were recorded in the northwestern part of the study area, from the reef northwards (Fig. 8A-D). A concentration of Common Scoters was found on the southeastern parts of the reef, around the area of the Horns Rev 1 wind farm. In this area increasing numbers of birds were recorded as the season progressed.

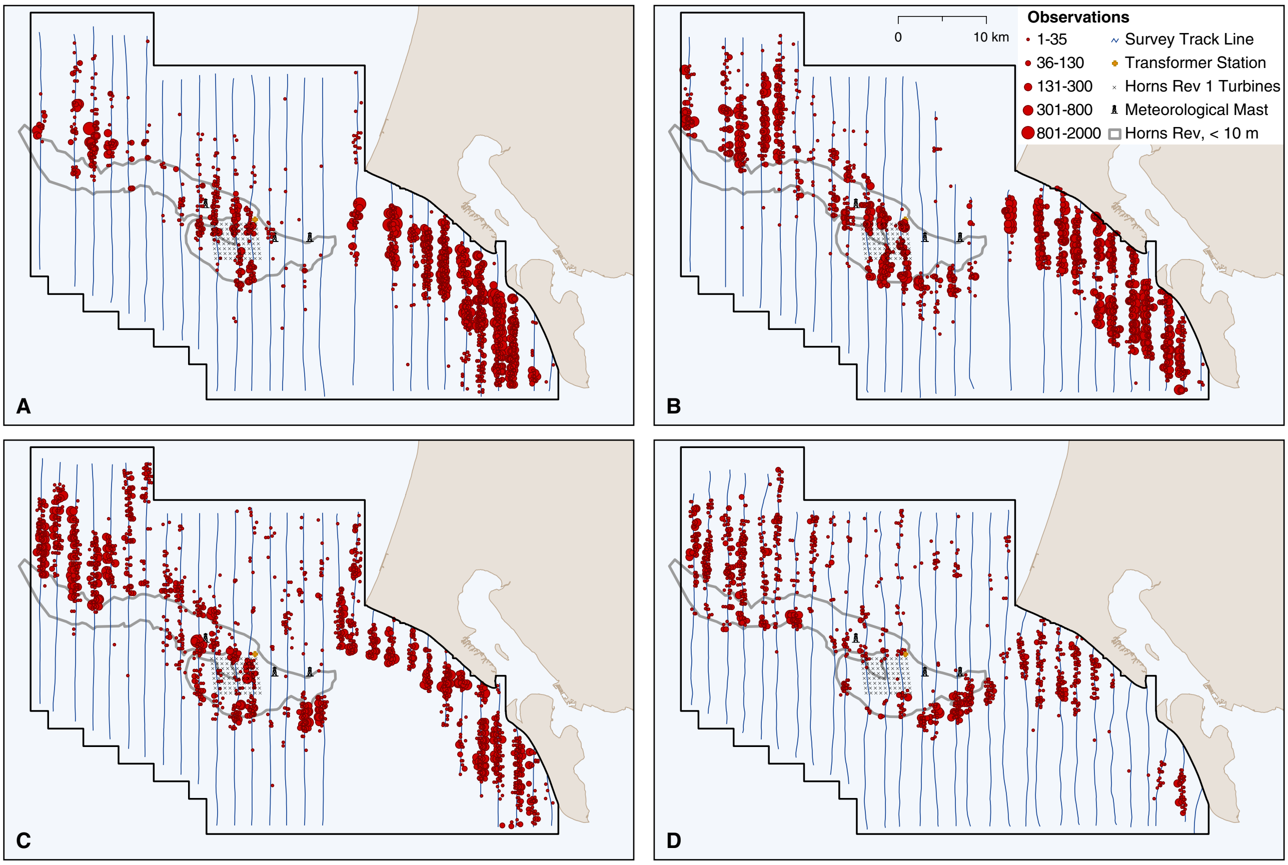


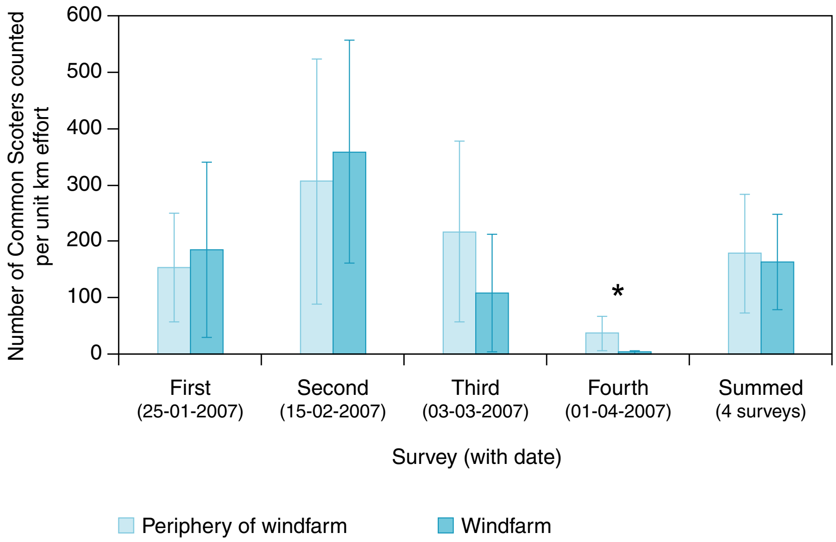
Figure 8. Distribution map of 106,113 Common Scoters observations in the study area, 25 January 2007 (A), of 133,262 Common Scoters observations in the study area, 15 February 2007 (B), of 87,890 Common Scoters observations in the study area, 3 March 2007 (C) and of 29,370 Common Scoters observations in the study area, 1 April 2007 (D). Turbine positions and the extension of the reef with water depth of less than 10 m are shown. Thin blue lines identify track lines.

Common Scoters were recorded within the Horns Rev 1 wind farm during all four surveys. On 25 January 2,112 birds were recorded within the wind farm area, mainly in the northern and central southern parts (Fig. 8A). On 15 February a total of 4,624 Common Scoters were recorded within the wind farm area, distributed similarly to the previous survey, but with more birds in the southeastern corner (Fig. 8B). On 3 March, when 1,359 birds were recorded within the wind farm area, most birds were seen in the northeastern and northern parts (Fig. 8C). On 1 April only 35 Common Scoters were recorded in the wind farm area (Fig. 8D).

Common Scoter were thus present in the wind farm area and the 2 km zone, assuming an even distribution of the species over the entire study area, with D-values of +0.13 and +0.20. When including the 4 km zone the D-value approached neutral, with a D-value of +0.05 (Table 3).

Mean encounter rates of Common Scoters within six 2 km x 2 km grid squares covering the Horns Rev wind farm did not differ from those in the 14 2 km x 2 km grid squares immediately surrounding these 6 grid squares (Figure 9). Student t-tests corrected for unequal variance show no significant differences for the first three surveys ($P > 0.05$), but a significantly low encounter rate in the wind farm during the fourth survey in early April ($t_{13} = 2.18$, $P = 0.048$). When analysed on the basis of the summed data set for the four surveys there was no significant difference between encounter rates in the wind farm grid squares and periphery grid squares.

Figure 9. Mean encounter rates of common scoters within six 2 km x 2 km grid squares covering the Horns Rev wind farm (open histogram columns + 95% confidence intervals) and in the 14 2 km x 2km grid squares immediately surrounding these 6 grid squares (shaded histogram columns). Student t-tests corrected for unequal variance show no significant differences for the first three surveys, but a significantly low encounter rate in the wind farm during the fourth survey. For the summed data set (4 surveys) there was not significant difference.



The cumulative frequency distributions of flocks and total numbers of Common Scoter with increasing distance from the centre of the wind farm differed significantly between all years in both class except between all birds in 2006 and 2007 (Fig. 10, Tables 4 and 5). For flocks the total number per year was as follows: 2004 (186), 2005 (68), 2006 (200) and 2007 (994). For the calculation on total number of birds the corresponding numbers were as follows: 2004 (7,833), 2005 (936), 2006 (3,097) and 2007 (35,870). All but 3 of these comparisons accorded with expectations under the hypothesis that Common Scoter showed an increasing tendency to distribute themselves nearer to the centre of the wind farm, but this tendency was clear overall (Fig. 11).

Figure 10. Cumulative percentage frequency distribution of Common Scoter flocks (upper "clusters") and individuals (lower) with increasing distance from the midpoint of the Horns Rev Wind Farm out to 6 km distance. Data are shown for the summed data from all surveys during January-April in each year, and the line representing an even distribution is indicated (hatched line). Tests for differences in frequency distributions are shown in Tables 4 and 5. Shaded areas indicate the areas affected by the presence of turbines and where these lie partially within the influence of the turbines.

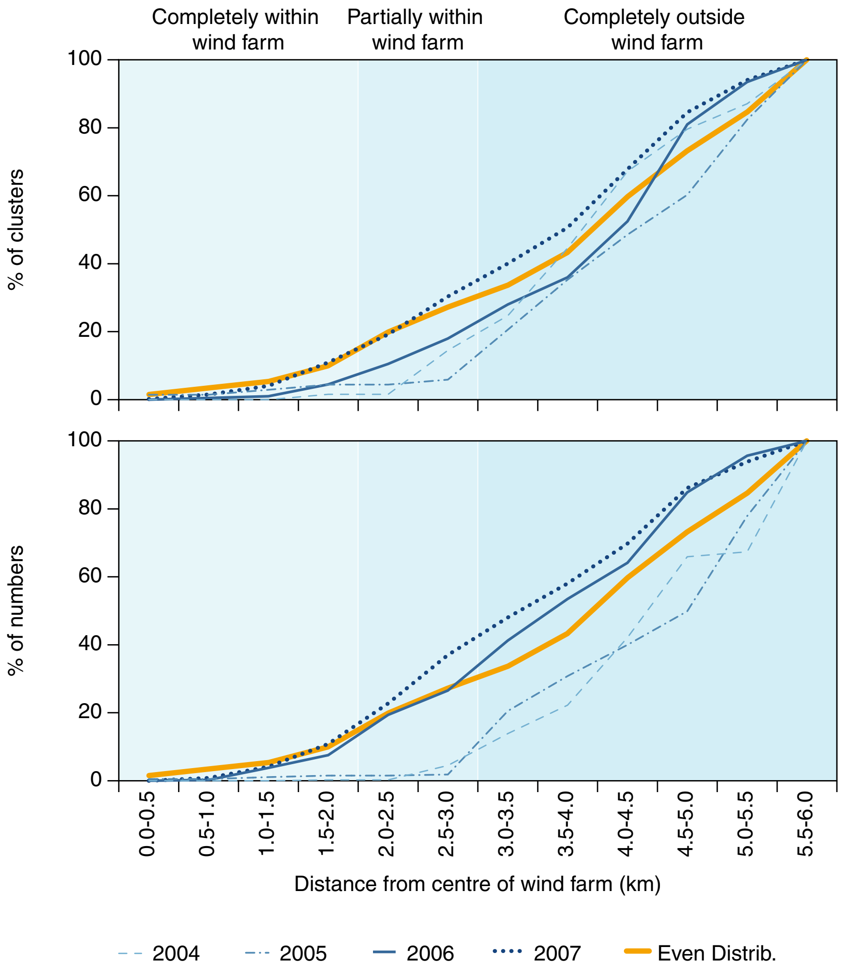


Table 4. Results of between year comparisons of Kolmogorov- Smirnov two sample tests to test whether the cumulative frequency distributions of flocks of Common Scoter in their distribution out from the centre of the Horns Rev wind farm were drawn from the same distributions. D values are shown for each test with the associated χ^2 value, significance is conventionally indicated, * shows $P < 0.05$, ** $0.05 < P < 0.01$, *** $0.01 < P < 0.001$, ^{NS} $P > 0.05$. Signs indicate the direction of the difference detected by each test, a plus indicates increasing proportions of birds within the wind farm.

	2005	**2006**	**2007**
2004	D = 0.193 χ^2 = 7.43** -	D = 0.147 χ^2 = 4.32** -	D = 0.176 χ^2 = 6.19** +
2005		D = 0.207 χ^2 = 8.57** +	D = 0.245 χ^2 = 12.00*** +
2006			D = 0.153 χ^2 = 4.69** +

Table 5. Results of between year comparisons of Kolmogorov- Smirnov two sample tests to test whether the cumulative frequency distributions of individual Common Scoter in their distribution out from the centre of the Horns Rev wind farm were drawn from the same distributions. D values are shown for each test with the associated χ^2 value, significance is conventionally indicated, * shows $P < 0.05$, ** $0.05 < P < 0.01$, *** $0.01 < P < 0.001$, ^{NS} $P > 0.05$. Signs indicate the direction of the difference detected by each test, a plus indicates increasing proportions of birds within the wind farm.

	2005	2006	2007
2004	D = 0.160 χ^2 = 5.13* -	D = 0.312 χ^2 = 19.49*** +	D = 0.358 χ^2 = 25.63*** +
2005		D = 0.350 χ^2 = 24.44*** +	D = 0.363 χ^2 = 26.28*** +
2006			D = 0.109 χ^2 = 2.20 ^{NS} +

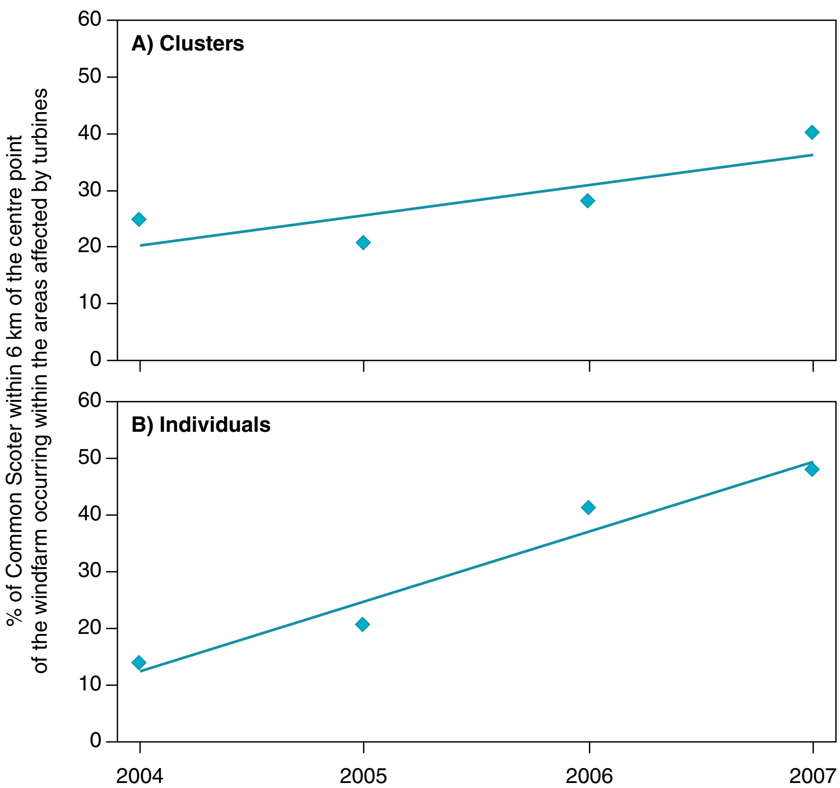


Figure 11. Changes during 2004-2007 in the frequency of all Common Scoter flocks (upper "clusters") and individuals (lower) occurring within 3 km of the centre of the Horn Rev wind farm as a percentage of all those registered out to 6 km. Fitted lines are least squares regression model fits for clarity.

3.3.5 Velvet scoter *(Melanitta fusca)*

A total of 458 Velvet Scoters were recorded during the four aerial surveys. Most birds were seen on 1 April (138) and 15 February (123) (Table 2).

The distribution of the Velvet Scoters varied little between surveys and has been pooled in one figure (Fig. 12). The majority of the birds were recorded in the areas off Skallingen, south of Blåvands Huk. Few birds were recorded on Horns Reef and off the coast of Fanø.

No Velvet Scoters were recorded within the Horns Rev 1 wind farm.

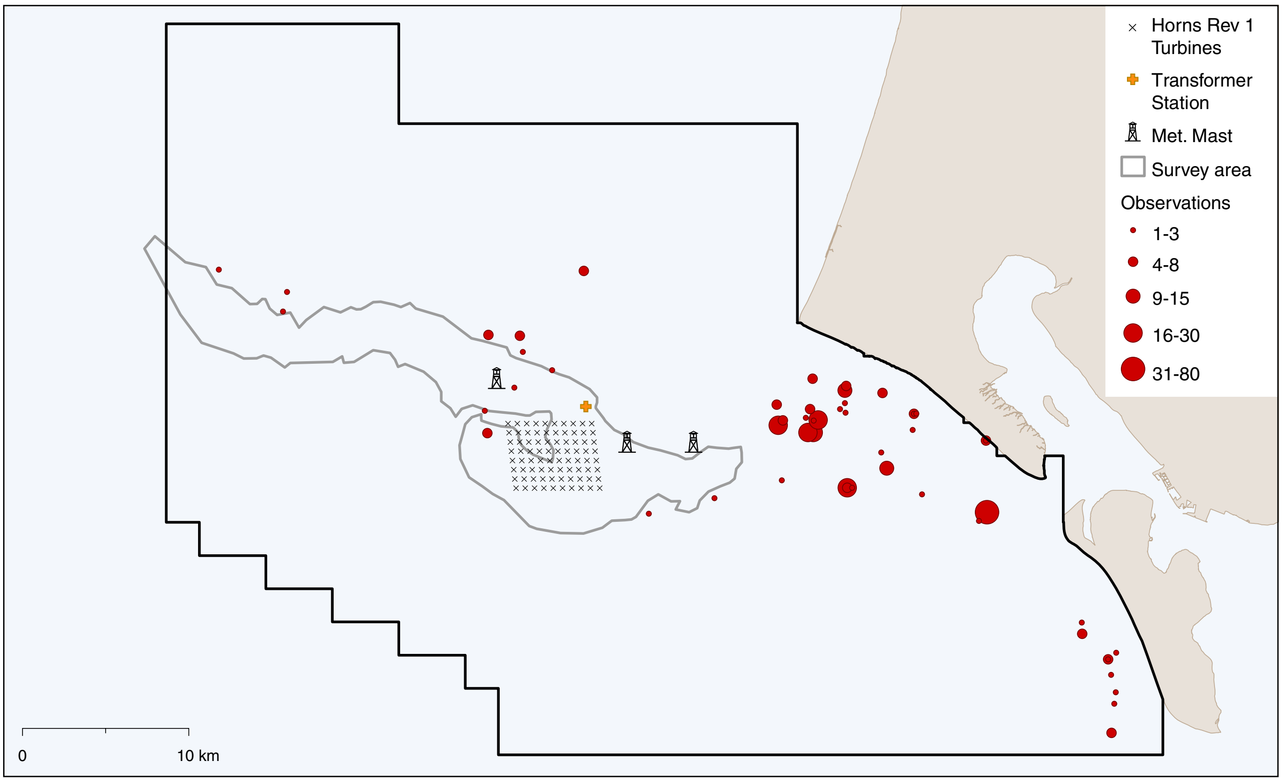


Figure 12. Distribution map of 358 Velvet Scoters observed in the study area during four surveys, 25 January, 15 February, 3 March and 1 April 2007. Turbine positions and the extension of the reef with water depth of less than 10 m are shown.

3.3.6 Herring gull (*Larus argentatus*)

A total of 7,661 Herring Gulls were recorded during the four aerial surveys. Most birds were seen on 25 January (3,038), but with only slightly lower numbers on 15 February (2,313) and 1 April (2,064). Surprisingly low numbers was recorded on 3 March (246) (Table 2).

The distribution of Herring Gulls varied considerably between surveys. High concentrations at sea were often observed around active fishing boats. Generally Herring Gulls were most abundant in the eastern parts of the study area. On 25 January many birds were recorded in the northern parts of the study area, north of the Horns Rev 1 wind farm (Fig. 13A), but with scattered birds in the area south of Skallingen and west of Fanø. Similarly on 15 February, where concentrations were also observed in the southern parts of the study area, south of the Horns Rev 1 wind farm (Fig. 13B). On 3 March the relatively few Herring Gulls were seen scattered over the entire study area, with a preference for the eastern parts (Fig. 13C). On 1 April birds were seen scattered in the eastern parts of the study area (Fig. 13D).

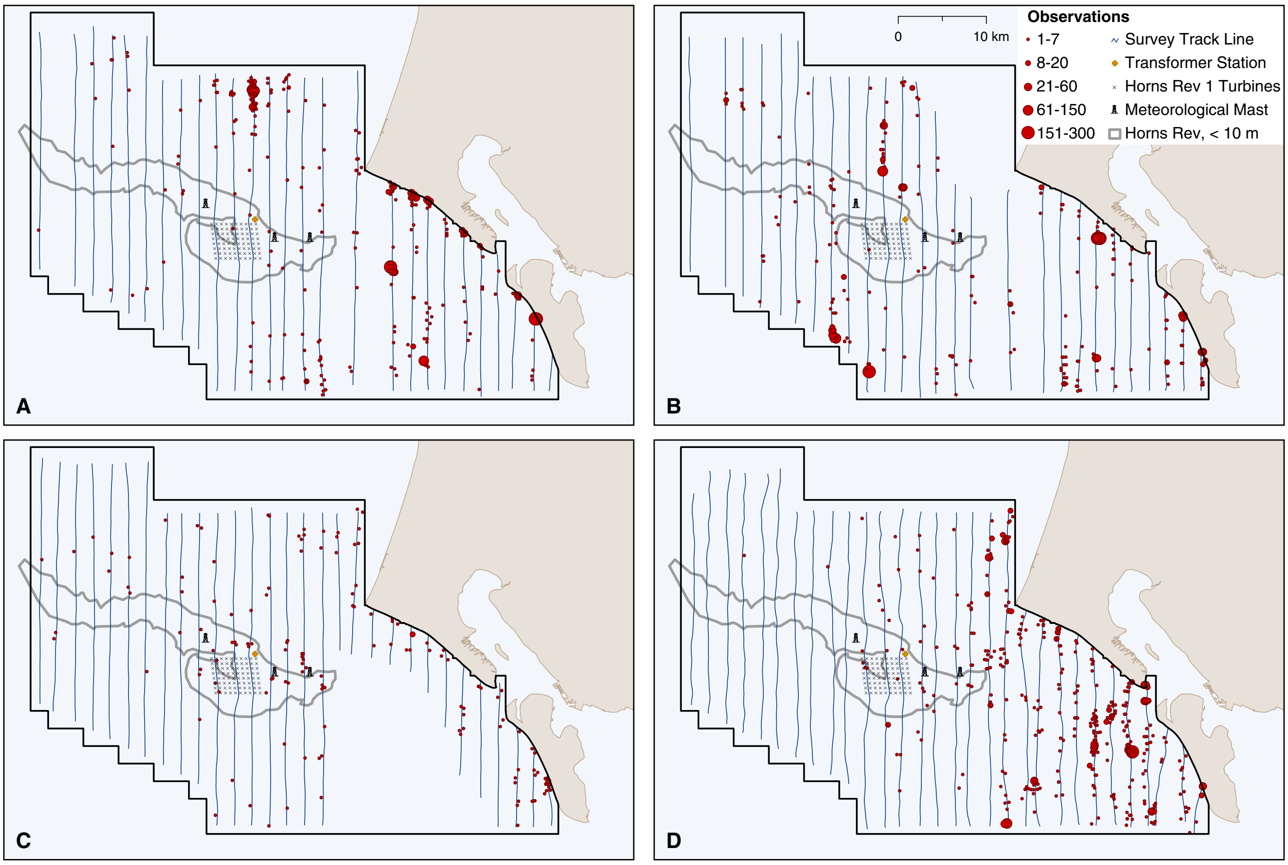


Figure 13. Distribution map of 3,038 Herring Gulls observations in the study area, 25 January 2007 (A), of 2,313 Herring Gulls observations in the study area, 15 February 2007 (B), 246 Herring Gulls observations in the study area, 3 March 2007 (C) and of 2,064 Herring Gulls observations in the study area, 1 April 2007 (D). Turbine positions and the extension of the reef with water depth of less than 10 m are shown. Thin blue lines identify track lines.

Herring Gulls were recorded within the Horns Rev 1 wind farm in low numbers during all four surveys. Being most abundant in the eastern parts of the study area, Herring Gulls were found in less than expected numbers in the wind farm area and its surroundings, assuming an even distribution over the study area. D-values of -0.85, -0.83 and -0.82 for the three distance zones respectively was found (Table 3).

3.3.7 Little gull *(Larus minutus)*

A total of 116 Little Gulls were recorded in the study area, most of which were seen on 1 April (79) (Table 2).

Little Gull was mainly recorded in the western parts of the study area, both south and north of the reef. Few birds were seen on the reef, and a single observation was done inside the Horns Rev 1 wind farm area (Fig. 14).

Little Gull showed relatively marked avoidance of the wind farm area (D-value = -0.31). The avoidance was less when including the 2 km zone around the farm (D-value = -0.18) and approached neutral when including the 4 km zone, with a D-value of -0.04 (Table 3).

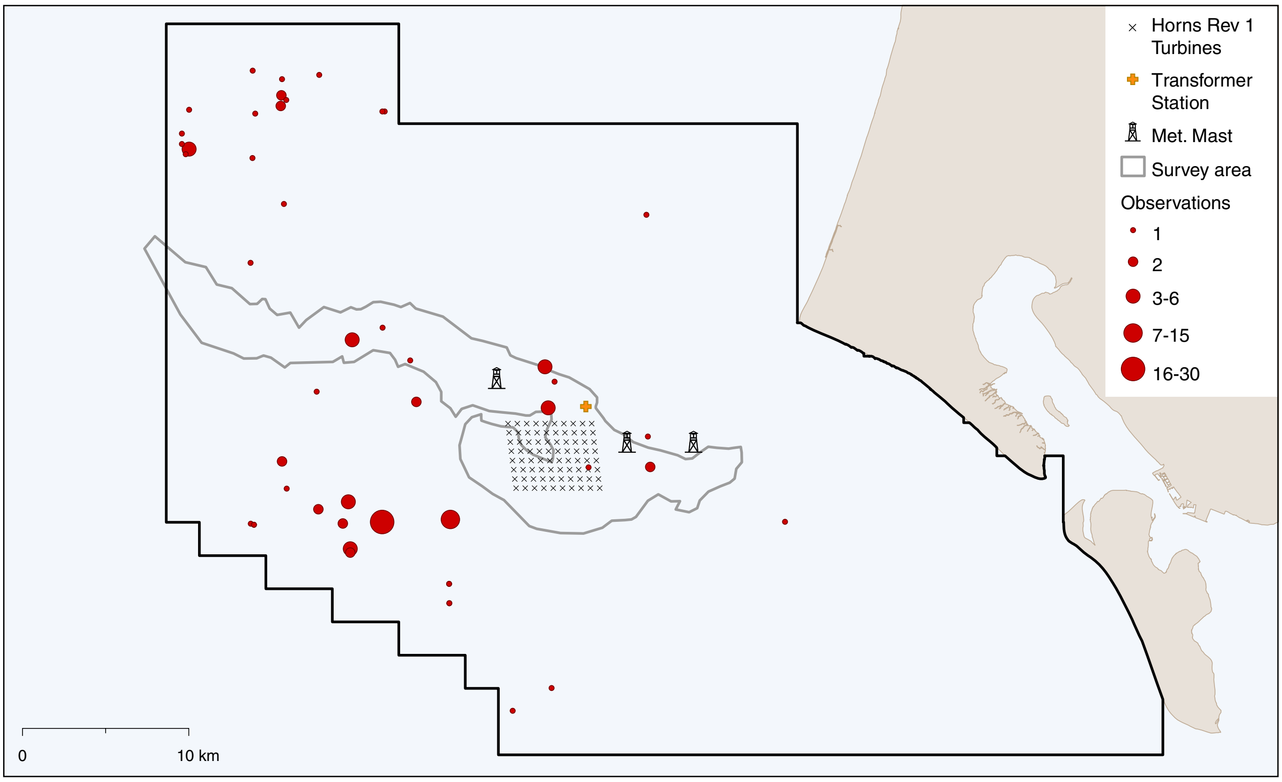


Figure 14. Distribution map of 116 Little Gulls observed in the study area during four surveys, 25 January, 15 February, 3 March and 1 April 2007. Turbine positions and the extension of the reef with water depth of less than 10 m are shown.

3.3.8 Razorbill (*Alca torda*) / Guillemot (*Uria aalge*)

A total of 232 Razorbills/Guillemots were recorded during the four aerial surveys. Most birds were recorded on 15 February (149) and 25 January (70) (Table 2).

86% of the birds were recorded as unidentified Razorbill/Guillemot, and only 7% were recorded as Razorbill and 7% as Guillemot.

Razorbills/Guillemots were most abundant in the western parts of the study area. On 25 January most birds were found north of the Horns Rev sand bar (Fig. 15A), while on 15 February most birds were found south of the reef (Fig. 15B). On 3 March and 1 April very few birds were present in the study area (Fig. 15C,D).

No Razorbills/Guillemots were found in the Horns Rev 1 wind farm area, which gave rise to Jacobs Index D-values of -1.00 for the wind farm area and the 2 km zone (Table 3).

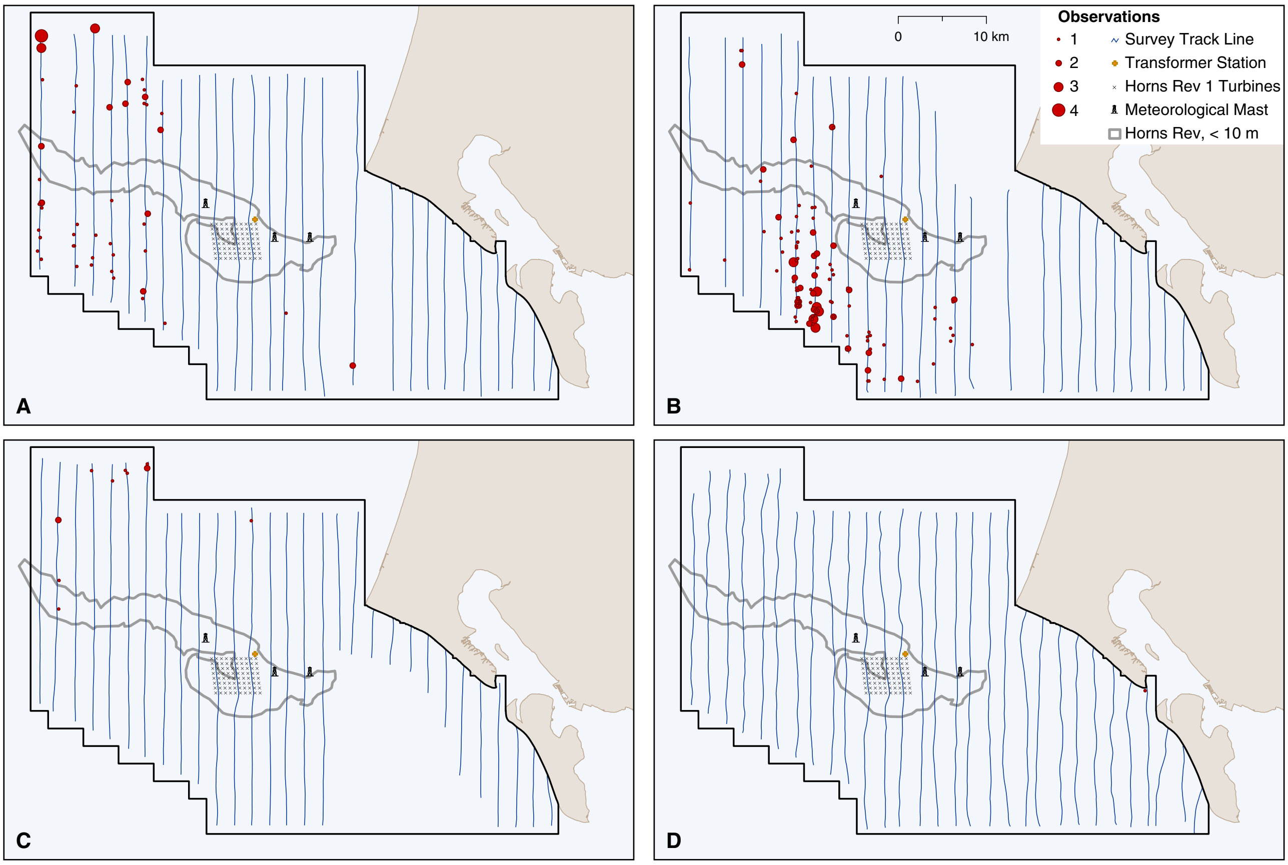


Figure 15. Distribution map of 70 Razorbills/Guillemots observations in the study area, 25 January 2007 (A), 159 Razorbills/Guillemots observations in the study area, 15 February 2007 (B), of 12 Razorbills/Guillemots observations in the study area, 3 March 2007 (C) and of 1 Razorbills/Guillemots observations in the study area, 1 April 2007 (D). Turbine positions and the extension of the reef with water depth of less than 10 m are shown. Thin blue lines identify track lines.

4 Discussion

The most significant effects on birds caused by the construction of wind farms in the marine environment consist of (i) collision mortality and (ii) avoidance effects, either causing changes to normal flight trajectories and/or effective habitat loss caused by behavioural avoidance of intact feeding resources (Fox et al. 2006a). In previous reports from post construction ornithological studies at Horns Rev, it was shown that Common Scoter in particular showed pronounced avoidance behaviour, generally avoiding flying between the turbines within the wind farm based on direct visual observations and avoiding feeding or resting between them based on aerial survey observation (Fox et al. 2006b, Petersen et al. 2006). Although small numbers of Common Scoter were recorded in a few surveys resting between the turbines, the evidence strongly suggested that, for whatever reason, the vast majority avoided occurring in the spaces between the turbines, which resulted in effective habitat loss in the area of sea affected. In all the reporting, however, two facts were stressed. Firstly, that because there were no Common Scoter present in the vicinity of the Horns Rev wind farm during the pre-construction baseline investigations, their appearance and distribution in and around the wind farm post construction could be the result of changes in the distribution and abundance of food, which did not form part of the investigation. Secondly, even if the avoidance of the wind farm was evident up to three years post construction, it could not be ruled out that this response to a novel stimulus may change with longer exposure.

It was therefore highly relevant that, after a prolonged period during 2004-2006 when Common Scoter apparently avoided the Horns Rev wind farm, despite higher densities in the surrounding areas of sea, helicopter pilots in January 2007 began to report many individuals of this species in increasing numbers well within the boundaries of the wind farm. Since this phenomenon represented a major change in the behaviour of a species of particular nature conservation concern, this investigation based on four supplementary aerial surveys was launched and particular attention paid to this change in this discussion section of the report.

The results from the four aerial surveys carried out in 2007 show that, in contrast to the earlier years post construction, Common Scoter were present in significant numbers between the turbines at Horns Rev 1. Using encounter rates of flocks and individuals per unit effort within 2 km x 2 km grid squares covering the area containing turbines and those immediately outside showed that during the period of highest densities, there were no differences between the mean density of Common Scoter within and outside the wind farm during three out of four counts. No significant difference between encounter rates inside and in the periphery of the wind farm was found when analysing the summed data set of the four surveys carried out in 2007. During the April 2007 count, the mean encounter rates were significantly lower inside the Horns Rev wind farm than outside, albeit that during this period the majority of the wintering birds present in the earlier counts had clearly left the area, so overall densities were much lower. It is interesting to speculate whether this was a real effect of turnover amongst individuals present, with departing "experienced" birds that had spent the winter in the area and "learned" that turbines presented no threat to their survival, replaced by naïve birds at lower densities which reacted as in earlier years by avoiding foraging or resting in the vicinity of turbines. However, this remains pure speculation.

The possibility remains that the general changes in distribution result from changes in distribution of the food resources amongst the benthos, such that the distribution of the birds on the sea surface simply reflects that of the abundance and distribution of their food on the sea bed. In the absence of a major study of the benthos and changes in the abundance and availability of their prey, it is simply not possible to refute or confirm this.

Nevertheless, there is some evidence from the results presented here from the 2007 surveys and the historical data from the earlier post construction surveys that there was a temporal element to the changes in distribution of Common Scoter over the period since construction of the Horns Rev 1 wind farm. The frequency distributions of flocks and birds at successive distances out from the centre of the wind farm differed significantly between years, and comparisons of these changes confirmed mostly to predictions under the assumption that birds in some way moderated their avoidance response to the turbines over time. The pattern in Figure 11 also confirms to this pattern, most dramatically amongst the proportion of individuals occurring within the area affected by the wind farm, which increased from just over 10% in 2004, progressively rising to 50% in the results from the survey in 2007. Whether this really represents habituation (i.e. the moderating response of an individual in response to exposure to a stimulus, in this case the presence of turbines) or modified behaviour of the population as a result of increasing numbers of hungry, naïve or exploratory individuals showing reduced avoidance response which affected the behaviour of other individuals, or simply the result of changes in the food distribution and abundance it is not possible to conclude with certainty.

Indeed, in many ways, the mechanism responsible is not important, the simple conclusion must be that in three out of four of the surveys carried out in 2007, there was no difference between mean encounter rates inside and immediately outside the wind farm and therefore there was no evidence of avoidance during those surveys. There was a significant difference in the April survey when densities were low and in all probability, wintering birds had been replaced by migrants from further south in the wintering range. These patterns were in marked contrast to the results of earlier years especially immediately after construction. We therefore conclude that Common Scoter may indeed occur in high densities between newly constructed wind turbines at sea, but this may only occur a number of years after initial construction. We cannot exclude the explanation that this reflects changes in food supply rather than a change in the behaviour of the birds themselves.

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

In 2007 divers, Gannet, Eider, Herring Gull, Little Gull and Razorbill/Guillemot were found in less than expected numbers in the wind farm site and its 2 and 4 km zones around the site when assuming an even distribution across the study area. There was no sign that divers, previously concluded to avoid the area of the wind farm and its surroundings, had changed their distribution relative to the wind farm.

5 Conclusion

This report summarise results from four aerial surveys of birds around the Horns Rev 1 wind farm in January to April 2007. Comparing with survey data from the corresponding months of 2004 to 2006 analyses of recent changes in habitat utilisation by Common Scoter in and around the Horns Rev 1 wind farm was performed.

The most abundant bird species in the study area were Common Scoter, Herring Gull, Eider and divers. Of these species Common Scoter was the only one that positively selected for the area of the wind farm, assuming an even distribution across the study area.

We compared Common Scoter encounter rates in six 2x2 km grid cells representing the wind farm area to 14 2x2 km grid cells surrounding the wind farm. This was done for each of the four surveys conducted in 2007, and we found no significant difference between encounter rates inside and around the wind farm for the three early surveys, while significantly lower encounter rates was found for the April 2007 survey. Based on the summed data set from 2007 there was no significant difference between encounter rates in the wind farm site and the periphery.

From a selection of Common Scoters recorded within 6 km from the centre point of the Horns Rev 1 wind farm an analysis of cumulative distance frequency distribution was conducted for each year between 2004 and 2007. Significant differences were found between all years when calculated on the basis of number of flocks, and from 2005 gradually higher proportions of the birds were found within the wind farm area. The highest proportion of birds within the wind farm area was found in 2007.

The same pattern was found when analysing the proportion of birds within 3 km of the wind farm centre point to the total number of birds present within 6 km of the centre point. Most pronounced change was found amongst the proportion of individuals occurring within the area, which increased from just over 10% in 2004, progressively rising to 50% in the results from the survey in 2007.

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

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

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National Environmental Research Institute, NERI, is a part of University of Aarhus.

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

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