National Environmental Research Institute
Ministry of the Environment · Denmark

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Annual status report 2004

NERI Report
Commisioned by Elsam Engineering A/S
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Ib Krag Petersen

Data Sheet

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Contents

National Environmental Research Institute

Synopsis

This report presents data from four aerial surveys of birds in the Horns Rev wind farm area in 2004. Three surveys from the winter and spring of 2004 are thoroughly reported here. The fourth survey of 9 September 2004 is reported in general terms, but not included in presentations of distribution and effect analyses of the wind farm. Data from this survey will be thoroughly dealt with in a future report. Including the four surveys of 2004, a total of 29 surveys have been performed in that area since August 1999.

The four surveys in 2004 were performed on 29 February, 26 March, 10 May and 9 September.

The operational phase of the wind farm commenced in 2002. Hence nine surveys from 2003 and 2004 have been conducted during the post-construction period. In order to achieve maximal compatibility between pre- and post-construction data sets, most analyses were comparing surveys done in February through May of 2000 and 2001 (seven surveys) and 2003 and 2004 (six surveys).

Common Scoter was by far the most numerous bird species in the study area in 2004 as well as during the previous years of investigations. More than 95,000 individuals were observed in 2004. Herring Gull was the second most numerous species in 2004, with more than 4,400 birds observed. Divers, Gannet, Eiders, Little Gull, Arctic/Common Tern and Guillemot/Razorbill were relatively regular in the study area, and are treated in detail in this report.

Divers, Common Scoter and Guillemots/Razorbills showed an increased avoidance of the wind farm area (and zones within 2 and 4 km of it) after the erection of the wind turbines. In contrast, Herring Gulls, Little Gulls and Arctic/Common Terns showed a decreased avoidance of the wind farm area.

Common Scoter showed a difference in the spatial distribution within the study area in 2004 compared to previous years. Shallow offshore areas west of the wind farm became important to the species, with occurrence of birds in the westernmost parts of the survey area. Furthermore, the seasonal shift in offshore appearance of Common Scoter described in previous reports seems to have changed into a more permanent presence during winter. This leads to the hypothesis that a food resource has formed in these areas, which was not present during the pre-construction period.

Given the apparent general changes in Common Scoter distribution in the study area comparison of pre- and post-construction distribution analyses for this species must be interpreted with caution. Despite this the data strongly indicate that common scoters respond to the presence of the wind turbines by avoidance of that area. The area southeast of the wind farm, previously used by Common Scoter and particularly in February through April, became less attractive to the species. Simultaneously areas west and north of the wind farm, with previously very few Common Scoters, supported greater numbers of this species, while only very few birds were recorded within the wind farm.

The reason for the change in avoidance of the wind farm area for divers, Common Scoter and Guillemot/Razorbill is unknown. Disturbance effects from the wind turbines is one possible reason. Disturbance from increased human activity associated with maintenance of the wind turbines could be another. But changes in the distribution of food resources in the study area could potentially play a role too.

The change in gull and tern preference for the wind farm area is likely to have been caused by the presence of the wind turbines and the associated boat activity in the area.

Dansk resumé

Denne rapport præsenterer resultater fra fire optællinger af fugle fra fly i undersøgelsesområdet for Horns Rev havvindmøllepark i 2004. Resultaterne fra disse optællinger bearbejdes, hvor de tre optællinger fra vinteren og foråret 2004 indgår i en løbende, grundigere analyse af møllernes effekt på områdets fugleforekomster, mens en fjerde optælling foretaget den 9. september 2004 blev indarbejdet på et mere summarisk niveau. Denne optælling vil blive grundigere afrapporteret i en kommende rapport. Hermed er der i perioden august 1999 - september 2004 i alt foretaget 29 optællinger af fugle i undersøgelsesområdet på Horns Rev.

De fire optællinger i 2004 blev foretaget på følgende datoer: 29. februar, 26. marts, 10. maj og 9. september.

Havvindmølleparkens driftsfase startede i 2002. Optællingerne foretaget i 2003 og 2004 dækker således alle driftsfasen. For at opnå bedst sammenlignelighed imellem data fra forundersøgelserne er de analyser af effekten af vindmøllernes mulige indflydelse på fuglenes fordeling i området foretaget på baggrund af optællinger fra februar til maj i henholdsvis 2000 og 2001 (syv optællinger foretaget under forundersøgelser) og 2003 og 2004 (seks optællinger foretaget under driftsfasen).

Sortand var langt den hyppigst forekommende art i undersøgelsesområdet i 2004, ligesom det har været tilfældet de foregående undersøgelsesår. Godt 95.000 sortænder blev optalt i 2004. Sølvmåge var den næsthyppigste art i 2004 med mere end 4.400 observerede individer. Lommer, sule, skarv, ederfugl, dværgmåge, hav-/fjordterne og alk/lomvie forekom relativt hyppigt i undersøgelsesområdet, og behandles i denne rapport.

Lommer, sortand og alk/lomvie viste under driftsfasen en mindre præference for selve mølleparken, samt zoner på 2 og 4 km omkring denne i forhold til perioden før vindmølleparkens opførelse. Omvendt viste sølvmåge, dværgmåge og hav-/fjordterne en større præference for mølleparken og de to zoner omkring denne.

Sortand fortsatte med at udvise ændringer i deres geografiske fordeling i undersøgelsesområdet i 2004. Lavvandede områder langt fra kysten blev udnyttet af fuglene, og sortænder blev observeret i den vestligste del af undersøgelsesområdet. Det sæsonbetonede fordelingsmønster, som er beskrevet i tidligere rapporter, ser ud til at have ændret sig til en mere permanent vinterudnyttelse af områder langt fra kysten. Årsagen hertil skønnes at være dannelse af en mere permanent føderessource for sortænder i disse områder.

Som følge af disse generelle geografiske ændringer i sortændernes fordeling i undersøgelsesområdet må analyserne af forskelle i fuglenes fordeling før og efter oprettelsen af vindmølleparken vurderes med forsigtighed. Resultaterne giver dog klare indikationer på at sortænder reagerer på vindmøllernes tilstedeværelse. Et område sydøst for mølleparken og tæt på denne var i 2003 og 2004 mindre attraktivt for arten end tidligere, specielt i marts-april. Derimod var områder vest og nord for mølleparken mere attraktive i 2003 og 2004 end tidligere, hvor disse kun blev udnyttet i meget ringe grad, mens kun meget få sortænder blev registreret inde i selve mølleparken.

Årsagen til den mindre præference for området i og omkring mølleparken i driftsfasen er for lommer, sortand og alk/lomvie ukendt. Forstyrrelse fra vindmøllerne kan være en mulighed. Det gælder også en forøget menneskelig aktivitet i forbindelse med driften af mølleparken, ligesom ændringer i forekomst og fordeling af arternes føderessourcer muligvis også kan påvirke fuglenes fordeling.

1 Introduction

1.1 Background

In February 1998, the Ministry of the Environment gave Elsam A/S and Eltra A.m.b.a. approval in principal to assess the feasibility of erecting a wind farm, capable of producing 160 MW of electric power, at Horns Rev, west of Blåvands Huk at the west coast of Jutland. The conditions imposed an environmental impact assessment (EIA) on the project and explicitly required that before, during and after-construction comparisons of bird distributions be carried out to investigate and demonstrate potential impacts resulting from the construction of the wind farm.

With regard to the potential impacts on birds from the wind farm, Elsam Engineering A/S (the former Elsam Projekt A/S and Tech-Wise A/S) in 1999 contracted the National Environmental Research Institute (NERI), Department of Wildlife Ecology and Biodiversity to perform studies to assess the impact. These studies were financed from PSO (Public Service Obligation) resources.

The southeastern part of the 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). In addition, Blåvands Huk, situated east of the wind farm area, acts as an important site for migrating waterfowl as well as for migratory terrestrial bird species, especially during autumn (Jacobsen in prep.).

The Horns Rev wind farm is situated outside any areas protected for their bird conservation interest. The Wadden Sea and neighbouring land areas constitute Ramsar area no. 27, and are also designated as Special Protection Areas under the EU Birds Directive (nos. 49, 50, 51, 52, 53, 55, 57, 60, 65 and 67) and as Special Areas for Conservation under the EU Habitats Directive (nos. 73, 78 and 90). Furthermore, the Wadden Sea also has the status of a Game Reserve (no. 48) with regulations relating to nature conservation and public access. For a more detailed description of the different protective measures and affected areas, see Noer et al. (2000).

1.2 The Horns Rev Project

The wind farm area is located in the southeastern part of the Horns Rev, c. 14 km west-southwest of Blåvands Huk in the Danish part of the North Sea (Fig. 1). Geomorphologically, the Horns Rev formation is described as a terminal moraine ridge, consisting of relatively well sorted sediments of gravel and sand (Danish Hydraulic Institute 1999). The water depth within the wind farm area varies from 6.5 m to 13.5 m.

Construction activities at Horns Rev started in September 2001. The first activities were associated with pile ramming supports for the transformer station in September-October 2001 and to various tests of equipment and positioning. The establishment of turbine foundations was started in March 2002, and turbine erection in April. Installation of the transformer station was completed in April 2002. The wind farm started to operate in the last quarter of 2002.

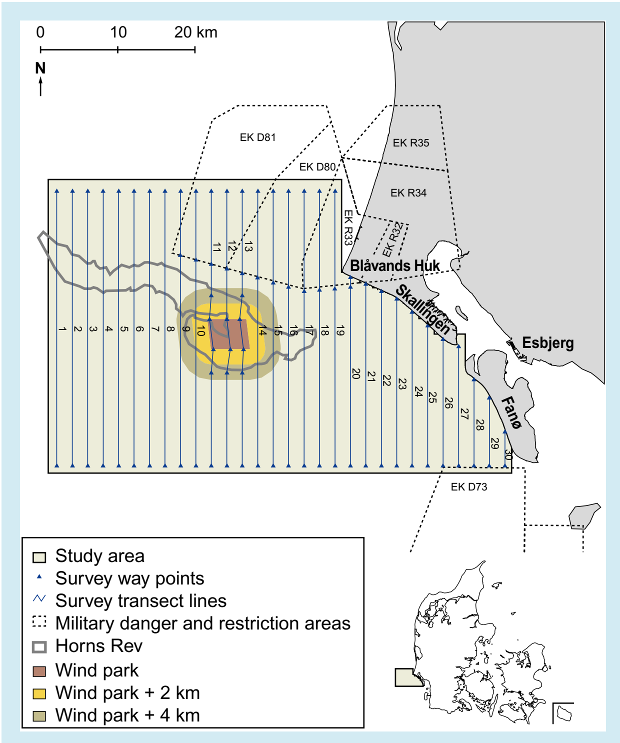

Figure 1. The study area, showing the total survey area (outlined in red) and survey transect net (blue lines). The wind farm area and the 2 and 4 km zones around it, are shown. Also shown are military restriction areas.

The wind farm has a capacity of 160 MW and comprises 80 turbines. Each turbine tower reaches 70 m above sea level. The rotor diameter is 80 m resulting in a maximum height to the upper wing tip of 110 m. The minimum free height from sea level to lower wing tip is 30 m. The distance between adjacent turbines and the turbine rows is 560 m giving an open space of nearly 500 m between turbines. The turbines are equipped with a white strobe light about 10 m above sea level for ship traffic and a red strobe light at the top of the turbines for air traffic. The wind farm covers an area of c. 20 km^2.

The turbine foundation is a monopole rammed into the substrate. The total area occupied physically by the 80 wind turbines will constitute a maximum of 0.3% of the total wind farm area. Cables between the turbines and from the wind farm to land have been bedded down c. 1 m into the seabed.

A transformer station of 20 x 28 m mounted on three legs and 14 m above sea level is located 560 m north of the northeasternmost wind turbine.

During the fully operational phase, service and maintenance of the turbines are expected in the future to constitute 150 days per year and will be carried out partly from ship and partly from helicopter. In 2003 and 2004 the maintenance activities have been more intensive than this due to necessary technical adjustments. Thus the level of maintenance traffic in 2003 and 2004 was similar to that of the construction phase in 2002 (Elsam Engineering pers. com.).

2 Methods

2.1 Study area

Up until August 2002 the study area covered a total area of approximately 1,700 km² around the wind farm, surveyed along 26 transect lines. From August 2002 four transect lines, numbers 27 to 30, were added east of the study area, as outlined below (Fig. 1). This addition increased the study area by 146 km², to a total of 1846 km².

Given no *a priori* knowledge of the magnitude of potential disturbance effects from the wind farm on birds, the study area was designed to cover all potential zones of impact. For the specific detection of potential displacement effects, bird distributions were assessed in zones in the vicinity of the proposed wind farm to compare with those throughout the study area. These zones were chosen to include the following areas: 1) the wind farm, 2) the wind farm area and a 2 km zone (+2 km zone) around it, and 3) the wind farm area and a 4 km zone (+4 km zone) around it (Fig. 1).

2.2 Study period

Data on number and spatial distribution of bird species in the Horns Rev area have been collected regularly by aerial surveys during the period August 1999 - October 2004 (Noer et al. 2000, Christensen et al. 2001, 2002, Petersen et al. 2004, Petersen 2004a). Since construction activities started in September 2001, data collected during the preceding period represents undisturbed conditions, and thus constitutes the base-line, while data collected during the period September 2001 - April 2002 was considered to represent data from the period of construction (Christensen et al. 2003). After this a total of 11 aerial surveys have been performed at Horns Rev, one in August 2002, six in 2003 and four in 2004, all representing the post-construction period of the Horns Rev wind farm. In the present report data from three surveys conducted in winter and early spring of 2004 are reported and analysed. A survey performed on 9 September 2004 will be reported and analysed in a future report. Thus the contents of this report will include the same data as a note to ELSAM Engineering earlier this year (Petersen 2004a). The data and this report have undergone internal quality control.

Details on each of the three surveys from the winter and early spring of 2004 are found in Table 1.

2.3 Aerial surveys of birds

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

During the surveys, two observers each covered one side of the aircraft. Only experienced observers 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 when detected.

Excluding the two initial surveys, the study area was covered by a total of 26 north-south oriented, parallel transects, flown at 2 km intervals from Skallingen in the east, westwards to a point 37 km off Blåvands Huk (Fig. 1). The transects covered a total linear track of 821 km. From August 2002, four transect lines were added, covering the area from the eastern boundary of the previous study area towards the west coast of Fanø. This increased the transect line length to 860 km. Transect endpoints were entered into the aircraft's GPS as way points, used for navigation along the transect tracks. The covered area was further divided into grid cells of 2x2 km.

Based on an increasing understanding of the recording probabilities of the bird species most often observed in the area, transect width was changed on two occasions to optimise survey data. In the final set-up, transect bands were determined using an inclinometer (predetermined vertical angles of 10° and 25° below the horizontal measured abeam flight direction), and thus

Table 1. Summary details of the 28 aerial surveys carried out in the study area, August 1999-May 2004. Table shows the dates when the surveys were carried out, the different transect widths used on different aerial survey dates, and the total distance of transect surveyed (including counts from both sides of the aircraft).

Survey Number	Date	Band A	Band B	Band C	Km Transect Covered
1	19990803	44-250 m	>250 m		1,492
2	19990903	44-163 m	163-432 m	432-1,000 m	1,417
3	19991112	44-163 m	163-432 m	432-1,000 m	1,488
4	20000217	44-163 m	163-432 m	432-1,000 m	1,653
5	20000221	44-163 m	163-432 m	432-1,000 m	1,148
6	20000319	44-163 m	163-432 m	432-1,000 m	1,611
7	20000427	44-163 m	163-432 m	432-1,000 m	1,476
8	20000821	44-163 m	163-432 m	432-1,000 m	1,475
9	20001006	44-163 m	163-432 m	432-1,000 m	1,411
10	20001222	44-163 m	163-432 m	432-1,000 m	1,224
11	20010209	44-163 m	163-432 m	432-1,000 m	1,509
12	20010320	44-163 m	163-432 m	432-1,000 m	1,636
13	20010421	44-163 m	163-432 m	432-1,000 m	1,473
14	20010822	44-163 m	163-432 m	432-1,000 m	1,637
15	20010926	44-163 m	163-432 m	432-1,000 m	1,523
16	20020107	44-163 m	163-432 m	432-1,000 m	1,370
17	20020312	44-163 m	163-432 m	432-1,000 m	1,456
18	20020409	44-163 m	163-432 m	432-1,000 m	1,355
19	20020808	44-163 m	163-432 m	432-1,000 m	1,370
20	20030213	44-163 m	163-432 m	432-1,000 m	1,291
21	20030316	44-163 m	163-432 m	432-1,000 m	1,696
22	20030423	44-163 m	163-432 m	432-1,000 m	1,716
23	20030905	44-163 m	163-432 m	432-1,000 m	1,573
24	20031204	44-163 m	163-432 m	432-1,000 m	1,392
25	20031230	44-163 m	163-432 m	432-1,000 m	1,269
26	20040229	44-163 m	163-432 m	432-1,000 m	1,741
27	20040326	44-163 m	163-432 m	432-1,000 m	1,735
28	20040510	44-163 m	163-432 m	432-1,000 m	1,730
29	20040909	44-163 m	163-432 m	432-1,000 m	1,582

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 for the individual surveys are shown in Table 1.

During the aerial surveys a computer logged flight track data from a differential GPS at five second intervals. Each record contained longitude, latitude and time. Accuracy of GPS longitude and latitude was normally considered to be within 2 m.

In situations where the GPS failed during track-logging, positions of each bird observation were calculated by interpolation. In these cases the spatial accuracy of the observation data is slightly reduced. In 2003 there was GPS coverage throughout during all surveys but on 23 April, where coverage failed along 240 km of the easternmost transect lines.

The majority of records were considered to have a temporal accuracy to within four seconds. With a flight speed of 185 km/h the positional accuracy on the longitudinal axis was within 206 m. In the few situations where observers encountered high bird densities, grouping of observa-

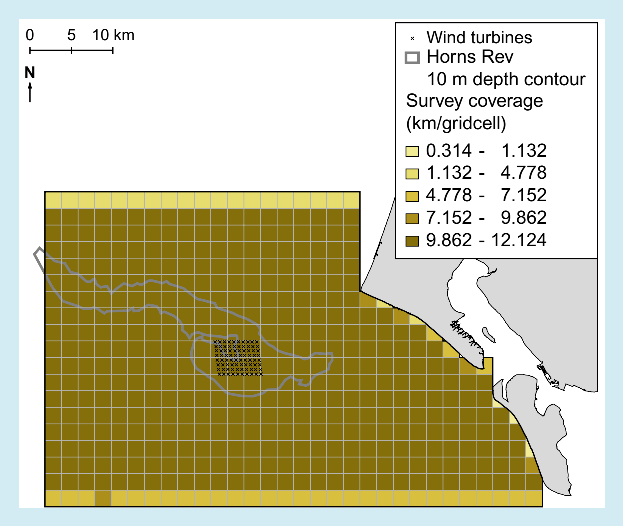

Figure 2. Transect length survey effort (in km) per 2 x 2 km grid squares in the study area, summed for three surveys performed in 2004. See text for details.

tions in periods of up to 10 seconds have occurred, leading to an accuracy of observation positioning of up to 515 m.

As the detection probability of birds are highly sensitive to weather conditions, surveys were not initiated when wind speed exceeded 6 m/s. 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. The survey coverage of the study area in 2004 is shown in Fig. 2.

2.3.1 Aerial surveys between wind turbines

At the time of the aerial survey in August 2002, all turbines in the wind farm had been erected. This necessitated a slight modification of the survey transect lines, in order to avoid turbines. The survey altitude was 76 m, while height to highest turbine wing tip is 110 m.

Because of engineering activities in the wind farm area, the aircraft was not allowed to fly between the turbines during the survey of August 2002. In subsequent surveys of the wind farm area, surveys were undertaken at 76 m, along the modified transect lines (Fig. 1).

2.4 Data analyses

After transcription of observation data and flight track data into spreadsheet tables, a combination of ArcView GIS and TurboPascal software was used to geo-reference each 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 location and size of 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 survey effort.

For all relevant species, distribution maps based on pooled data from all 28 surveys conducted during the baseline and construction periods are presented for the study area summarised at a resolution of 2x2 km. The maps are corrected for variation in survey coverage.

Presentation of bird densities is coupled with methodological problems related to varying coverage of transects, varying transect length, as well as from a decreasing probability of detecting a bird with increasing distance to the aircraft (see Noer et al. 2000 for a more detailed discussion) that have not been corrected for. Therefore, the analyses are based on the observed numbers and describe relative densities.

To assess the number of birds of the different species that would be susceptible to potential disturbance effects from the wind turbines, and to assess the importance of the 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. This was done for the 7 pre-construction surveys performed between February and May, and similarly for 6 post-construction surveys performed during the same time of year. For these zones the preference of the most numerously occurring species was calculated using Jacobs selectivity index (Jacobs 1974).

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 proportion of the length of transect in relation to transect length in the total area (one-sample χ^2-test). In this report, tests were made on the basis of numbers of observed clusters. For some species a cluster can hold a wide range of number of individual birds, from 1 to 26,000 in the case of Common Scoter. Results from tests based on number of clusters are used for comparison of pre-construction and post-construction in this report. Results based on tests on number of individuals are was also made and presented, regardless of the fact that birds observed as groups (clusters) does not meet the criteria of being independent. Results from these latter tests are only used when explicitly stating that they are based on number of observed birds.

A comparison of pre- and post-construction D-values and preference for these zones was used to describe changes in the bird utilisation of the zones.

2.5 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 and spell check
- layout followed by proof-reading
- approval by project managers.

3 Results

3.1 Bird numbers and distributions in the Horns Rev area

A total of four aerial surveys were conducted in the Horns Rev study area in 2004. Three of these, carried out on 29 February, 26 March and 10 May, are reported and analysed in this report, while one survey of 9 September will be reported in a future report.

Bird species and numbers recorded during the three aerial surveys in the Horns Rev study area in the winter/spring of 2004 are presented in Table 2. Species recorded in low numbers or with little relevance in a conservation context are excluded from the table. The total number of birds that were recorded during the 28 aerial surveys during August 1999 - May 2004 is shown in Appendix I, although a few observations of tersrestrial species are omitted.

Table 2. Listing of the total number of birds recorded during three aerial surveys of the study area carried out in the winter/spring of 2004. Only those species of particular significance are provided in the table, numbers of less common species can be found in Appendix I.

Species	Total	29 Feb 2004	26 Mar 2004	10 May 2004	9 Sept 2004
Diver sp.	320	225	74	21	8
Red-throated Diver	373	63	293	17	
Black-throated Diver	11	8	3		
Grebe sp.	1			1	
Fulmar	43	16	4	23	1
Gannet	408	1	15	392	7
Cormorant	1			1	41
Long-tailed Duck	2	1	1		
Eider	913	566	292	55	7
Common Scoter	95270	42260	42312	10698	2715
Velvet Scoter	233	139	30	64	40
Red-breasted Merganser	1			1	
Skua sp.	3			3	2
Herring Gull	4423	3644	566	213	2438
Lesser Black-backed Gull	2		1	1	5
Great Black-backed Gull	187	14	11	162	34
Black-headed Gull	1		1		7
Little Gull	131	60	71		1
Kittiwake	350	50	280	20	24
Gull sp.	572	131	269	172	44
Common Tern	2			2	
Arctic/Common Tern	344			344	5
Sandwich Tern	34			34	8
Tern sp.	47			47	7
Razorbill	27		27		
Razorbill/Guillemot	169	89	79	1	32
Guillemot	27		27		

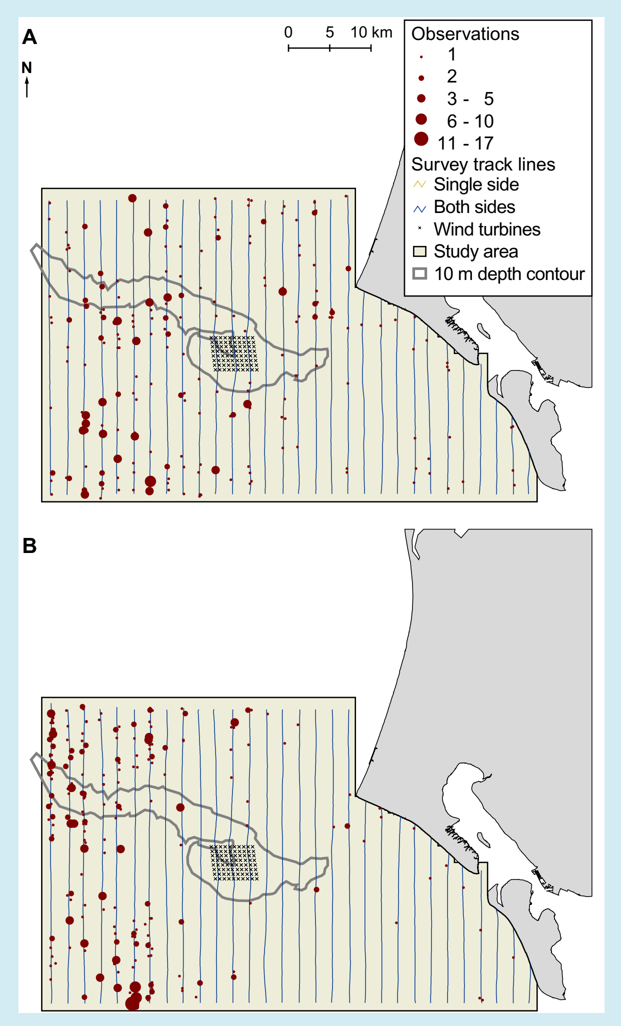

Figure 3. Distribution map of diver observations in the study area on A) 29 February 2004 and B) 26 March 2004. Turbine positions are shown. Thin blue lines identify track lines flown with coverage on both sides of the aircraft, yellow lines those with observations from only one side of the aircraft.

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

- Red- and Black-throated Diver,
- Arctic and Common Tern,
- Guillemot and Razorbill.

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

In 2004 the most numerously recorded bird species in the study area was Common Scoter, with 95,270 observed individuals. The second most numerous species was Herring Gull, with 4,423 observed individuals (Table 2).

3.1.1 Red- and Black-throated Diver *Gavia stellata/arctica*

A total of 3,338 divers were observed during the 28 surveys (Appendix I).

During the three winter/spring surveys of 2004 a total of 704 divers were recorded (Table 2). Of these 666 were counted during the February and March surveys. Of the 704 divers recorded in 2004 45% were unidentified diver sp., while 53% were red-throated diver and 2% were black-throated diver.

Concentrations were observed in the southwestern and western parts of the study area on 29 February 2004, while on 26 March most birds were recorded in the northwestern and southwestern parts of the study area (Fig. 3a-b). The general distribution pattern was similar to that observed during the surveys performed before 2004, al-

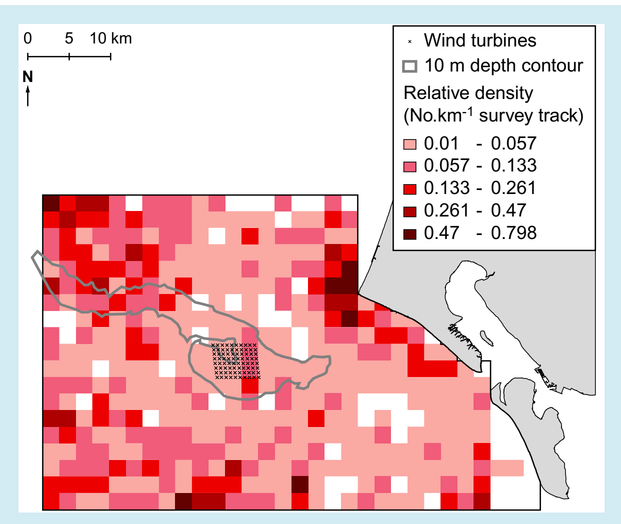

Figure 4. Cumulative distribution map of diver observations in the study area, based on 25 aerial surveys between August 1999 and December 2003. Data are expressed as relative density measured as observations per kilometre of flown transect coverage for each survey in each 2 x 2 km grid square.

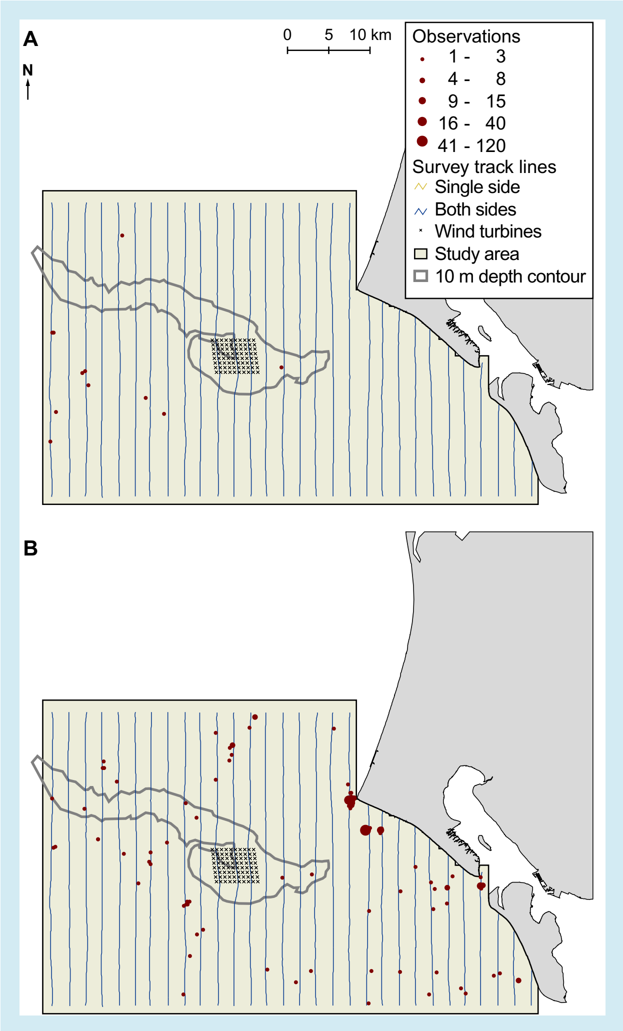

Figure 5. Distribution map of Gannet observations in the study area on A) 26 March 2004 and B) 10 May 2004. Turbine positions are shown. Thin blue lines identify track lines flown with coverage on both sides of the aircraft, yellow lines those with observations from only one side of the aircraft.

though no concentration of divers was observed close to Blåvands Rev this year (Fig. 4).

3.1.2 Gannet *Sula bassana*

A total of 1,075 Gannets has been recorded during the 28 surveys. Of these 408 were recorded in winter/spring of 2004, of which 392 were recorded on 10 May (Table 2 and Appendix I).

The Gannet is an offshore species, feeding on pelagic fish. In winter/spring of 2004 most birds were observed in the eastern part of the study area, particularly at Blåvands Rev, close to the coast of Jutland (Fig. 5a-b). This distribution pattern was strikingly different from the general pattern, as observed for the previous 25 surveys (Fig. 6). 96% of the gannets recorded in 2004 were observed on 10 May, when many birds were gathered close to land.

3.1.3 Eider *Somateria mollissima*

A total of 19,057 Eiders has been recorded during the 28 surveys at Horns Rev. Of these 913 birds were recorded in winter/spring of 2004 (Table 2 and Appendix I).

Eider is an inshore diving duck, mainly feeding on epifauna molluscs. In 2004 Eiders were recorded in all three surveys, being most numerous in February 2004 with 566 individuals. Their distribution was mainly confined to the coastal areas off Skallingen and Fanø (Fig. 7a-b), with only very few observations further offshore, southeast and west of the wind farm. Thus, the general distribution pattern observed in 2004 closely resembles the overall distribution pattern of the species, based on data from 25 surveys conducted between 1999 and 2004 (Fig. 8).

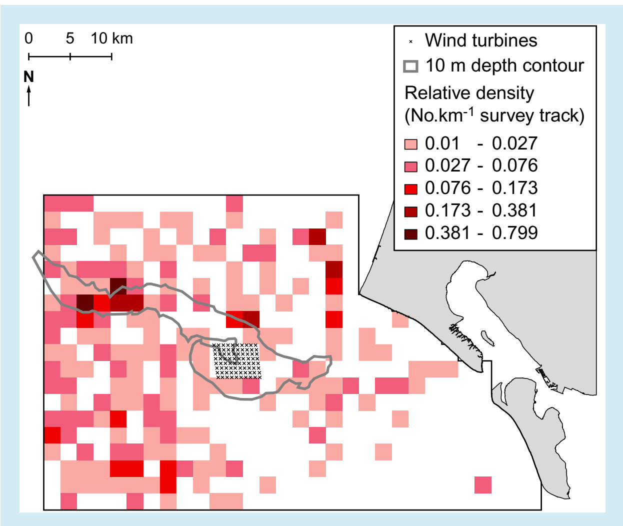

Figure 6. Cumulative distribution map of Gannet observations in the study area, based on 25 aerial surveys between August 1999 and December 2003. Data are expressed as relative density measured as observations per kilometre of flown transect coverage for each survey in each 2 x 2 km grid square.

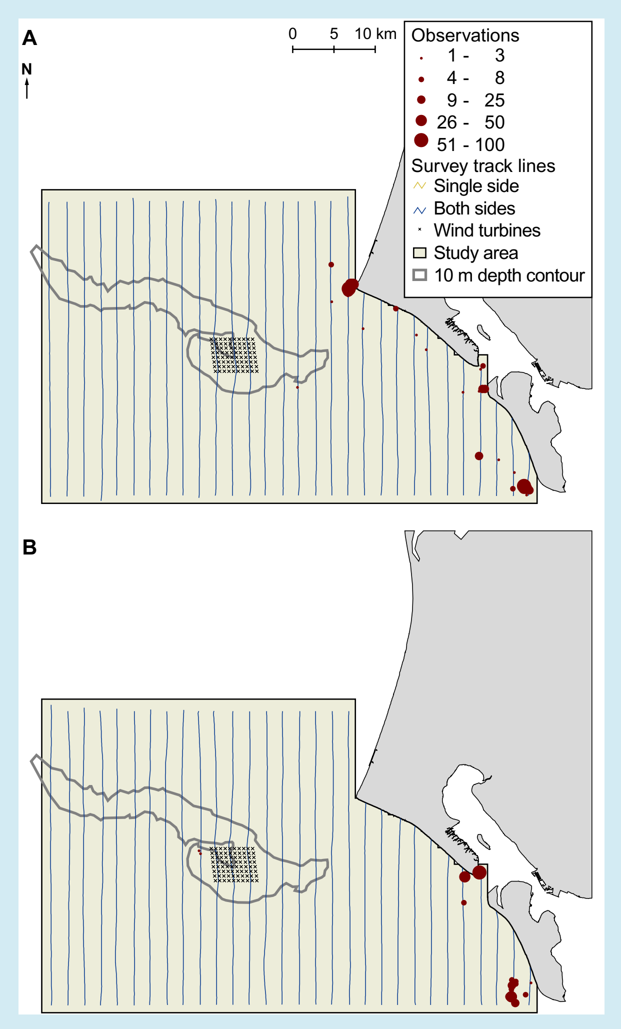

Figure 7. Distribution map of Eider observations in the study area on A) 29 February 2004 and B) 26 March 2004. Turbine positions are shown. Thin blue lines identify track lines flown with coverage on both sides of the aircraft, yellow lines those with observations from only one side of the aircraft.

3.1.4 Common Scoter *Melanitta nigra*

A total of 814,715 Common Scoters has been recorded during the 28 surveys, making this species far the most numerous in the study area. Of these 95,270 individuals were recorded in winter/spring of 2004 (Table 2 and Appendix I).

Common Scoter is a diving duck, mainly feeding on infauna molluscs in soft substrates. On the two surveys of 29 February and 26 March the majority of common scoters were observed along the coast of Skallingen and Fanø. On both surveys a concentration of common scoters was observed northwest of Blåvands Huk, on the northern slope of Blåvands Rev (Fig. 9a-b). In the southeastern area of Horns Rev, immediately southeast of the wind farm, where a concentration of common scoters was found prior to construction of the wind farm, almost no birds were recorded. On both surveys common scoters were observed in the westernmost parts of Horns Rev, and particularly on 26 March with high numbers of birds all along the extension of the reef. On 29 February a concentration was seen close to the northwestern corner of the wind farm. The number of common scoters was reduced at the time of the survey on 10 May (Fig 9c). This time of year the birds leave for the breeding grounds. On this survey concentrations were seen north of Blåvands Huk, close to the northwestern corner of the wind farm and smaller numbers along the northern parts of Skallingen.

Thus the distribution pattern of common scoter during the winter and spring of 2004 was markedly different from that observed during previous years of investigation (Fig. 10). The core area remain coastal parts off Skallingen and Fanø, but

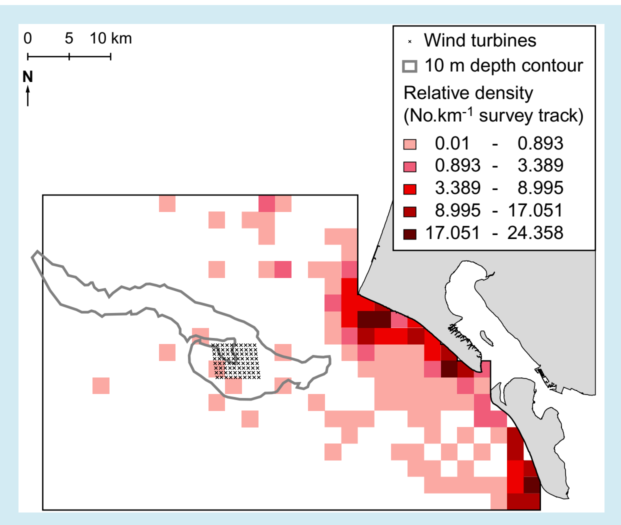

Figure 8. Cumulative distribution map of Eider observations in the study area, based on 25 aerial surveys between August 1999 and December 2003. Data are expressed as relative density measured as observations per kilometre of flown transect coverage for each survey in each 2 x 2 km grid square.

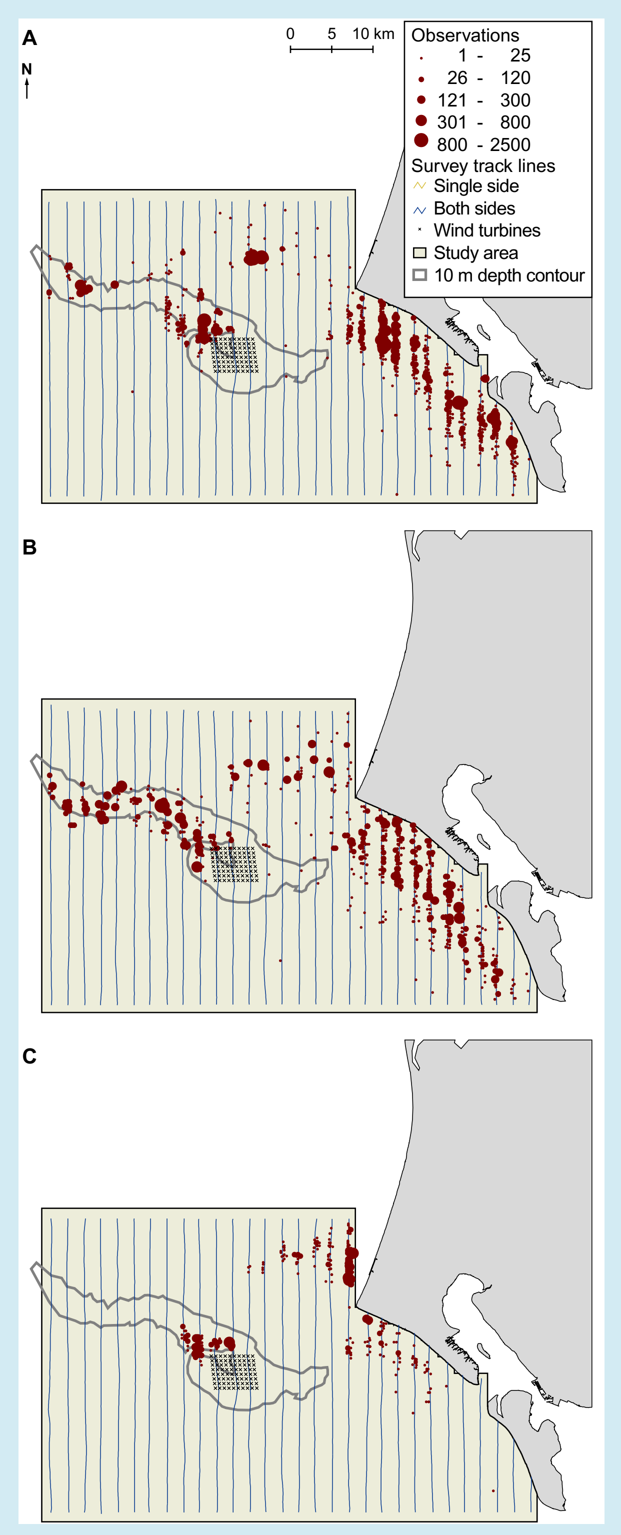

Figure 9. Distribution map of Common Scoter observations in the study area on A) 29 February 2004, B) 26 March 2004 and C) 10 may 2004. Turbine positions are shown. Thin blue lines identify track lines flown with coverage on both sides of the aircraft, yellow lines those with observations from only one side of the aircraft

Horns Rev has become much more important than previously observed for this species. This is also the case for an area on the northern slopes of Blåvands Rev. Despite the fact that Horns Rev has become more important to common scoters the southeastern area of the reef, that previously held high numbers of birds in early spring, seems to have lost its importance. This is most likely caused by the intense boat traffic associated with the wind farm in this area and the fact that the immediate areas east and south of there had water depth greater than the optimal depth for this species. Common scoters hardly utilise the wind farm area at all, but had a permanent concentration close to the northwestern corner of the wind farm. In this area birds were recorded closer to the wind turbines than was the case during the construction phase and the first year of the operational phase.

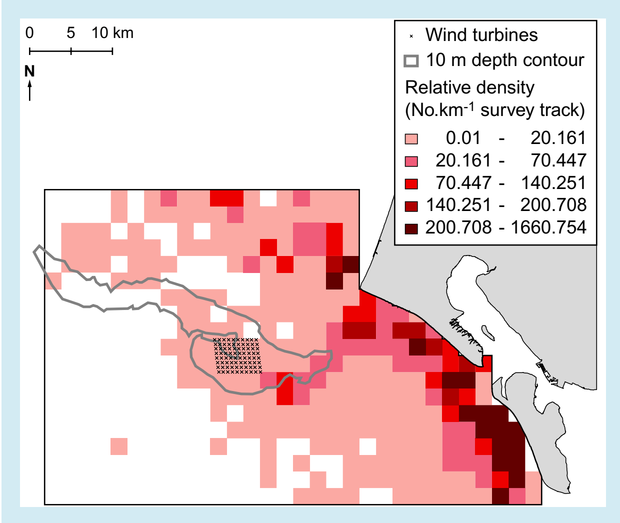

Figure 10. Cumulative distribution map of Common Scoter observations in the study area, based on 25 aerial surveys between August 1999 and December 2003. Data are expressed as relative density measured as observations per kilometre of flown transect coverage for each survey in each 2 x 2 km grid square.

3.1.5 Herring Gull *Larus argentatus*

A total of 37,838 Herring Gulls has been recorded during the 28 surveys. Of these 4,423 were recorded during the three winter/spring surveys of 2004, of which far most birds (3,644) were recorded on 29 February (Table 2 and Appendix I).

In 2004, Herring Gulls were observed in most parts of the survey area. On 29 February, when most birds were present, concentrations were seen in the southwestern and northwestern areas, and moderate numbers in the coastal parts (Fig. 11a).

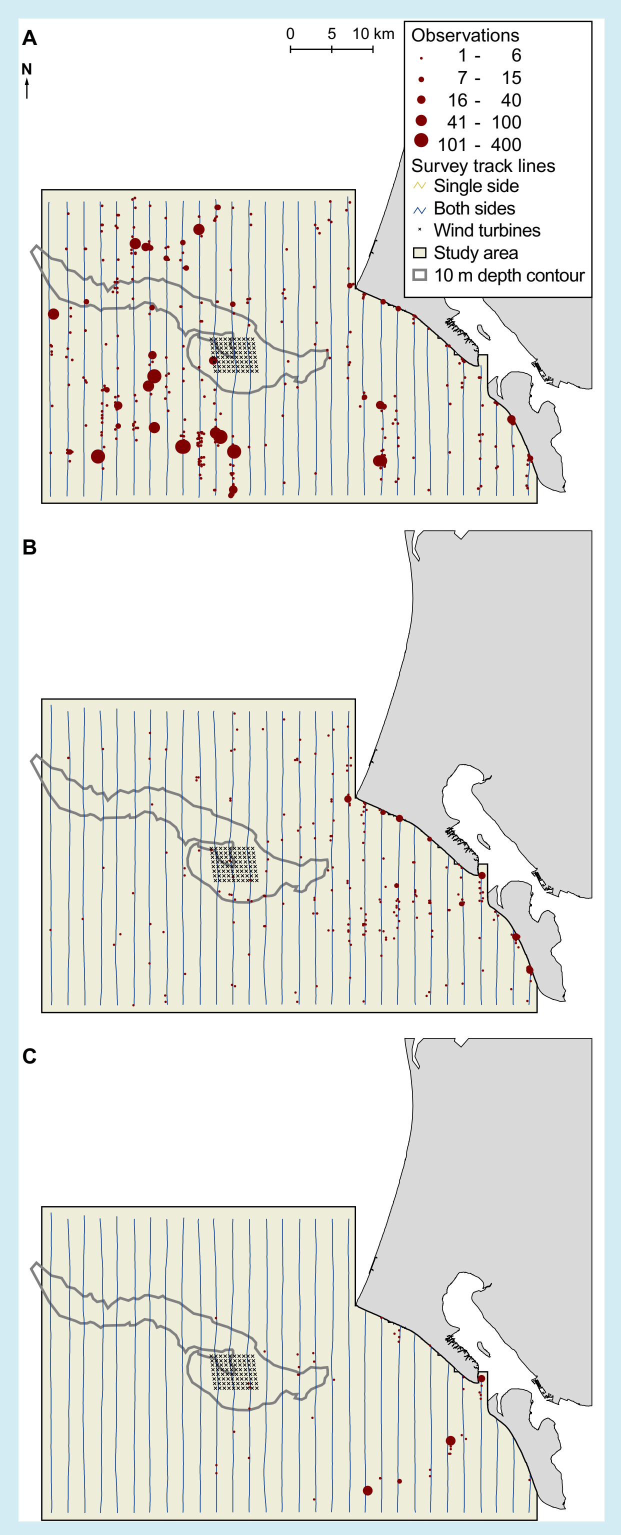

Figure 11. Distribution map of Herring Gull observations in the study area on A) 29 February 2004, B) 26 March 2004 and C) 10 May 2004. Turbine positions are shown. Thin blue lines identify track lines flown with coverage on both sides of the aircraft, yellow lines those with observations from only one side of the aircraft.

This distribution was partly influenced by high fishing vessel activity in the southwestern area

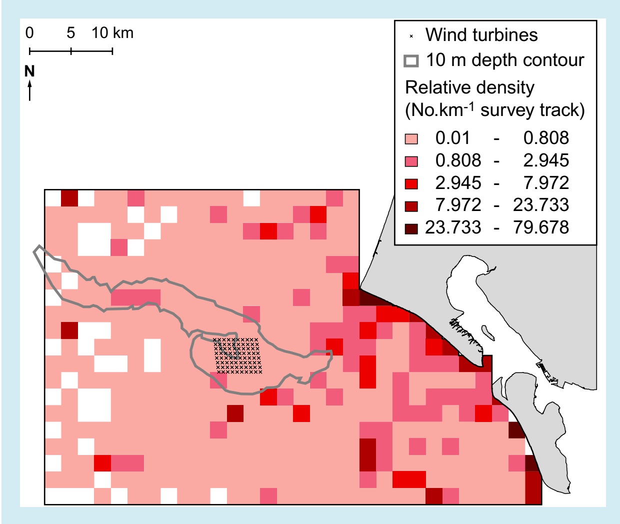

Figure 12. Cumulative distribution map of Herring Gull observations in the study area, based on 25 aerial surveys between August 1999 and December 2003. Data are expressed as relative density measured as observations per kilometre of flown transect coverage for each survey in each 2 x 2 km grid square

of the study area. On 26 March the 566 observed birds were recorded in the eastern parts of the survey area, most of which very close to the coast (Fig. 11b). On 10 May most of the birds were recorded in the tidal outlet from Ho Bugt and the Esbjerg area (Fig. 11c).

Offshore gatherings of Herring Gulls were mainly caused by active fishing vessels, which was the case on 29 February. The distribution found in March and May 2004 fitted the general distribution pattern of the previous 25 surveys, whereas on 29 February Herring Gulls were found in more offshore areas than usually observed (Fig. 12).

3.1.6 Little Gull *Larus minutus*

A total of 1,304 Little Gulls has been recorded during the 28 surveys. Of these 131 were observed during three surveys in the winter and spring of 2004 (Table 2 and Appendix I).

In this part of the world Little Gull winter in offshore areas, where they feed on zooplankton. The birds therefore show a very variable distribution pattern, governed by local fronts that bring prey to the sea surface. In 2004, as in previous years, most Little Gulls were seen in the western and central parts of the wind farm (Figs. 13a-b). The distribution pattern observed in 2004 fitted the

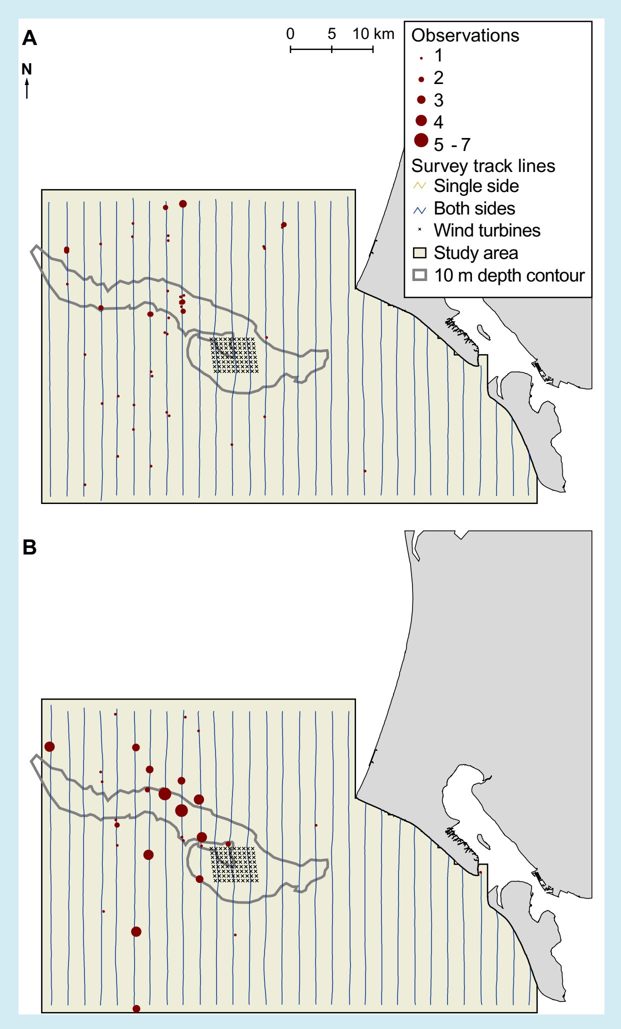

Figure 13. Distribution map of Little Gull observations in the study area on A) 29 February 2004 and B) 26 March 2004. Turbine positions are shown. Thin blue lines identify track lines flown with coverage on both sides of the aircraft, yellow lines those with observations from only one side of the aircraft.

overall distribution pattern found during the 25 surveys conducted up till 2004 (Fig. 14).

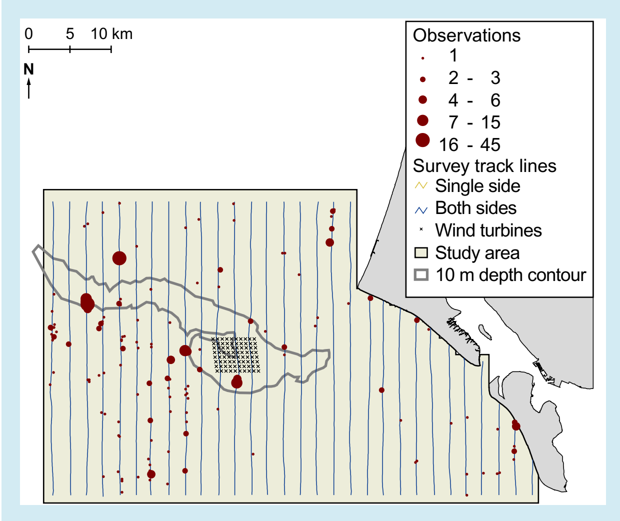

Figure 15. Distribution map of Arctic/Common Tern observations in the study area, 10 May 2004. Turbine positions are shown. Thin blue lines identify track lines flown with coverage on both sides of the aircraft, yellow lines those with observations from only one side of the aircraft.

3.1.7 Arctic/Common Tern *Sterna paradisaea/hirundo*

A total of 3,208 Arctic/Common Terns has been recorded during the 28 surveys. Of these 344 were observed during a survey conducted on 10 May 2004, while none were observed during two earlier surveys in winter and spring of 2004 (Table 2 and Appendix I).

In 2004 these terns were primarily observed in the vicinity of the sand bar at Horns Rev and in a restricted area of the southwestern part of the survey area (Fig. 15). This distribution pattern fitted the general distribution pattern for previous surveys (Fig. 16).

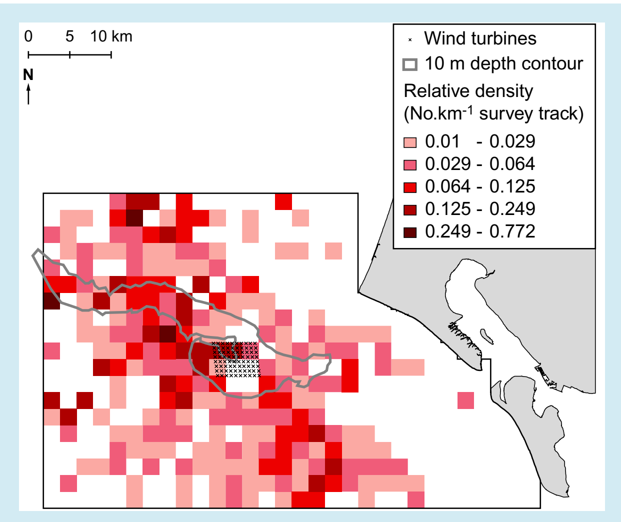

Figure 14. Cumulative distribution map of Little Gull observations in the study area, based on 25 aerial surveys between August 1999 and December 2003. Data are expressed as relative density measured as observations per kilometre of flown transect coverage for each survey in each 2 x 2 km grid square.

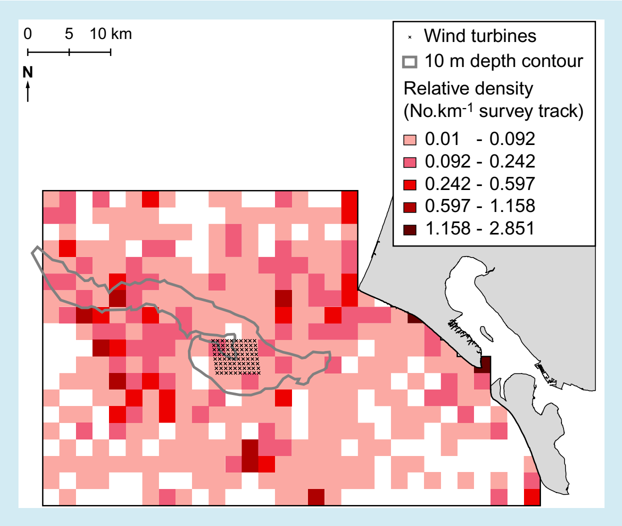

Figure 16. Cumulative distribution map of Arctic/Common Tern observations in the study area, based on 25 aerial surveys between August 1999 and December 2003. Data are expressed as relative density measured as observations per kilometre of flown transect coverage for each survey in each 2 x 2 km grid square.

3.1.8 Guillemot *Uria aalge*/ Razorbill *Alca torda*

A total of 1,824 Guillemots/Razorbills was recorded during the 28 surveys. Of these 223 were recorded in 2004 (Table 2 and Appendix I).

These alcid species mainly feed on pelagic fish. This means that they distribute according to concentrations of suitable prey, which in turn is determined by hydrographic features of the sea. Therefore large variations in numbers as well as distributions have been observed between surveys. Generally the study area does only cover the fringe of the wider distribution of Guillemots and Razorbills in the Danish part of the North

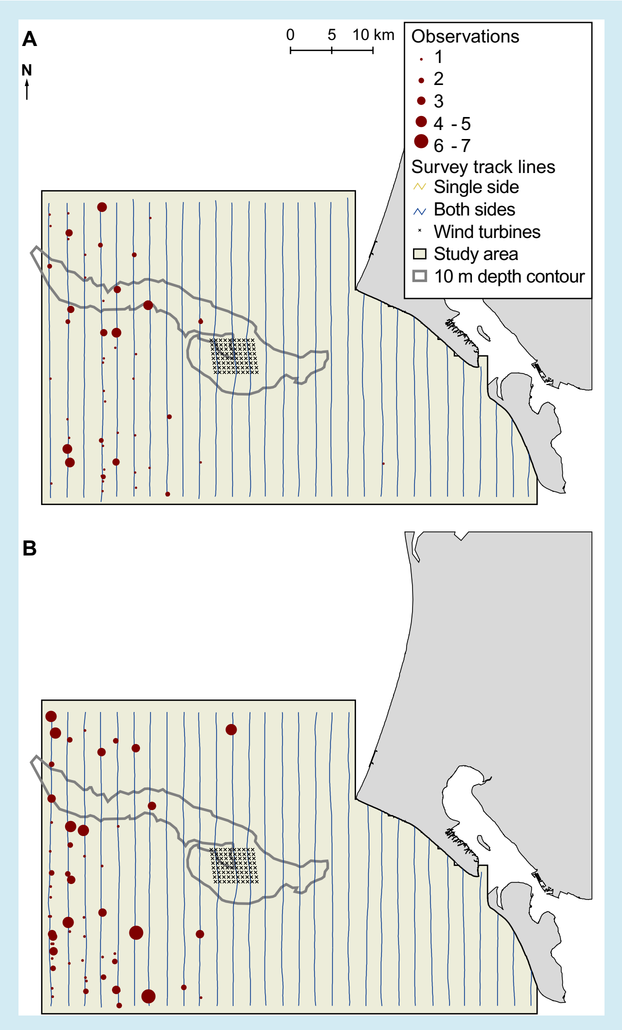

Figure 17. Distribution map of Guillemot/Razorbill observations in the study area on A) 29 February 2004 and B) 26 march 2004. Turbine positions are shown. Thin blue lines identify track lines flown with coverage on both sides of the aircraft, yellow lines those with observations from only one side of the aircraft.

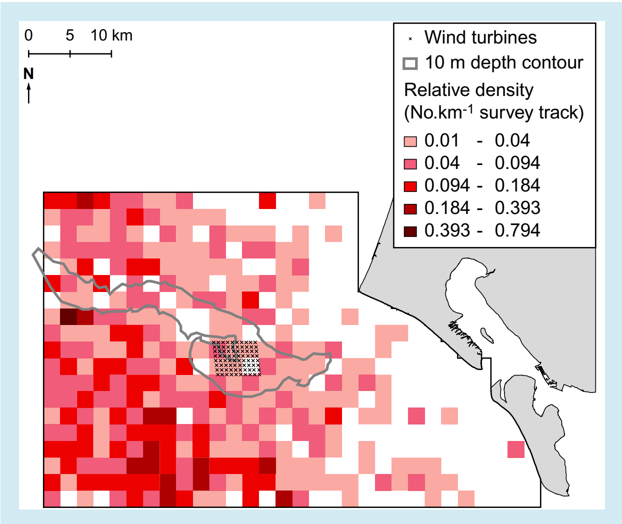

Figure 18. Cumulative distribution map of Guillemot/Razorbill observations in the study area, based on 25 aerial surveys between August 1999 and December 2003. Data are expressed as relative density measured as observations per kilometre of flown transect coverage for each survey in each 2 x 2 km grid square.

Sea. In 2004, the birds were mainly found in the southwestern and southern parts of the study area, with concentrations also seen in the northwestern parts of the area (Fig. 17a-b), which is similar to the overall distribution pattern of the previous 25 surveys (Fig. 18).

3.2 Utilisation of the Horns Rev wind farm area and surroundings by birds, pre- and post erection of wind turbines

A total of 28 surveys of birds has been carried out in the Horns Rev area between August 1999 and May 2004. The wind farm construction phase was initiated in September 2001, but no construction activities took place between October 2001 and March 2002. Thus a total of 16 aerial surveys were performed during the pre-construction period. The operation (post-construction) phase started in late autumn of 2002, and thus the first aerial survey data obtained during wind farm operation was in February 2003. A total of 9 surveys from 2003 and 2004, the operational phase of the wind farm, are available. In order to optimise comparison between the pre- and post-construction data set analyses below have been carried out on the basis of 7 pre-construction surveys and 6 post-construction surveys, all performed between February and May (see Table 1).

The importance of the wind farm area and of the adjacent 2 and 4 km zones to birds occurring at Horns Rev was assessed from the preference of the birds for these areas using Jacobs selectivity index. The index indicates whether a species occurred in a higher or lower proportion in an area than expected, assuming a geographically even distribution. Changes in this index from pre- and post-construction phase was used to describe changes in bird distributions in the vicinity of the wind turbines.

Most of the birds treated here appear in flocks (clusters), in some cases comprising several thousand individuals. A c^2-test requires independent observations. The observations are primarily clusters of birds, and thus the individual bird can not be regarded an independent sample. In Tables 3 and 4 the significance level of the c^2-test is indicated using individual numbers as sample size

Table 3. Percentage of birds (number of individuals) encountered in the wind farm area (MA) based on 7 pre-construction 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 from the pre-construction period (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 c^2-tests. Significance levels (S) are indicated 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	S	MA+2	D for MA+2	S	MA+4	D for MA+4	S	N
Diver sp.	1.54	-0.01	n.s.	4.97	0.02	n.s.	7.05	-0.16	**	1106
Gannet	0.00	-1.00	n.s.	0.00	-1.00	n.s.	1.35	-0.77	*	74
Eider	0.01	-0.99	***	0.01	-1.00	***	0.03	-0.99	***	9168
Common Scoter	0.71	-0.38	***	4.31	-0.06	***	15.17	0.26	***	71978
Herring Gull	0.05	-0.94	***	0.31	-0.88	***	1.12	-0.81	***	13027
Little Gull	0.00	-1.00	n.s.	0.00	-1.00	n.s.	5.41	-0.30	n.s.	37
Kittiwake	0.35	-0.63	n.s.	2.83	-0.27	n.s.	7.77	-0.11	n.s.	283
Arctic/Common Tern	1.02	-0.21	n.s.	2.39	-0.35	*	5.29	-0.31	***	586
Razorbill/Guillemot	1.37	-0.07	n.s.	4.11	-0.08	n.s.	5.02	-0.33	*	219
% of total survey coverage	1.56			4.79			9.52			

Table 4. Percentage of birds (number of individuals) encountered in the wind farm area (MA) based on 6 post-construction 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 from the post-construction period (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. Significance levels (S) are indicated 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	S	MA+2	D for MA+2	S	MA+4	D for MA+4	S	N
Diver sp.	0.00	-1.00	***	0.12	-0.95	***	0.99	-0.81	***	1611
Gannet	0.00	-1.00	*	0.00	-1.00	***	0.67	-0.87	***	450
Eider	0.00	-1.00	***	0.11	-0.96	***	0.27	-0.94	***	4730
Common Scoter	0.05	-0.93	***	1.29	-0.56	***	2.50	-0.58	***	578233
Herring Gull	0.22	-0.74	***	1.11	-0.61	***	2.45	-0.59	***	13298
Little Gull	0.24	-0.71	**	7.02	0.24	***	14.29	0.27	***	826
Kittiwake	0.00	-1.00	*	4.92	0.06	n.s.	5.46	-0.25	*	366
Arctic/Common Tern	0.00	-1.00	**	5.74	0.14	n.s.	11.83	0.16	*	575
Razorbill/Guillemot	0.00	-1.00	n.s.	0.97	-0.65	**	1.94	-0.66	***	309
% of total survey coverage	1.42			4.41			8.81			

anyway, because weighting an observation of a single Common Scoter equally with an observation of, say, 10,000 Common Scoters seems unwise. Parallel calculations, using clusters as the sample unit, are also presented (Tables 5 and 6).

3.2.1 Red- and Black-throated Diver *Gavia stellata/arctica*

During the pre-construction period divers were encountered in the wind farm area and the two

Table 5. Percentage of bird flocks (clusters) encountered in the wind farm area (MA) based on 7 pre-construction 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 clusters for each species/species group recorded throughout the surveys from the total study area from the pre-construction period (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. Significance levels (S) are indicated 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	S	MA+2	D for MA+2	S	MA+4	D for MA+4	S	N
Diver sp.	1.91	0.10	n.s.	5.18	0.04	n.s.	7.49	-0.13	n.s.	734
Gannet	0.00	-1.00	n.s.	0.00	-1.00	n.s.	2.63	-0.59	n.s.	38
Eider	0.29	-0.69	n.s.	0.29	-0.89	***	0.58	-0.89	***	345
Common Scoter	0.60	-0.45	**	3.54	-0.16	*	10.55	0.06	n.s.	1327
Herring Gull	0.33	-0.66	***	1.11	-0.63	***	4.19	-0.41	***	1529
Little Gull	0.00	-1.00	n.s.	0.00	-1.00	n.s.	10.53	0.06	n.s.	19
Kittiwake	0.71	-0.38	n.s.	3.55	-0.16	n.s.	9.93	0.02	n.s.	141
Arctic/Common Tern	1.53	-0.01	n.s.	3.45	-0.17	n.s.	8.43	-0.07	n.s.	261
Razorbill/Guillemot	1.22	-0.12	n.s.	3.66	-0.14	n.s.	4.88	-0.34	n.s.	164
% of total survey coverage	1.56			4.79			9.52			

Table 6. Percentage of bird flocks (clusters) encountered in the wind farm area (MA) based on 6 post-construction 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 clusters for each species/species group recorded throughout the surveys from the total study area from the post-construction period (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. Significance levels (S) are indicated 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	S	MA+2	D for MA+2	S	MA+4	D for MA+4	S	N
Diver sp.	0.00	-1.00	***	0.22	-0.91	***	1.73	-0.69	***	924
Gannet	0.00	-1.00	n.s.	0.00	-1.00	*	1.49	-0.73	**	134
Eider	0.00	-1.00	*	0.90	-0.67	**	1.80	-0.68	***	334
Common Scoter	0.39	-0.57	***	4.20	-0.03	n.s.	6.65	-0.15	***	4885
Herring Gull	1.55	0.04	n.s.	4.11	-0.04	n.s.	8.75	0.00	n.s.	1680
Little Gull	0.51	-0.48	n.s.	7.11	0.25	*	16.75	0.35	***	394
Kittiwake	0.00	-1.00	n.s.	2.70	-0.25	n.s.	4.05	-0.39	n.s.	148
Arctic/Common Tern	0.00	-1.00	n.s.	4.07	-0.04	n.s.	7.80	-0.07	n.s.	295
Razorbill/Guillemot	0.00	-1.00	n.s.	1.10	-0.61	*	2.20	-0.62	**	182
% of total survey coverage	1.42			4.41			8.81			

zones around the farm at frequencies that did not differ significantly from the average in the entire study area. 7.5% of the observed diver groups were recorded within 9.5% of the survey effort, giving rise to D-values of 0.10, 0.04 and –0.13 for the three zones (Table 5). For the post-construction period a marked avoidance of the wind farm area, including also the 2 and 4 km zones around it, was noticed, with D values of –1.00, -0.91 and –0.69 for the windfarm area, the 2 and 4 km zones, respectively (Table 6). These results indicate an increased avoidance of the wind farm area after the erection of the turbines. The overall number of divers in the study area during the post-construction phase was high, compared to pre-construction surveys (Fig. 4a-b, Table 2 and Appendix I).

3.2.2 Gannet *Sula bassana*

Gannets were observed in the wind farm area and the two zones around it in less than expected numbers, assuming a geographically even distribution, both during pre- and post-construction of the wind farm. There were no observations of Gannets in the wind farm area and the 2 km zone around it pre- or post-construction. D-values for the 4 km zone indicated a slightly increased avoidance of the wind farm after erection of the turbines, with values going from -0.77 to -0.87 for the four km zone (Tables 3 and 4). When testing on cluster size (on number of flocks rather than number of individuals) this avoidance was not significant for any of the distance zones in the pre-construction period, and only significant for the four km zone in the post-construction situation. Before drawing firm conclusions on the changes in selectivity for the wind farm and its surroundings more data is needed for this species.

3.2.3 Eider *Somateria mollissima*

Eider showed a clear avoidance of the area of the wind farm and the two zones around it, both pre- and post-construction and calculated on number of individuals as well as number of clusters. The D-values differed very little between the pre- and post-construction situation (Tables 3 to 6).

3.2.4 Common Scoter *Melanitta nigra*

The number of Common Scoters increased in the survey area from the 7 pre-construction surveys to the 6 post-construction surveys, with much higher numbers observed during the post-construction phase. Common Scoter were encountered within the wind farm area, as well as the 2 and 4 km zones around it, significantly less than expected, assuming a geographically even distribution, both prior to and following the erection of the wind turbines.

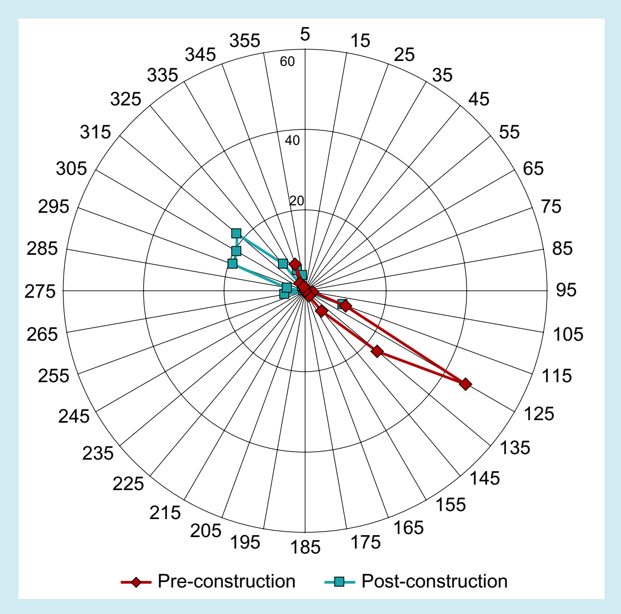

Figure 19. Pre- and post-construction comparison of Common Scoter numbers in 10° direction bins around the wind farm. Data were weighted by numbers and based on birds observed within 4 km of the wind turbines in the months of February till May of 2000 and 2001 (pre-construction and 2003 and 2004 (post-construction).

When calculating on the basis of clusters the degree of avoidance increased from the pre- to post-construction situation, going from a D value of -0.45 to -0.57 in the wind farm area itself. When including the two km zone around the wind farm an increased selectivity was seen, with D-values from -0.16 to -0.03. For the four km zone the avoidance increased from 0.06 to -0.15. When calculating on number of individuals the corresponding D value decreased from -0.38 to -0.93 in the wind farm area itself, from -0.06 to -0.56 when including the two km zone and from 0.26 to -0.58 when including the four km zone.

In earlier reports a seasonal pattern has been described, with birds being concentrated close to land from September through until January/February, but showing a gradual movement towards the southeastern parts of Horns Rev from March through April (Christensen et al. 2003, Petersen et al. 2004). In March and April 2003 this general movement was again observed. However, there was a general shift in distribution away from the area southeast of the wind farm to areas west and particularly north of the wind farm, into areas where very few Common Scoters had previously been observed (Petersen et al. 2004). During the surveys performed in 2004 this general pattern was maintained, with only few birds in the area southeast of the wind farm and with a concentration of birds around the northwestern corner of the wind farm. Thus a general shift in Common Scoter in the near vicinity of the wind farm was observed. During the pre-construction phase surveys from February to May most Common Scoters were observed southeast (120-140°) of the wind farm, with 46% of the birds recorded closer than 4 km to the wind farm in the interval between 120 and 130°. 90% of the birds were recorded between 100 and 160° off the wind farm (Fig. 19). During the comparable post-construction surveys a clear shift was noticed, with only 11% of the birds in the interval 100-160°, while 73% were recorded in the direction interval 280-330° (Figure 19).

At the same time Common Scoters did appear on Horns Rev, west of the wind farm, in the western parts of the study area during surveys in February and March 2004. Utilisation of these areas by Common Scoter has not been noticed earlier.

A comparison of the pre- and post-construction frequency distribution of Common Scoter at increasing distances from the wind turbines was made, based on data from 7 pre-construction and 6 post-construction surveys, all from the period between February and May. Based on cumulative percentages of bird numbers in each 500 m distance interval away from the wind turbines, a marked reduction in post-construction utilisation of areas at distances of 2-8 km was noticed. The immediate surroundings of the wind farm, out to approximately 2 km showed less pronounced changes (Fig. 20). When performing the equivalent analysis on birds observed within 4 km of the turbines the result showed that the distance interval between 0 and 500 m from any turbine was used by a slightly higher percentage of the birds during pre-construction as compared to the post-construction phase. In the increasing distance intervals from 500 m to 4 km a higher percentage of the birds were recorded during the post-construction phase than during the pre-construction phase (Fig. 21).

A direct disturbance effect out to a distance of 8 km from the turbines is regarded highly unlikely. An explanation for the above results (see Fig. 20) involves the patchiness of the habitat exploited by Common Scoter. The species is also highly gregarious, so birds tend to aggregate in local concentrations in response to rich feeding patches, and probably react as groups to changes in local

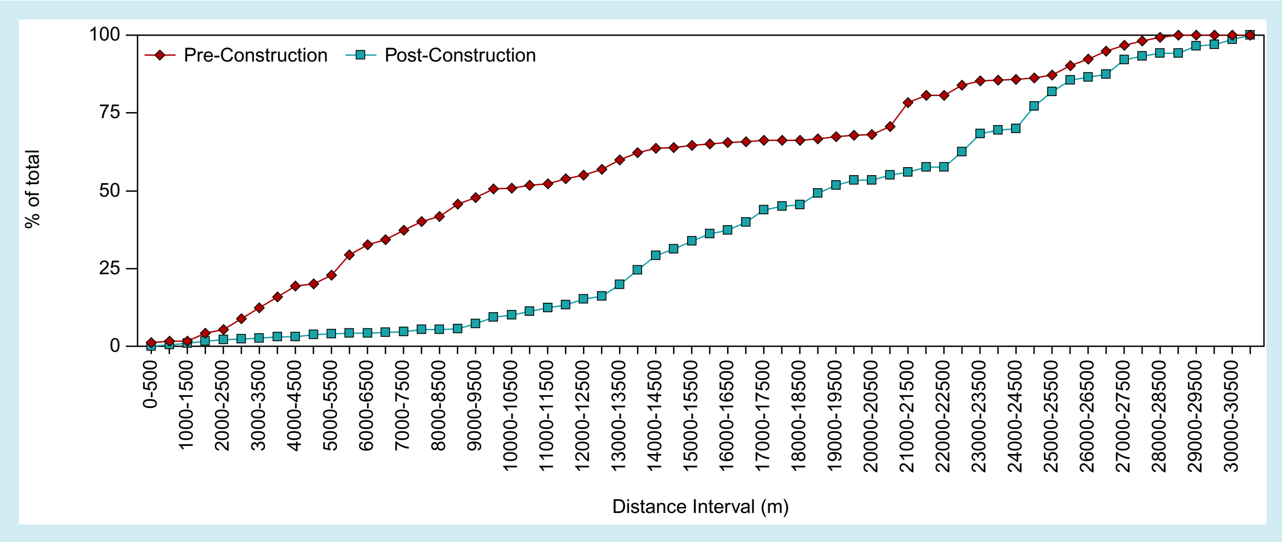

Figure 20. Cumulated frequency distribution of distance to nearest wind turbine in 500 m intervals from observations of Common Scoter, pre- and post-construction. Data were weighted by numbers and based on all birds observed within the study area in the months of February till May of 2000 and 2001 (pre-construction, red) and 2003 and 2004 (post-construction, blue).

foraging success. Since substantial distances may separate these patches, responses to declining feeding success (including, for example, increases in human disturbance) at one site may result in local abandonment of one area in favour of a distant feeding area. These feeding areas may be less suitable than the original ones because food intake rates are decreased as a result of increased bird densities and hence competition, deeper water or lower food quality (Nehls & Ketzenberg 2002). The difference between the curves representing pre- and post-construction distance intervals from the wind turbines at distances greater than 27 km is caused by the fact that the four additional transects situated close to Fanø, which were surveyed in 2003 and 2004, contribute observations in the distance classes between 27 to 32 km from the wind farm (Fig. 20). These four transects were not covered during the pre-construction surveys, and no other part of the study area was further away than 27 km during this period.

During observations of flight trajectories of birds around the Horns Rev wind farm in the spring of 2003 and 2004 Common Scoters were observed to avoid flying between the wind turbines (Christensen et al. 2004, Christensen & Hounisen 2004). When flying birds avoid the wind farm area, this will influence where birds settle to feet or rest.

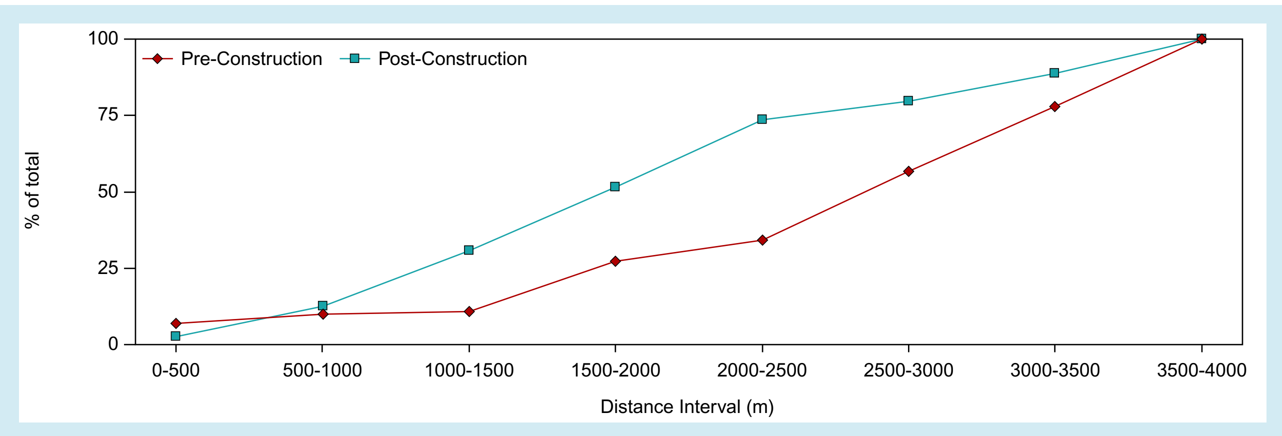

Figure 21. Cumulated frequency distribution of distance to nearest wind turbine in 500 m intervals from observations of Common Scoter, pre- and post-construction. Data were weighted by numbers and based on birds observed within 4 km of the wind turbines in the months of February till May of 2000 and 2001 (pre-construction, red) and 2003 and 2004 (post-construction, blue).

Thus the avoidance patterns shown by flying birds, are likely to contribute to the overall avoidance distance shown by the species when counted during aerial survey.

The significant post-construction changes in distribution of Common Scoter in the vicinity of the wind farm may be caused by several factors. The physical presence of the turbines is one major potential factor, but the increased boat traffic associated with the maintenance of the wind farm especially at enhanced levels immediately following construction could be another. However, an apparent general change in the distribution of Common Scoter across the study area, and particularly the increased use of the western and central parts of Horns Rev, indicates that other factors influence the observed changes. Such factors could be the distribution of food resources in the study area. This seems especially likely given that the area north and west of the turbines had not been seen to be exploited in pre-construction seasons.

3.2.5 Herring Gull *Larus argentatus*

Herring Gulls showed an increased preference for the wind farm area after erection of the turbines. Pre-construction D-values of -0.66, -0.63 and -0.41 for the 0, 2 and 4 km zones around the farm were found, with corresponding post-construction D-values of 0.04, -0.04 and 0.00 (Tables 5 and 6). When calculated on number of individuals the tendency for reduced avoidance of the wind farm area was also found (Tables 3 and 4).

Herring Gulls, like other gull species, are attracted to human activities at sea. The increased post-construction preference for the wind farm area may be caused by the presence of the wind turbines, but increased boat activity associated with the maintenance of the turbines could be an additional factor. The observed post-construction increased preference for the wind farm area by this species is consistent with similar analyses of the period of the construction phase (Christensen et al. 2003).

3.2.6 Little Gull *Larus minutus*

Little Gull showed a shift from avoidance to preference for the wind farm area. Due to the low number of records during the pre-construction period the avoidance of the wind farm area failed to reach levels that were statistically significant. The result from post-construction surveys showed a significant preference for the 2 and 4 km zones around the wind farm. D-values based on clusters for the windfarm area increased from -1.00 to 0.48, and similarly increased from -1.00 to 0.25 when including the 2 km zone and from 0.06 to 0.35 when including the 4 km zone. A similar tendency was observed when calculated on the basis of individuals (Tables 3 to 6).

3.2.7 Arctic/Common Tern *Sterna paradisaea/hirundo*

Arctic/Common Tern showed a general avoidance of the wind farm area, both pre- and post-construction. Due to a low number of clusters during the post-construction period the distribution did not differ from the expected, assuming a geographically even distribution of these terns (Tables 3 to 6).

3.2.8 Guillemot *Uria aalge* / Razorbill *Alca torda*

Guillemots/Razorbills showed an increased avoidance of the wind farm area and the adjacent zones, with pre-construction D-values, based on clusters, of -0.12, -0.14 and -0.34 for the three distance zones, as compared to post-construction D-values of -1.00, -0.61 and -0.62 for the three zones (Tables 5 and 6). Similar increased post-construction avoidance was found when calculating on the basis of individual birds (Tables 3 and 4).

4 Discussion and conclusions

4.1 Existing knowledge on habitat loss or gain caused by wind turbines.

Until now the only study dealing with waterfowl/seabird habitat loss or gain resulting from the construction of marine wind farms was a study concerning wintering Eiders at Tunø Knob, Denmark, where impacts out to a distance of 100-300 m were found. However, that study concentrated upon only one less vulnerable species, Eider, considered relatively robust to disturbance, although they still show reactions to human and other activity (e.g. Christensen & Noer 2001). Furthermore that study involved an inshore wind farm consisting of only 10 small turbines in two rows (Guillemette et al. 1999).

At Horns Rev Divers, Common Scoter and Guillemot/Razorbill showed an increased avoidance of the wind farm area after the erection of the wind turbines, including also zones of 2 and 4 km around the wind farm. In contrast Herring Gull, Little Gull and Arctic/Common Tern showed an increased preference for the wind farm area, while Great Black-backed Gull, Little Gull and Arctic/Common Tern showed a general shift from pre-construction avoidance to post-construction preference for the wind farm area (Petersen et al. 2004). At the Nysted wind farm site south of Lolland initial comparisons of pre- and post-construction distribution of Long-tailed Duck and Eider indicated a reduced preference for the wind farm site and its close vicinity during the post-construction phase, while Herring Gull showed increased preference for the windfarm (Kahlert et al. 2004, Petersen 2004b).

4.2 Change in distribution of Common Scoter

Gradual changes in the general distribution of Common Scoter within the study area have previously been described (Petersen et al. 2004). The data collected in winter and spring of 2004 confirm a continued change in distribution. The coastal areas west of Skallingen and Fanø still comprised the core area for the species, but shallow offshore areas that were not previously utilised by Common Scoter held considerable numbers in winter and spring of 2004. This was true for Horns Rev, west of the wind farm as well as slightly deeper areas in the northern parts of the study area. Initially this change in distribution was believed to be of a seasonal character, with birds starting in coastal areas in autumn and early winter, gradually moving further offshore during February to April. It was speculated that this change could be caused by local temporal abundance of favoured food resources, maybe the egg of Sandeel.

Results from aerial surveys in December 2003 till May 2004 indicate that this seasonal change was not apparent during this winter and spring, as birds are found in the shallow offshore areas throughout the winter season. The mechanism behind this change is unknown. A sudden availability of new food resources in these areas is the obvious explanation, most likely mollusc species, but the precise character of this is not clear.

In general the gross changes in Common Scoter distribution are not believed to be caused by the presence of the wind farm. Nevertheless there are strong indications that common scoter did respond to the presence of the wind turbines and probably also to the human activities associated with the wind farm. A reduced post-construction preference for the wind farm area gives an indication. Secondly, the fact that the birds to a great extent deserted the area southeast of the wind farm after the erection of the turbines, and a new concentration appeared around the northwestern corner of the wind farm, supports the conclusion.

4.3 Conclusions

During three aerial surveys of birds in the Horns Rev study area Common Scoter and Herring Gull were the most numerous species.

Divers, Common Scoter and Guillemot/Razorbill showed an increased avoidance of the wind farm area after erection of the wind turbines, including also zones of 2 and 4 km around the wind farm. In contrast Herring Gull, Little Gull and Arctic/Common Tern showed an increased preference for the wind farm area.

Changes in general distributions of Common Scoter as compared to previous years were observed. The species was found in shallow offshore parts of the study area. This general shift in distribution was not believed to be caused by the presence of the wind turbines. There are, on the other hand, clear indications that Common Scoter responded to the presence of the wind farm by generally avoiding the area. An area southeast of the wind farm, previously used by Common Scoter, particularly in February through April, was used less by this species. Simultaneously, areas west and north of the wind farm with previously very few Common Scoters supported greater numbers of the species in 2003 and 2004.

The reason for the change in avoidance of the wind farm area for divers, Common Scoter and Guillemot/Razorbill is unknown. Disturbance effects from the wind turbines are one possible reason. Disturbance from increased human activity associated with maintenance of the wind turbines could be another. However, changes in the distribution of food resources in the study area could potentially play a role too.

The change in gull and tern preference for the wind farm area is likely to have been caused by the presence of the wind turbines and the associated boat activity in the area.

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Appendix I

Species	Total	1999			2000							2001					2002				2003						2004		
		0308	0309	1211	1702	2102	1903	2704	2108	0610	2212	0902	2003	2104	2208	2609	0701	1203	0904	0808	1302	1603	2304	0509	0412	3012	2902	2603	1005
Diver sp.	2487	23	5	56	314	106	129	113	6	23	38	187	149	87	2	3	54	125	138	3	168	56	284	2	16	80	225	74	21
Red-throated Diver	832			15			12					9										198	196	1	18	10	63	293	17
Black-throated Diver	19																	1			2		3			2	8	3	
Big Diver sp.	2					1															1								
Red-necked Grebe	9								1													5		2		1			
Crested Grebe	1													1															
Grebe sp.	6																4					1							1
Fulmar	122	3	16						1	38			1			1	3								1	15	16	4	23
Gannet	1075	25	266	2			6	7	33	42			1	60	63	10		1	1	1		3	39	105	2		1	15	392
Cormorant	248	3	2	1				2	80			1	20	2	25	32				6		1		72					1
Grey Heron	1																					1							
Anseridae	31																						31						
Whooper Swan	13										13																		
Greylag Goose	45																		44			1							
Pink-footed Goose	25													25															
Brent Goose	24							9								15													
Canada Goose	2								2																				
Shelduck	1																		1										
Mallard	47				2		2	4														6	33						
Teal	22													4								18							
Wigeon	37															31						6							
Pochard	1									1																			
Golden-eye	9											1									6	2							
Long-tailed Duck	20											5	1									6	6				1	1	
Eider	19057		5	458	2114	181	476	97	37	42	2062	5438	763	99	2	3	823	448	75	3	3013	720	84	32	818	351	566	292	55
Common Scoter	814715	68	119	10231	7190	3861	10459	9230	283	2208	8436	11041	13295	16902	319	4661	30483	10877	3802	992	75992	381042	25929	3397	51965	36663	42260	42312	10698
Velvet Scoter	1277			28				16		1	19	58	148	343	2	2	4	5	5		28	245	75	10	13	42	139	30	64
Red-breasted Merganser	23				3		1						2	2		12						1	1						1
Oystercatcher	304			1					39					2						16	4	211			31				
Lapwing	1					1																							
Grey Plover	17	5								8												4							
Golden Plover	57						2				55																		

Species	Total	1999			2000							2001					2002				2003						2004		
		0308	0309	1211	1702	2102	1903	2704	2108	0610	2212	0902	2003	2104	2208	2609	0701	1203	0904	0808	1302	1603	2304	0509	0412	3012	2902	2603	1005
Bar-tailed Godwit	16								14											2									
Redshank	2								1											1									
Turnstone	2							2																					
Snipe	4																					4							
Sanderling	68			19				9							10						30								
Dunlin	50			20																30									
Small Wader sp.	250	16																						3					231
Great Skua	4	1	1	1				1																					
Arctic Skua	43		20	1											15	1				1				5					
Skua sp.	9							1	5																				3
Common Gull	513	110		38		13	3	27	7	6	7	5	34	11	6	10	3	6	2	11	7	152	4	44	2	3		2	
Herring Gull	37838	254	699	236	4025	3327	1857	112	775	191	230	672	1169	1865	820	856	917	1553	804	1989	4151	2695	2029	1611	319	259	3644	566	213
Lesser Black-backed Gull	110	9	1				3	1	39	3				1	29	6			2	13			1					1	1
Great Black-backed Gull	998	19	129	21	4	14	31	11	55	24	2	5	3	56	96	59	27	16	3	141		18	19	45	6	7	14	11	162
Black-headed Gull	638	8	10		1	1	14		164	1		3		253	69	13		1		26	1	53	5	7	7			1	
Little Gull	1304			8			5				5	5	26	1		1	76	82	127	15	6	372	317		104	23	60	71	
Kittiwake	3356	186	324	520	18	41	70	2	579	35	17	30	14	108	183	251	142	303		70	12	3	1	4	37	56	50	280	20
Gull sp.	2990		13		2	4	1		16	30	3			670		5						12	162	33	177	1290	131	269	172
Common Tern	9			5					2																				2
Arctic Tern	1758	692	100				1	545												69			10						341
Arctic/Common Tern	1450								175					40	843	4			1	16			219	143	6				3
Sandwich Tern	718	48	12				1	12	67					231	11	37		4	2	241		1	3	14					34
Tern sp.	347								47				3	24	3				2				172	46	3				47
Little Auk	4									3								1											
Razorbill	53			9		3		2			1			1			5				5							27	
Razorbill/Guillemot	1690		59	372	59	67	18	3	48	162	35	32	14	8	16	36	104	59	3	20	77			100	189	40	89	79	1
Guillemot	81		4	3	3	4	2		12	18			2	1	1						3	1						27	
Puffin	1									1																			

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Publications:
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Bird numbers and distributions in the Horns Rev offshore wind farm area

National Environmental Research Institute
Ministry of the Environment