National Environmental Research Institute
Department of Coastal Zone Ecology

Base-line investigations of birds in relation to an offshore wind farm at Horns Rev, and results from the year of construction

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Commissioned by Tech-wise A/S 2002

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Synopsis

The present report presents the base-line investigations of birds conducted during August 1999-April 2001 in relation to construction of an offshore wind farm at Horns Rev, 14 km west-south-west of Blåvandshuk, in the Danish North Sea. The report also presents data collected during the period September 2001-April 2002, when construction of the wind farm was in progress. The wind farm will consist of 80 wind turbines, each of 2 MW, and cover an area of c. 20 km^2.

The eastern part of the North Sea constitutes major staging and wintering grounds for huge numbers of water- and seabirds. The area is also known to be an important site for migrating birds, which especially in autumn pass in large numbers. As Denmark has obligations to protect and maintain the bird populations it was laid down in the approval for erection of the wind farm that the impact on birds should be investigated. According to the 1% criteria defined in the Ramsar Convention, the eastern part of the North Sea including the wind farm area is of international importance to divers, Common Tern, and Sandwich Tern. A number of other species, e.g. Common Eider, Common Scoter, Guillemot and Razorbill, are present in the area in significant numbers as well, though these numbers do not make up 1% of the populations.

Detailed distributions of birds in the area around and at Horns Rev were virtually unknown until initiation of this project. Previous bird counts in this area have been carried out almost exclusively from the coast and detailed knowledge exists concerning the numbers of roosting at and migrating birds from the westernmost point of Jutland, Blåvandshuk. To describe the numbers and distributions of birds staging and wintering in the Horns Rev area, bird investigations were initiated in 1999 by using standardised transect counts from aircraft. Up to April 2002, 18 aerial counts have been carried out over an area of c. 1,700 km^2 centred on the Horns Rev project area.

The counts have shown that the two species feeding on the bottom fauna (Eider and Common Scoter) were mainly found in the coastal parts of the study area (within the 6 m depth contour), although Common Scoters showed a consistent appearance in deeper parts in the area southeast of the wind farm during spring. In general, the offshore part of the study area was dominated by fish-eating species, divers, Gannet, alcids and terns, and with large numbers of gulls often recorded around fishing vessels. The distribution of fish-eating species was generally variable, probably because distributions and densities of fish varied in both space and time.

Assuming a free distribution of birds in the surveyed area, c. 1.6% of the total numbers recorded would be predicted to be present in the wind farm area during the base-line years. Only divers, Arctic/Common Terns and alcids converged to this value, though they did not exceed it significantly. All other species occurred in lower than expected numbers. Considering the wind farm area +2 km and +4 km zones, all species except Common Scoter were generally present in the projected wind farm area in lower than expected numbers. Common Scoter appeared in higher than expected numbers in the area between 2 km and 4 km from the wind farm area. These results lead to the conclusion that the wind farm area is of very limited significance for staging and wintering water- and seabirds.

The probability to detect potential long term effects of the operating wind farm was assessed from two-sample ?^{2}-tests comparing the numbers of birds recorded during the base-line years to varying changes. In this way the magnitude of decrease and increase in bird numbers within the wind farm area and wind farm area +2 km and +4 km zones that would be detected with a statistical certainty of 95% was estimated. Only six species were recorded in numbers large enough to allow testing.

Consistent significant avoidance reactions from the area within and close to the wind farm were not demonstrated for any species during the period of construction, and the low numbers of birds recorded within and close to the wind farm area made these analyses tentative for several species. Consequently, the present study did not document with statistical certainty that avoidance of the wind farm area was affected by construction activities. However, as the number of divers and alcids was consistently higher during the base-line years than during the period of construction, and all observations were made more than 2.5 km away from actual construction activities during this period, it may be possible that the distribution of divers and alcids was affected by construction activities.

The present analyses showed that Herring Gull was significantly attracted to the wind farm and adjacent +2 km and +4 km zones during the period of construction. The gulls were probably attracted by the activity of ships in the area and by the possibility to sit on the turbine foundations erected in the area.

Dansk Resume

Denne rapport præsenterer base-line undersøgelserne af fugle i perioden august 1999-april 2001 i relation til etablering af den havbaserede vindmøllepark på Horns Rev, 14 km sydvest for Blåvandshuk, i den Danske del af Nordsøen. Rapporten præsenterer også data indsamlet i perioden september 2001-april 2002 hvor anlægsarbejdet med mølleparken var i gang. Parken består af 80 vindmøller, hver på 2 MW, og dækker et område på 20 km^2.

Den østlige del af Nordsøen udgør et væsentligt raste- og overvintringsområde for et stort antal vandfugle. Området er også kendt som et vigtigt træksted for et stort antal fugle, specielt om efteråret. Disse forekomster, som for flere nordvest Palearktiske arter udgør mere end halvdelen af yngle- eller flywaybestandene, er af international betydning for bevarelse af vandfuglebestandene. I konsekvens af disse forekomster har Danmark forpligtigelse til, gennem både Ramsar og Bonn konventionerne og EF Fugle beskyttelses direktivet, at beskytte og bevare disse bestande. På den baggrund er det i principgodkendelsen af vindmølleparken anført, at der gennemføres undersøgelser af offshore vindmøllers påvirkning af vandfugle.

I henhold til Ramsar konventionen er et område af international betydning for en fugleart hvis 1% eller mere af bestanden forekommer på et givent tidspunkt af året. Ifølge dette kriterium, er området af international betydning for lommer, Fjordterne og Splitterne. Andre arter, f.eks. Edderfugl, Sortand, Lomvie og Alk, forekommer i betydelige antal, men udgør mindre end 1% af bestandene.

Et detaljeret kendskab til fordelingen af fugle i området omkring og på selve Horns Rev var meget mangelfuldt inden nærværende undersøgelse. De hidtidige registreringer af fugle i dette område er næsten udelukkende foretaget fra land og der eksisterer et detaljeret kendskab til antallet af fugle der raster og trækker forbi Jyllands vestligste punkt, Blåvandshuk. For at beskrive antal og fordeling af rastende og overvintrende fugle i Horns Rev området blev der i 1999 påbegyndt standardiserede transekttællinger fra fly. Indtil april 2002 er der gennemført 18 flytællinger, som har dækket et område på 1.700 km^2 omkring det udpegede mølleområde på Horns Rev.

Tællingerne viste, at arter der fouragerer på bundlevende dyr (Edderfugl og Sortand) hovedsageligt forekom kystnært (inden for 6 meter dybdekurven), selv om Sortand også blev registreret på større dybder i området sydøst for mølleparken i forårsperioden. Generelt var de arter der blev observeret i væsentlige antal langt fra kysten fiskeædende lommer, Suler, alkefugle og terner, samt et stort antal måger, som ofte var koncentreret omkring fiskerbåde. Fordelingen af fiskeædende arter var meget variabel, sandsynligvis som følge af en rumlig og tidsmæssig variation i fordelingen og tætheden af fisk.

Under antagelse af en ensartet fordeling af fugle i det optalte område, forventedes ca. 1,6% af det totale antal observerede fugle at forekomme i selve det projekterede mølleområde. Kun for lommer, Hav- og Fjordterne og alkefugle nærmede andelen i mølleområdet sig denne værdi, dog uden at overskride den signifikant. Alle øvrige arter forekom i mølleområdet i antal der lå under det forventede. I mølleområdet udvidet med hhv. en 2 km og 4 km zone forekom kun Sortand i antal højere end forventet i området mellem 2 km og 4 km fra mølleparken. På baggrund heraf kan det konkluderes, at mølleområdet er af begrænset betydning for rastende vandfugle.

Sandsynligheden for at dokumentere potentielle langtidseffekter af mølleparken blev vurderet ud fra ?^{2}-test, hvor det observerede antal fugle i base-line årene blev sammenlignet med hypotetiske ændringer. På denne måde estimeredes størrelsen af den reduktion eller stigning i fuglenes antal der efter mølleparkens etablering ville kunne detekteres med en statistisk sikkerhed på 95%. Kun seks arter forekom i så store antal at de kunne indgå i denne beregning.

Der blev ikke konsistent påvist signifikante reduktioner i antallet af fugle i og nær mølleparken i anlægsperioden, og det lave antal fugle registreret i disse områder gjorde testen usikker for flere arter. På baggrund af denne undersøgelse kunne det derfor ikke påvises med statistisk sikkerhed at fuglene undgik mølleområdet som følge af anlægsaktiviteter. Det kan dog ikke udelukkes, at fordelingen af lommer og alkefugle var påvirket af anlægsaktiviteter, da antallet af disse arter generelt var højere i base-line perioden end i anlægsperioden, og at ingen observationer i anlægsperioden blev gjort tættere end 2,5 km fra nærmeste anlægsaktivitet.

Analysen viste med statistisk sikkerhed at Sølvmåge blev tiltrukket til mølleømrådet og til mølleområdet +2 km og +4 km zonerne i anlægsperioden. Mågerne er sandsynligvis tiltrukket af skibene i området samt af muligheden for at sidde på de møllefundamenter der blev rejst i området.

1 Introduction

1.1 Background

In February 1998 it was decided to erect an offshore wind farm with a capacity of up to 150 MW at Horns Rev. The wind farm should be established as 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.

In order to assess the potential impacts from the offshore wind farm at Horns Rev on bird numbers and distribution, Tech-wise A/S (former Elsamproject A/S) contracted the National Environmental Research Institute (NERI), Department of Coastal Zone Ecology, to take responsibility for such bird studies.

The southeastern part of the North Sea, including Horns Rev, constitutes major staging and wintering grounds for huge numbers of water- and seabirds (Laursen et al. 1997). In addition, Blåvandshuk, situated at the coast east of the wind farm area, act as an important site for migrating waterfowl as well as for migratory terrestrial bird species, especially during autumn (Jacobsen in prep.).

According to the Ramsar Convention, an area is classified as being of international importance to a species if 1% of its flyway population is present regularly at some time of the annual cycle (Prater 1981). Based on this 1%-criterion the area around Horns Rev has been classified as being of international importance to staging and wintering Red- and Black-throated Diver *Gavia stellata/arctica* and Red-necked Grebe *Podiceps grisegena* (Laursen et al. 1997). Of species present on the Danish Red-list, which includes breeding species that are uncommon or immediately threatened (Stoltze & Pihl 1998a), Little Gull *Larus minutus*, Guillemot *Uria aalge* and Razorbill *Alca torda* occur at Horns Rev. Of breeding and non-breeding species that are potentially threatened, according to the Danish Yellow-list (Stoltze & Pihl 1998b), Red-throated Diver, Eider *Somateria mollissima*, Common Scoter *Melanitta nigra*, Guillemot and Razorbill occur at Horns rev.

1.2 The Horns Rev project

The wind farm area is located in the southeastern part of the Horns Rev, c. 14 km west-south-west of Blåvandshuk 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.

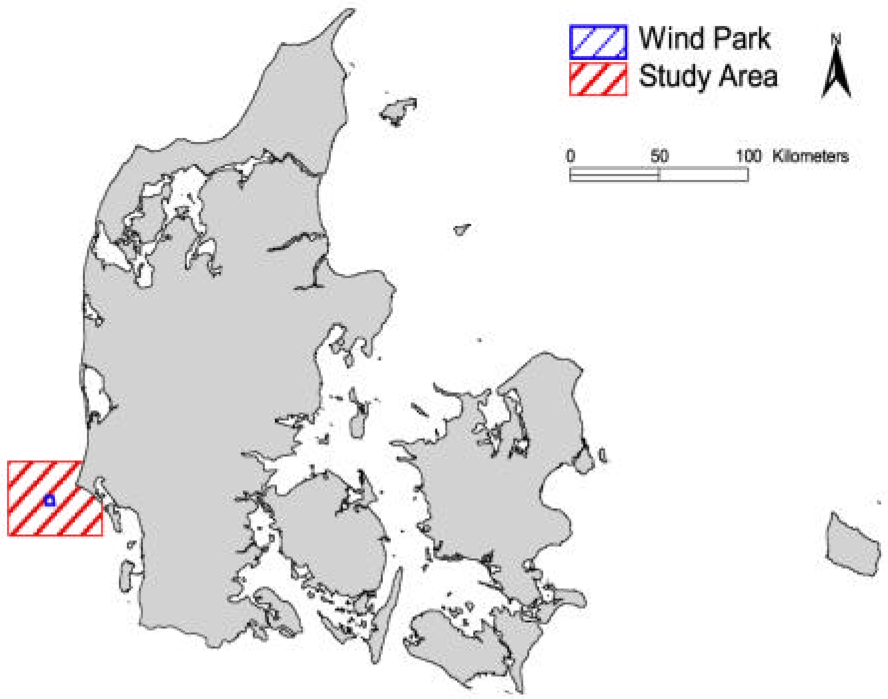


Fig. 1: The study area, with indication of the wind park position.

Construction activities at Horns Rev started in September 2001. The first activities were related to ramming poles for the transformer station September-October 2001 and to various tests of equipment and positioning. Establishment of turbine foundations started in March 2002, and erection of turbines in April. Installation of the transformer station was performed in April 2002. The wind farm started to operate in the 4th quarter of 2002.

The wind farm has a capacity of 160 MW and comprises 80 turbines. The height of the turbine tower is 70 m and the rotor diameter 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 the turbines. The turbines are equipped with white strobe light about 10 m above sea level for ship traffic and with red strobe light at the top of the turbines for air traffic. The wind farm covers an area of c. 20 km².

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 has been bedded down c. 1 m into the substrate.

A transformer station of 20 x 28 m on three poles and 14 m above sea level is located 560 m north of the north-easternmost wind turbine.

Service and maintenance of the turbines are estimated to constitute 150 days per year and will be carried out partly from ship and partly from helicopter.

The Horns Rev wind farm is situated outside special protected areas in relation to bird conservation. However, the first 5 km of the cable from land passes through special protected areas. 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 concerning nature conservation and public access. For a more detailed description of the different protective measures and affected areas, see Noer et al. (2000).

1.3 Conditions of approval

In the approval for offshore wind farms given by the Energy Agency the following specifications for the programme to be designed for monitoring impacts were laid down:

- I/S Elsam is required to develop a programme for monitoring environmental impacts during the construction and the following initial phase of operation.

- The programme should cover:
  1) The area of construction, i.e. the area of the wind park and cables with land connections,
  2) The so-called area of impact, i.e. the area where impacts during construction and operation are expected,
  3) The area of reference, i.e. one or more otherwise comparable areas, without impacts from wind turbines on the environment.

- In the conditions it is emphasised several times that particular attention must be drawn to waterbirds and migrating birds and, through specific studies, provide impact assessment analyses for these species.

- I/S Elsam is required to develop a dynamic monitoring programme, capable of demonstrating positive and negative impacts on the environment resulting from the construction and operation of the wind farm. It is considered of decisive importance that the programmes documenting the base-line conditions in the area are sufficiently comprehensive to rule out the possibility that so-called ‘natural variability’ will not subsequently mask the impacts the programme is designed to document.

1.4 Environmental impact assessment studies

The set up of predictive assessments of impacts on birds from the wind farm at Horns Rev has been severely impeded by two major disadvantages. Firstly, due to the remoteness and harsh environment with difficult operating conditions detailed knowledge of the numbers and ecology of birds exploiting the offshore environment is very limited compared to the existing knowledge of species exploiting inshore or terrestrial environments. Secondly, even if the general knowledge relating to the impacts of wind farms on birds has greatly improved in recent years, the bird species occurring in the offshore environments and their behaviour have not been included in these studies.

Hence, the numbers, precise distributions and ecology of seabirds, and their reactions to offshore wind farms are at present very poorly known.

Acknowledging the specifications laid down by the Energy Agency in the conditions for approval of offshore wind farm constructions, NERI has developed a monitoring programme, which includes:

1) description of the natural variation in bird numbers and distribution in the Horns Rev area before establishment of the wind farm (base-line investigations),
2) monitoring of potential impacts on birds during the construction and the operational phase of the wind farm.

1.4.1 Potential impacts of offshore wind farms on birds

Based on existing experience the potential impacts on birds from offshore wind turbines are predicted to be:

- Disturbance/attraction effects.
- Collision risk.
- Physical change of the habitat where the turbines are erected.

Impacts related to disturbance effects from the wind farm may be expected on some bird species during both construction and operation. Disturbance effects related to the period of construction may have marked impacts on bird numbers and distributions close to the construction areas. However, the construction activities will be of temporary duration (approximately one year) and hence predicted to be of low importance considering the expected lifetime of the wind farm. It is therefore expected that impacts, which may have more permanent implications for birds, will largely relate to the period when the turbines are operating. Likewise attraction effects for some species can be expected to occur during both construction and during operation of the wind farm, but also to show variation between these periods as construction activities may reduce a possible attraction. Assessments of potential disturbance/attraction effects to birds will consequently be focused on impacts expected to occur when the wind farm is in operation, although effects from the construction activities will be assessed in the present report as well.

Collision of birds with the wind turbines is assessed to potentially occur in relation to:

- Annual migration of birds between breeding areas and winter quarters,
- Daily flights of birds between e.g. roosting sites and foraging areas,
- Active foraging flights,
- Birds flushed due to disturbance (e.g. turbine maintenance activities),
- Birds attracted to the wind farm area.

No base-line data has been collected on collision risk of birds at Horns Rev, as no platform for detailed observations in the wind farm area has existed.

The physical habitat loss caused by the wind turbines is assumed to be of minor importance to birds as the wind turbines will cover less than 0.3% of the total wind farm area. However, the turbine foundations may act as artificial reefs, which may provide a basis for a new fauna mainly consisting of Balanoids and some Polychaetes. Due to impact from waves and current, mussels are unlikely to settle permanently on the turbine foundations (Elsamprojekt A/S 2000). The low number of fish in the wind farm area is not expected to increase due to the presence of the turbines (Danmarks Fiskeriundersøgelser 2000). Thus, the occurrence of marine invertebrates and fish that is expected to occur on the turbine foundations is supposed to mainly represent species of low food value to birds. For these reasons, specific bird studies focusing on effects due to the physical changes of the habitat are not carried out.

1.5 Base-line investigations

The base-line investigations of bird occurrence in the Horns Rev area were designed to obtain data that would comply with the specifications given in the conditions of approval. Preferably, the base-line investigation should include migrating, staging and wintering species occurring within and around the wind farm area. However, due to the remoteness of the wind farm area, it was recognised that reliable data on bird migration, migration intensity and migration corridors through the wind farm area were not possible to obtain. For this reason, the base-line investigations focused on the occurrence of staging and wintering species.

The present report gives a description of the numbers and distribution of the most numerous and important bird species recorded in the area during the base-line period and period of construction. It also gives a description of the annual and seasonal variation in the occurrence of these species, evaluates the potential long-term impacts of the wind farm on bird exploitation of the Horns Rev area, and assesses the impact from construction activities.

2 Methods

2.1 Study period

Data on numbers and spatial distribution of birds in the Horns Rev area have been collected regularly by aerial surveys during the period August 1999-April 2002. 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. Data from a survey in August 2002 was not included in the construction period, as the aircraft was not allowed to fly within the wind farm area.

2.2 Study area

Determination of a study area at Horns Rev including a reference area where the only parameter different from the construction and impact area is the wind farm is difficult to set up for birds due to large year to year variation in numbers and distribution. Likewise, the size of the impact area is dependent upon the nature of the possible disturbance effects, which at present are unknown for most species of seabirds.

The original design of aerial transect counts made in April 1999 attempted to adapt to these concepts, covering the Horns Rev area from the projected wind farm to the west-northwest. The two sets of initial counts, however, clearly demonstrated that densities of birds on Horns Rev were low, and that proper mapping of distributions in the area necessitated a considerably extended level of coverage.

For this reason, the study area was extended to cover a total area of approximately 1,700 km^2 (38 x 52 km excluding the land area at Blåvandshuk) around the wind farm (Fig. 2). The extent of the chosen area was basically determined by the c. 800 km that can be covered during one day of flight observations, and the conceptual framework was that the selected area would include both impact and reference areas.

Given no a priori knowledge of the magnitude of potential disturbance effects from the wind farm on birds, the study area was designed to include potential zones of impact. These zones were chosen to include the following areas: 1) the wind farm, 2) the wind farm area + a 2 km zone around it, and 3) the wind farm area + a 4 km zone around it (Fig. 2).

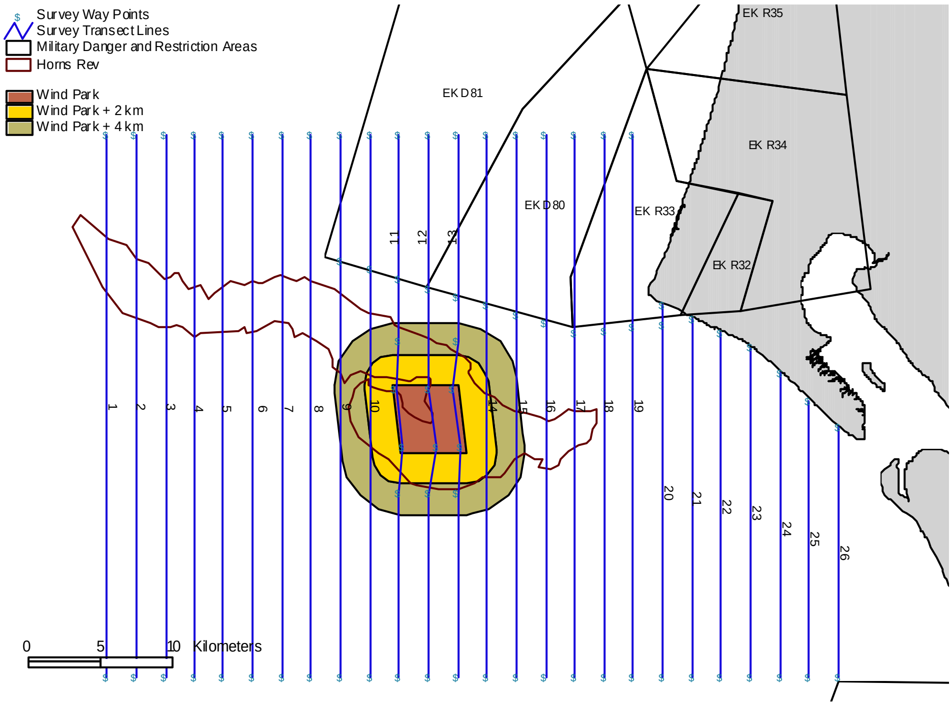


Fig. 2: The ideal survey transect lines, with the 10 m contour of Horns Rev (Horns Rev) and military danger and restriction areas shown. When active, access to restriction and danger areas was prohibited. The wind park and the 2 km and 4 km zones around it are indicated.

2.3 Aerial surveys of birds

Aerial surveys of birds were commenced in April 1999. Based on experiences from the first two surveys in April and May 1999, which covered a much smaller area (see Noer et al. 2000), the extent of the area covered was increased. Likewise, transects was changed to a north-south orientation to optimise detection of any depth-related distribution of birds over the reef proper and to reduce interference of glare to observations.

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).

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.

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 Blåvandshuk (Fig. 2). The transects covered a total linear track of 821 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 grids 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, the transect bands used were determined by use of 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 used during the aerial surveys are shown in Table 1.

Table 1. Summary of 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).

Date	**Transect A**	**Transect B**	**Transect C**	**Km transect covered (both sides)**
20 April 1999	44-300 m	>300 m		497
4 May 1999	44-300 m	>300 m		618
3 August 1999	44-250 m	>250 m		1273
3 September 1999	44-163 m	163-432 m	432-1.000 m	1449
12 November 1999	44-163 m	163-432 m	432-1.000 m	1467
17 February 2000	44-163 m	163-432 m	432-1.000 m	1642
21 February2000	44-163 m	163-432 m	432-1.000 m	1154
19 March 2000	44-163 m	163-432 m	432-1.000 m	1642
27 April 2000	44-163 m	163-432 m	432-1.000 m	1441
21 August 2000	44-163 m	163-432 m	432-1.000 m	1449
6 October 2000	44-163 m	163-432 m	432-1.000 m	1467
22 December 2000	44-163 m	163-432 m	432-1.000 m	1642
9 February 2001	44-163 m	163-432 m	432-1.000 m	1154
20 March 2001	44-163 m	163-432 m	432-1.000 m	1642
21 April 2001	44-163 m	163-432 m	432-1.000 m	1441
22 August 2001	44-163 m	163-432 m	432-1.000 m	1637
26 September 2001	44-163 m	163-432 m	432-1.000 m	1523
7 January 2002	44-163 m	163-432 m	432-1.000 m	1369
12 March 2002	44-163 m	163-432 m	432-1.000 m	1456
9 April 2002	44-163 m	163-432 m	432-1.000 m	1355

During the aerial surveys a computer logged flight track data from a differential GPS at five seconds intervals. Each record contained longitude, latitude, altitude 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 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 within four seconds. With a flight speed of 185 km/h the positional accuracy on the longitudinal axis was within 206 m. In few situations with high bird densities, grouping of observations in periods of up to 10 seconds have occurred, leading to an accuracy of observation positioning of up to 515 m.

As the survey results are highly sensible to weather conditions, surveys were not carried out when wind speed exceeds 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. The relative coverage of the study area is shown in Fig. 3.

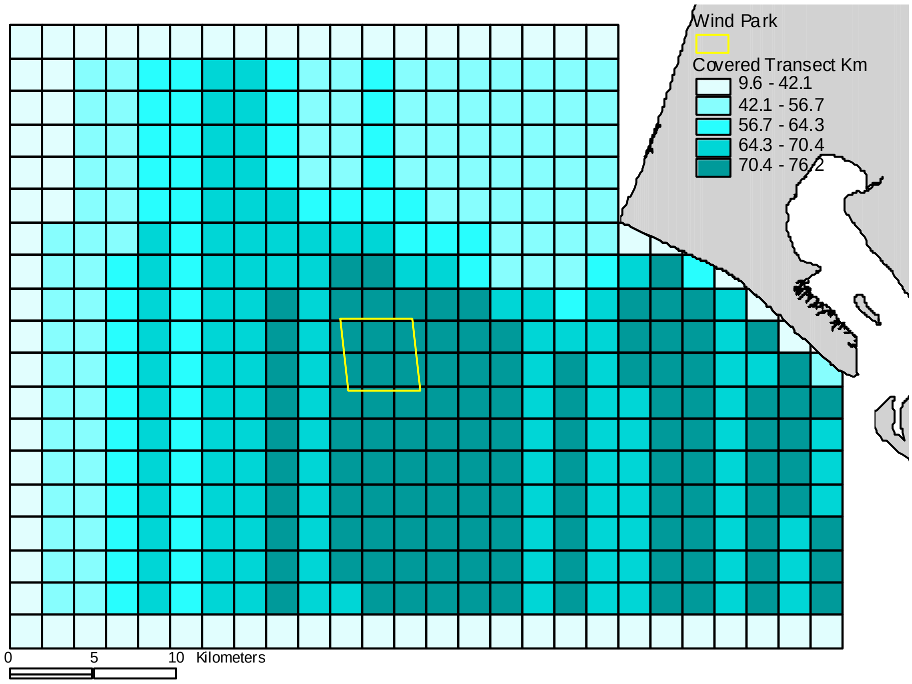


Fig. 3: The coverage of each grid cell as the number of transect kilometers surveyed 1999-2002. In cases with survey coverage both sides of the aircraft, coverage equals length of the segment multiplied by 2.

2.3.1 Construction activities during aerial surveys

Construction activities during the autumn 2001 was related to establishing the foundations for the transformer station located 560 m north of the most northwestern wind turbine. During late autumn and midwinter, activities was suspended due to severe weather conditions and resumed in early March 2002. Activities in March and April 2002 were related to establishment of both the wind turbines and the transformer station.

On the date of bird survey 26 September 2001, activities related to the transformer station involved at least two large vessels equipped with cranes and jack-up towers.

On 7 January 2002 no activities took place, and only the basic frame of the transformer station and associated scaffolds were present in the area.

On 12 March 2002, one ship was making surveys of the seabed for deposition of erosion cover.

On 9 April 2002 one jack-up and one associated vessel were engaged at the transformer station, while three vessels were engaged with seabed surveys/deposition of erosion cover, mounting of basic turbine foundations and deposition of scour protection at at least eight turbines. On 9 April the poles and basic turbine foundations were in place for a total of six turbines.

During 9 April some boat traffic between land and the transformer station may have occurred at various times, but at unknown frequency. Likewise, some traffic of vessels within and close to the wind farm area have taken place, as three boats frequented eight turbines during that date.

A summary of construction activities on the days of aerial surveys and a description of turbine location is given in Appendix 1.

2. 4 Data analyses

Data from two initial aerial surveys in April and May 1999 and from three ship surveys are due to various reasons not included in the following data analyses (see discussion of methods in Noer et al. 2000).

After transcription of observation data and flight track data into tables, a combination of 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.

For all relevant species, distribution maps based on pooled data from all 18 surveys conducted during the base-line and construction period are presented for the study area with a resolution of 2x2 km. The maps are corrected for variation in survey coverage. For bird species showing consistent seasonal differences in their distribution, the density distribution is shown for specific parts of the year, e.g., pooled data from surveys in March. With the purpose of describing the general patterns of bird distributions in the total study area, inclusion of data from the period of construction, in which the bird distributions may potentially be affected, was not considered a bias, as this area represents c. 1.2% of the total study area.

Presentation of bird densities is coupled with methodological problems related to varying coverage of transects and varying transect length (see above), and from a decreasing probability of detecting a bird with increasing distance from 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 the relative densities.

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. 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 share of the length of transect in relation to transect length in the total area (one-sample ?^{2}-test). Since construction activities were going on during the last study year (September 2001-April 2002), the analyses were made exclusively for data recorded during August 1999-August 2001 when no disturbance in the Horns Rev area associated with the wind farm took place, and for data exclusively collected during the period of construction (September 2001-April 2002).

As the period of construction did not include an August survey it was not possible to assess disturbance effects for species which have peak occurrence at this time of the season, e.g., Gannet *Sula bassanus*, Arctic/Common Tern *Sterna pardisaea/hirundo*, Sandwich Tern *Sterna sandvicensis*, Common Gull *Larus canus* and Black-headed Gull *Larus ridibundus* (cf. Table 2).

To assess the minimum detectable change in bird numbers within and close to the wind farm area, we applied a ?^{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 ?^{2} two–sample tests was used to elucidate potential disturbance effects during the period of construction compared to the base-line. In case bird numbers were too small to allow a ?^{2}-tests, Fisher's exact test was applied (SAS Institute 1999-2001). In all ?^{2}-tests a Yates correction were used to make a continuity adjustment.

We used the non-parametric Kruskal-Wallis tests (SAS Institute 1999-2001) to test for differences in the annual number of birds recorded per transect kilometer between the three study years.

2.5 Quality control

All observations of birds during the aerial surveys were recorded on to 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 made during this procedure.

The present report were 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 Bird numbers and distributions recorded 1999-2002

The recorded numbers of the species described in the following chapter are presented in Table 2. The remaining species, which occurred irregularly and in small numbers, will not be described. The total number of birds that were observed during the 18 aerial surveys during August 1999-April 2002 is shown in Appendix 2, although a few observations of terrestrial species are omitted.

Some closely related species occurring within the study area are very similar in plumage and difficult to identify to species during the aerial surveys. These include:
- Red- and Black-throated Diver,
- Arctic, Pomarine and Long-tailed Skua,
- 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 order to interpret the bird distributions in relation to the potential food resources, the following section treats the various species according to whether they feed on fish or bottom fauna.

Table 2. Number of birds observed in the Horns Rev area during eighteen aerial surveys August1999 – April 2002.

Bird species/Date	3 Aug. 1999	3 Sep. 1999	12 Nov. 1999	17 Feb. 2000	21 Feb. 2000	19 Mar. 2000	27 Apr. 2000	21 Aug. 2000	6 Oct. 2000	22 Dec. 2000	9 Feb. 2001	20 Mar. 2001	21 Apr. 2001	22 Aug. 2001	26 Sep. 2001	7 Jan. 2002	12 Mar. 2002	9 Apr. 2002	Total
Fish-eating species																			
Red-/Black-throated Diver (Gavia stellata/arctica)	23	5	71	314	106	141	113	6	23	38	201	149	87	2	3	54	127	138	1,601
Red-necked Grebe (Podiceps griseigena)								1											1
Fulmar (Fulmarus glacialis)	3	16						1	38			1			1	3			63
Gannet (Sula bassanus)	25	266	2			6	7	33	42			1	60	63	10		1	1	517
Cormorant (Phalacrocorax carbo)	3	2	1				2	80			1	20	2	25	32				168
Arctic/Common Tern (Sterna paradisea/hirundo)	692	100	5			1	545	177					40	844	4			1	2,409
Sandwich Tern (Sterna sandvicensis)	48	12				1	12	67					231	11	37		4	2	425
Guillemot/Razorbill (Uria aalge/Alca torda)		63	384	62	74	20	5	60	180	36	32	16	10	17	36	109	59	3	1,166
Common Gull (Larus canus)	110		38		13	3	27	7	6	7	5	34	11	6	10	3	6	2	288
Black-headed Gull (Larus ridibundus)	8	13		1	1	14		164	1		3		253	69	13	1	1		542
Lesser Black-backed Gull (Larus fuscus)	9	1				3	1	39	3				1	29	6			2	94
Herring Gull (Larus argentatus)	254	699	236	4,025	3,327	1,857	112	775	193	230	672	1,169	1,866	822	856	918	1,553	804	20,368
Great Black-backed Gull (Larus marinus)	19	129	21	4	14	31	11	55	24	2	5	3	56	97	60	27	18	3	579
Kittiwake (Rissa tridactyla)	186	324	520	18	41	70	2	579	35	17	30	14	108	183	251	145	304		2,827
Little Gull (Larus minutus)			8			5				5	5	26	1		1	76	82	127	336
Arctic/Pomarine/Long-tailed Skua (Stercorarius sp.)		20	1				1	5						15	1				43
Benthic foraging species																			
Eider (Somateria mollissima)		5	458	2,114	181	476	97	37	42	2,062	5,438	763	99	2	3	823	448	75	13,123
Common Scoter (Melanitta nigra)	68	119	10,231	7,190	3,861	10,459	9,230	283	2,208	8,436	11,041	13,295	16,902	319	4,661	30,483	10,877	3,802	143,465
Velvet Scoter (Melanitta fusca)			28				16		1	19	58	148	343	2	2	4	5	5	631

3.1.1 Fish-eating species

Red- and Black-throated Diver (Gavia stellata/arctica)

A total of 1,601 divers was recorded during the study period. The seasonal and annual occurrence was very consistent during all three study years with the highest numbers recorded during February-April and lowest numbers during August-January (Fig. 4). Generally, divers were observed as solitary individuals or in loose flocks of few birds. The annual average number of divers counted per transect kilometer did not change significantly between the three study years (Kruskal-Wallis test: $?^2$ = 0.547, df = 2, P = 0.760).

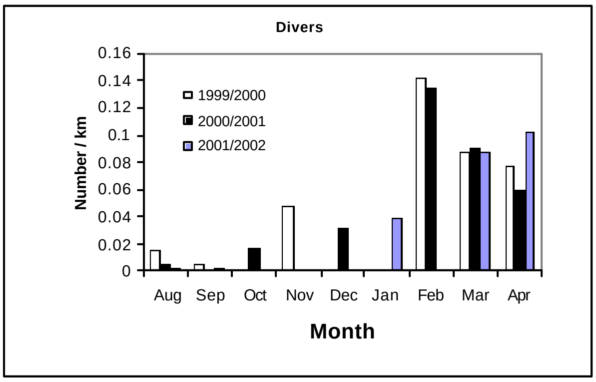


Fig. 4. The number of divers per transect kilometre recorded in 18 aerial counts during August 1999-April 2002.

The distribution of all 1,601 divers showed that the birds were recorded throughout the entire area, but with a tendency to occur in highest numbers northwest and southwest of Horns Rev and off Blåvandshuk and Skallingen and with relatively few birds in the central parts of the study area (Fig. 5).

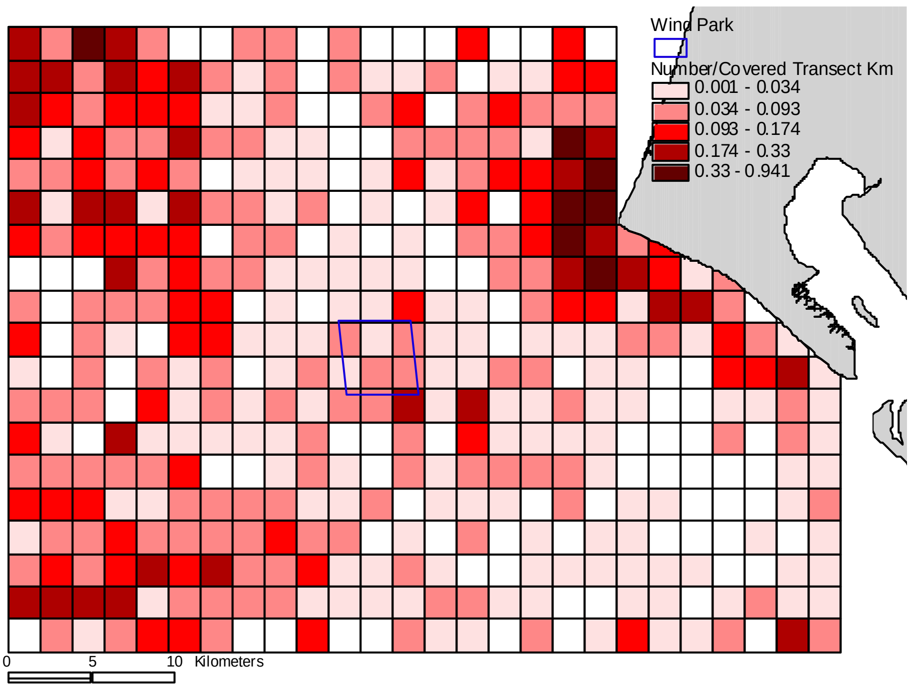


Fig. 5. The relative number of divers (N = 1,601) corrected for the coverage in each grid cell in the study area from 18 aerial surveys conducted during August 1999-April 2002.

Seasonal differences in the distribution of divers were found. During August-January the numbers were low and showed a very scattered distribution over the entire area (Fig. 6a). The distribution in February also showed that the divers occurred over the entire area, but with a clear aggregation of birds occurring off Blåvandshuk and Skallingen (Fig. 6b). During March-April most divers were recorded west of the wind farm area showing a very homogeneous occurrence in this part of the study area, but still with high numbers occurring off Blåvandshuk and Skallingen (Fig. 6c).

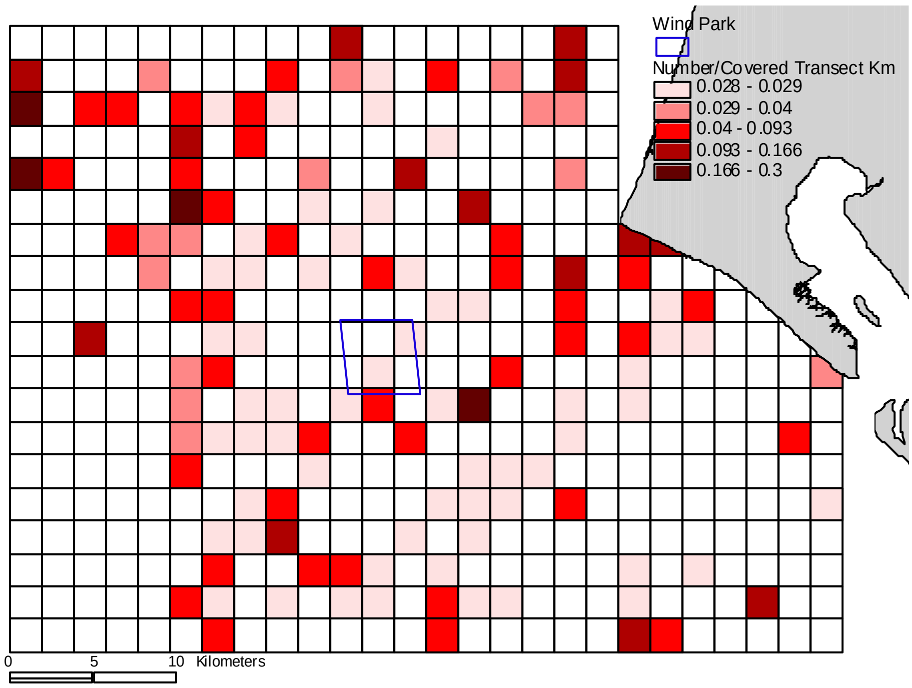


Fig. 6a

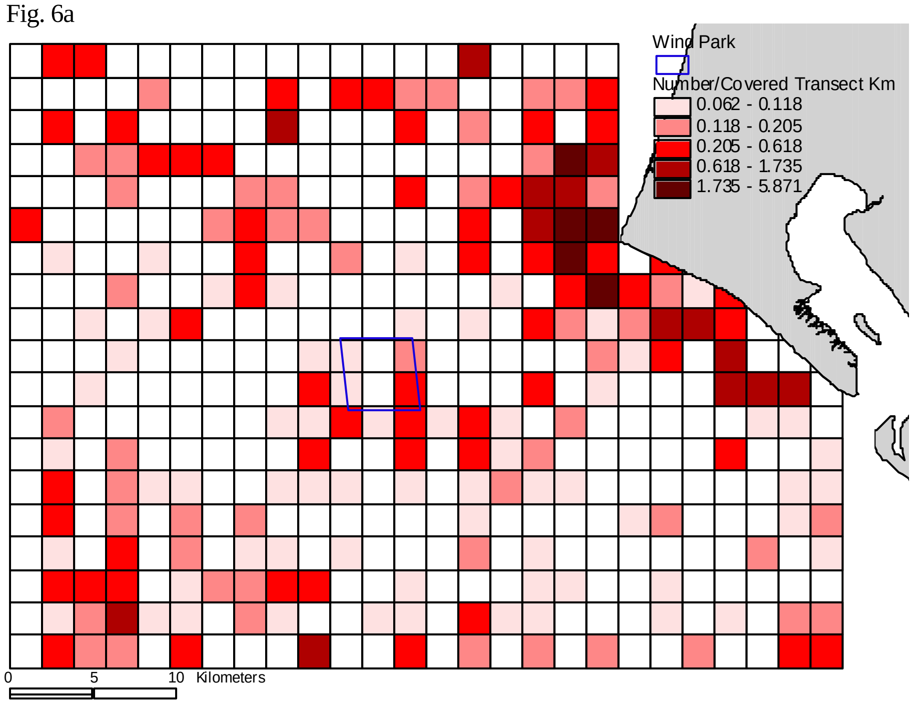


Fig. 6b

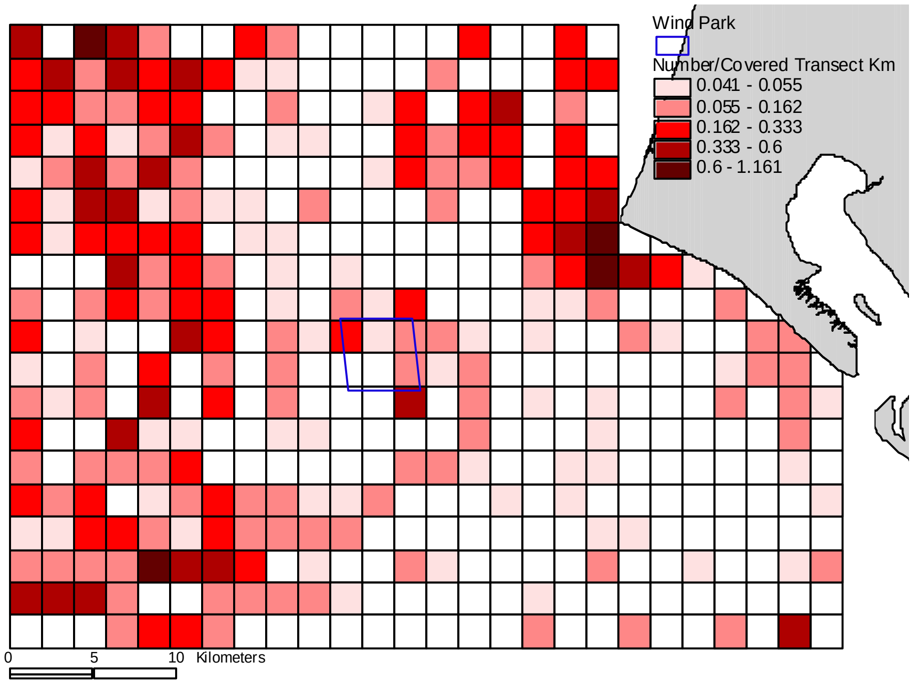


Fig. 6c

Fig. 6. The relative number of a) 225 divers recorded in nine aerial surveys during August-January 1999-2002, b) 621 divers recorded in three aerial surveys during February 1999-2002, c) 755 divers recorded in six aerial surveys during March-April 1999-2002, corrected for coverage in each grid cell.

Red-necked Grebe (Podiceps griseigena)

One Red-necked Grebe was recorded (August 2000). Combined with previous observations (from the ship survey) of three birds (Noer et al. 2000), there are no indications in the present material that the waters around Horns Rev are of ecological importance for this species.

This result contrast much higher numbers recorded during previous counts during the late 1980's and early 1990's (Laursen et al. 1997), suggesting that the Horns Rev area was of international importance to this species.

Fulmar (Fulmarus glacialis)

A total of 63 Fulmars was recorded during the study period. The seasonal occurrence matches the peak period of migration at Blåvandshuk (September-October), with all except one bird (observed in March) recorded during August-January and with highest numbers recorded in September and October (Table 2). Most observations were of solitary birds or of very small groups.

The distribution of all 63 Fulmars showed that most birds were recorded in the central parts of the study area around Horns Rev, but with very few observations over the reef proper (Fig. 7).

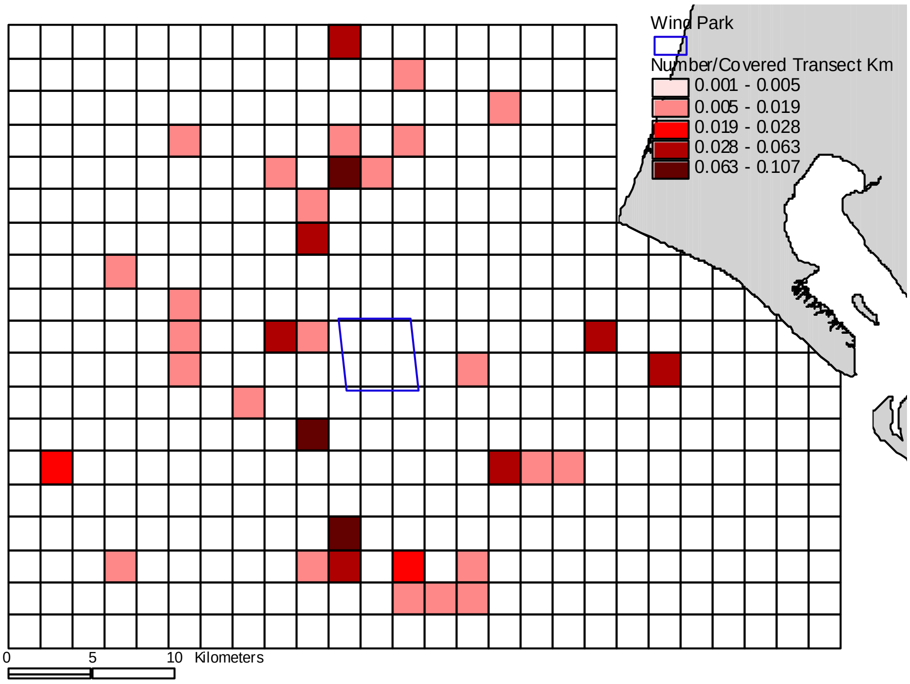


Fig. 7. The relative number of Fulmars (N = 63) corrected for the coverage in each grid cell in the study area from 18 aerial surveys conducted during August 1999-April 2002.

Gannet (Sula bassanus)

A total of 517 Gannets was recorded during the study period. The seasonal occurrence reflects the peak migration periods at Blåvandshuk in August-September and April-May with highest numbers observed in August, September, October and in April (Fig. 8). The lack of a count in September 2000 makes an assessment of between-year variation impossible, but the number of Gannets seems to vary markedly. Gannets were generally recorded solitary or in loose groups. The annual average number of Gannets counted per transect kilometer did not change significantly between the three study years (Kruskal-Wallis test: ?^{2} = 0.238, df = 2, P = 0.888).

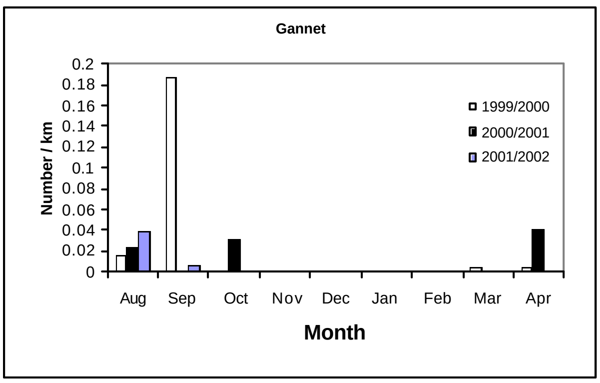


Fig. 8. The number of Gannets per transect kilometre recorded in 18 aerial counts during August 1999-April 2002.

The distribution of all 517 Gannets showed that most birds were recorded in the western part of the study area with a tendency for the highest densities to occur over the reef proper. Relatively high numbers were also recorded north of the wind farm area and off Blåvandshuk (Fig. 9).

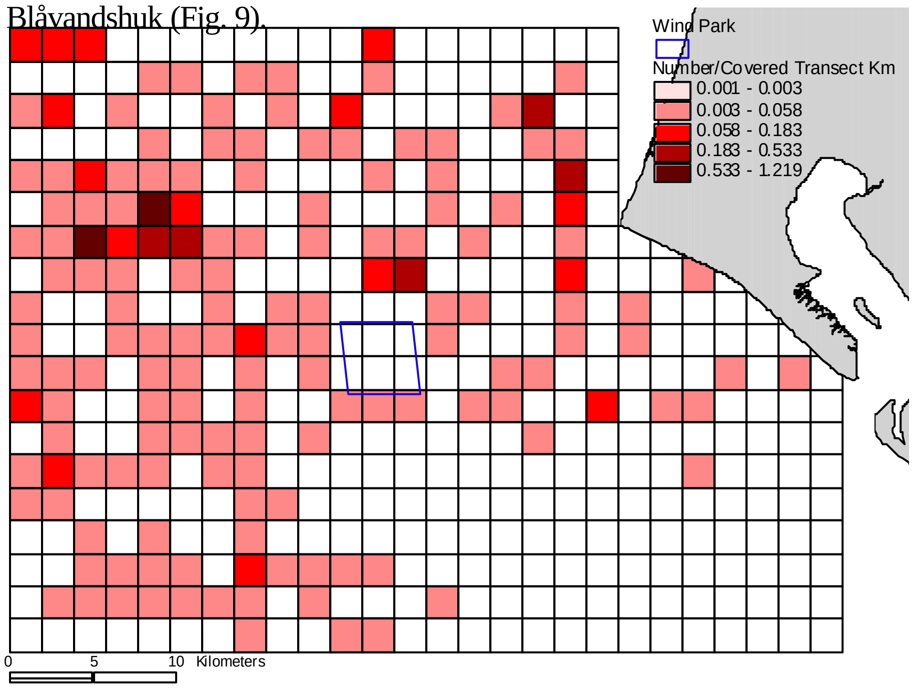


Fig. 9. The relative number of Gannets (N = 517) corrected for the coverage in each grid cell in the study area from 18 aerial surveys conducted during August 1999-April 2002.

The distribution of Gannets within the study area did not show a consistent seasonal pattern. In some surveys Gannets were recorded scattered over the entire area, in others most birds were either recorded southwest or northeast of Horns Rev. Gannets were regularly recorded over the western part of the reef proper, but very rarely in the southeastern part of the study area.

Cormorant (Phalacrocorax carbo)

A total of 168 Cormorants was recorded during the study period. Cormorants were observed from February to November with highest numbers in August and September (Table 2). During the autumn, most birds were recorded in flocks close to or at the coast of Blåvandshuk and Skallingen. Although Cormorants were only recorded in one of three surveys in March, most birds in this survey were recorded in the offshore part south of Horns Rev.

The distribution of all 168 Cormorants recorded during August 1999-April 2002 is shown in Fig. 10.

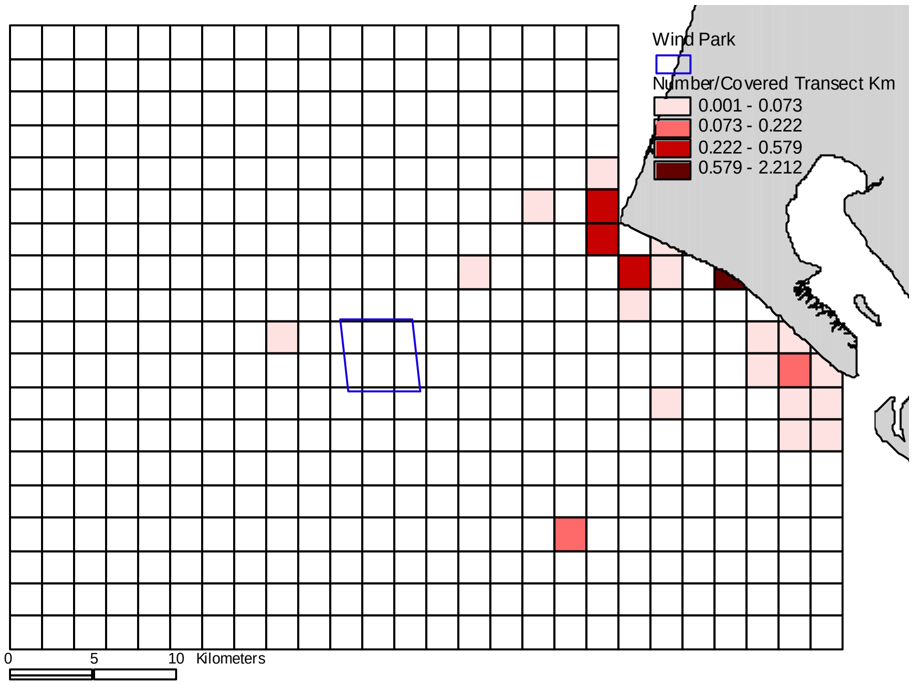
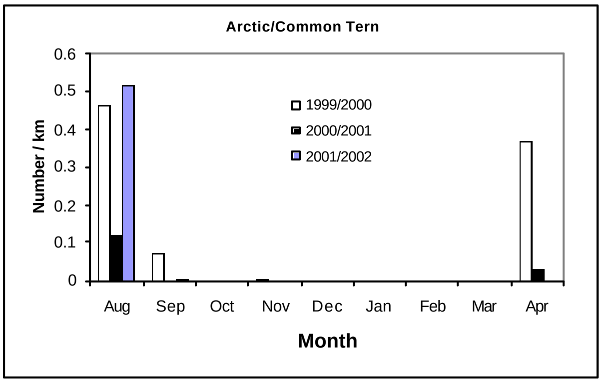


Fig. 10. The relative number of Cormorants (N = 168) corrected for the coverage in each grid cell in the study area from 18 aerial surveys conducted during August 1999-April 2002.

Arctic/Common Tern (Sterna paradisaea/hirundo)

A total of 2,409 Arctic/Common Terns was recorded during the study period. The seasonal occurrence reflects the peak migration periods in autumn and spring with observations only in August-September and March-April (Fig. 11). Large between-year variation is evident, with lowest numbers recorded in 2000/2001 and highest numbers in 1999/2000 and 2001/2002. Generally the terns were recorded very scattered in small flocks. The annual average number of terns counted per transect kilometer did not change significantly between the three study years (Kruskal-Wallis test: $?^2 = 2.205$, df = 2, P = 0.332).

Fig. 11. The number of Arctic/Common Tern per transect kilometre recorded in 18 aerial counts during



August 1999-April 2002.

The distribution of all 2,409 Arctic/Common Terns showed a scattered occurrence over the entire study area with a tendency of highest numbers in the coastal zone off Blåvandshuk and

Skallingen and in the area west of the wind farm area (Fig. 12). Assessed from distribution maps from individual surveys the occurrence of Arctic/Common Terns was variable with no consistent seasonal pattern. In some surveys, most birds were recorded either southeast of Horns Rev or off Blåvandshuk and Skallingen and in other surveys the terns occurred scattered over the study area.

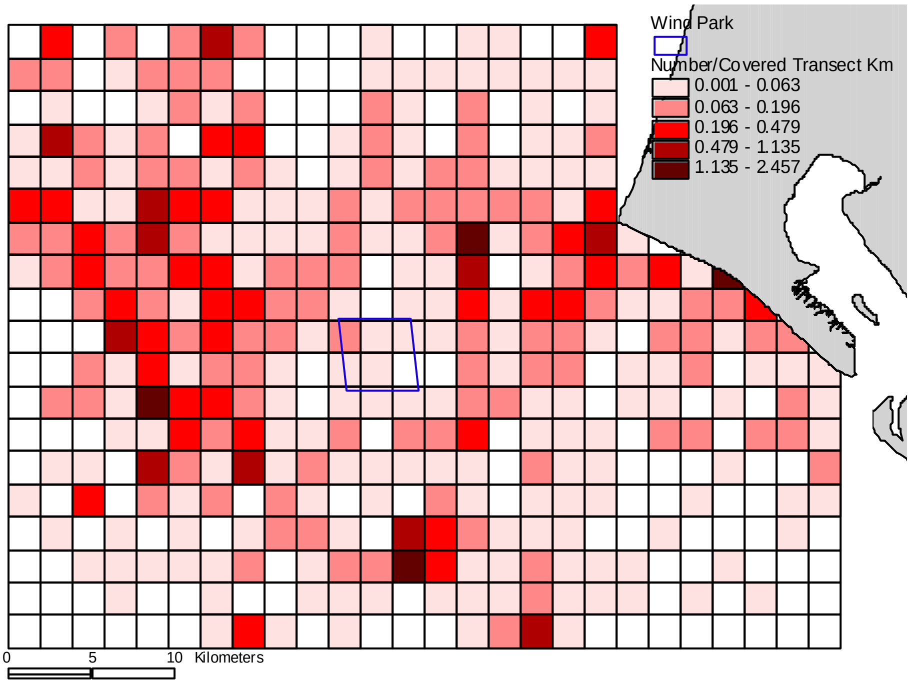


Fig. 12. The relative number of Arctic/Common Terns (N = 2,409) corrected for the coverage in each grid cell in the study area from 18 aerial surveys conducted during August 1999-April 2002.

Sandwich Tern (Sterna sandvicensis)

A total of 425 Sandwich Terns was recorded during the study period. The seasonal occurrence reflects the peak autumn (July-November) and spring (March-May) migration periods with observations only from August, September and March and April. The April counts document large year-to-year variation (Fig. 13). The annual average number of Sandwich Terns counted per transect kilometer did not change significantly between the three study years (Kruskal-Wallis test: $?^2 = 0.279$, df = 2, P = 0.870).

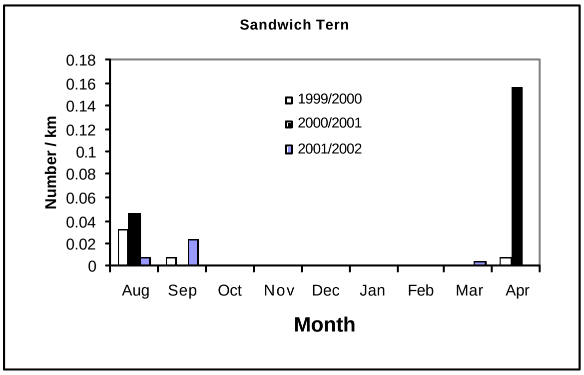


Fig. 13. The number of Sandwich Tern per transect kilometre recorded in 18 aerial counts during August 1999-April 2002.

The distribution of all 425 Sandwich Terns showed a very scattered pattern (Fig 14). However, there was a tendency that birds occurred in higher numbers off Blåvandshuk and on Horns Rev west of the wind farm area, a distribution comparable to the distribution of Arctic/Common Tern.

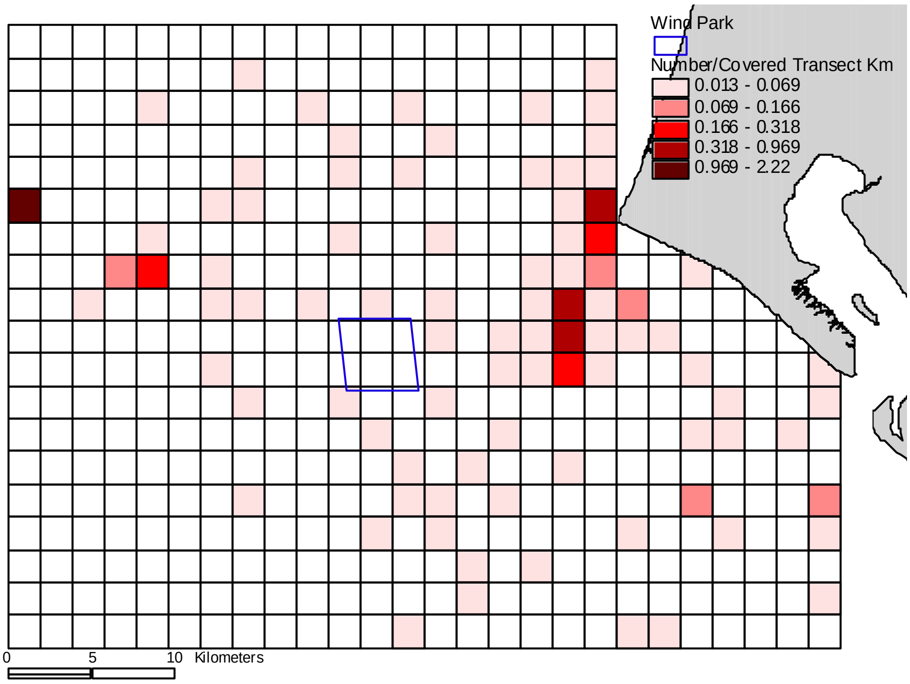


Fig. 14. The relative number of Sandwich Terns (N = 425) corrected for the coverage in each grid cell in the study area from 18 aerial surveys conducted during August 1999-April 2002.

The distribution of Sandwich Terns within the study area was variable with no consistent seasonal pattern. In general, most birds were recorded east of Horns Rev and southwest of Blåvandshuk. However, in the survey in August 1999 most birds were recorded over the reef proper and in the survey in September 2001 most birds were recorded close to the coast at Blåvandshuk.

Guillemot/Razorbill (Uria aalge/Alca torda)

A total of 1,166 alcids was recorded during the study period. The seasonal occurrence showed the largest numbers during autumn (October-November) and the smallest numbers during spring (March-April). Although constrained by the different timing of the autumn counts during the study period, the year-to-year pattern of the occurrence compliments each other (Fig. 15). Alcids were mostly recorded solitary or in small groups. The annual average number of alcids counted per transect kilometer did not change significantly between the three study years (Kruskal-Wallis test: $?^2 = 0.014$, df = 2, P = 0.993).

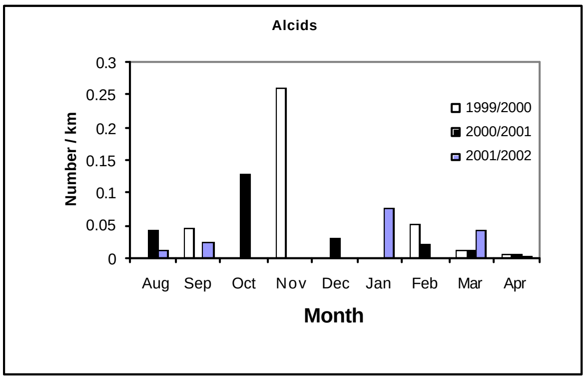


Fig. 15. The number of alcids per transect kilometre recorded in 18 aerial counts during August 1999-April 2002.

The distribution of all 1,166 alcids showed that the birds mainly exploited the most offshore parts of the study area (Fig. 16). Most birds were found west, south and north of Horns Rev, and with few individuals observed over the reef proper.

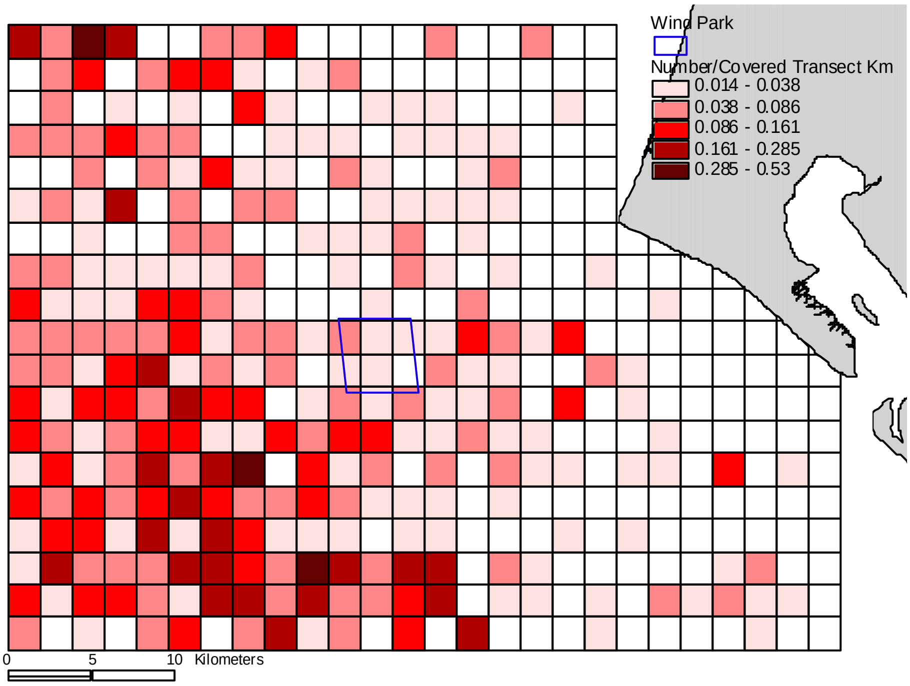


Fig. 16. The relative number of alcids (N = 1,166) corrected for the coverage in each grid cell in the study area from 18 aerial surveys conducted during August 1999-April 2002.

There seemed to be a consistent difference in the seasonal distribution of alcids with almost all records from the western part of the study area. During the autumn period (August-December) the alcids occurred both north and south of the reef proper (Fig. 17a). During late winter (January-February), almost all birds were recorded in the area south of Horns Rev (Fig 17b).

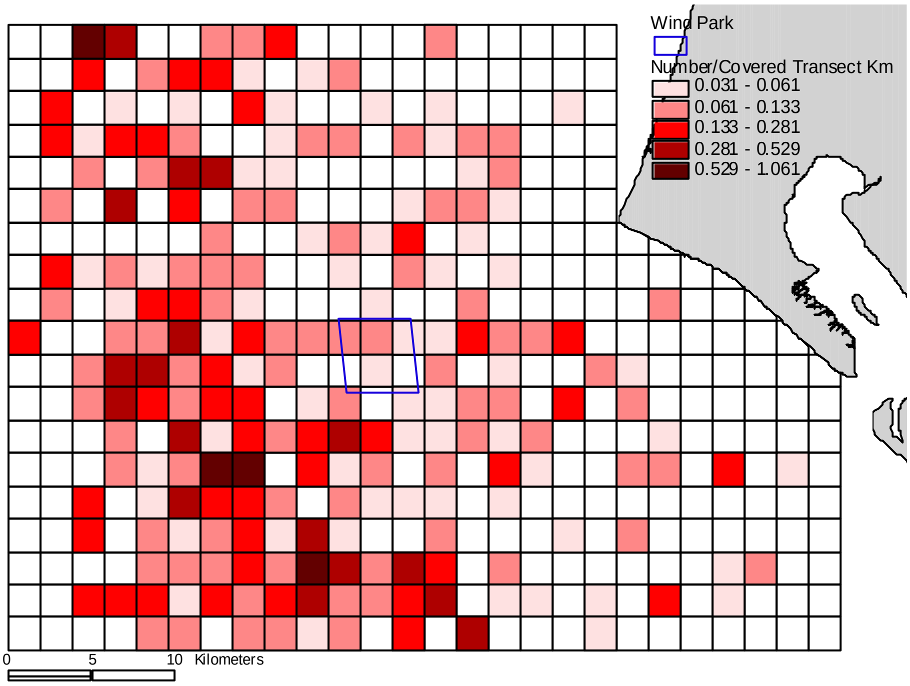


Fig. 17a

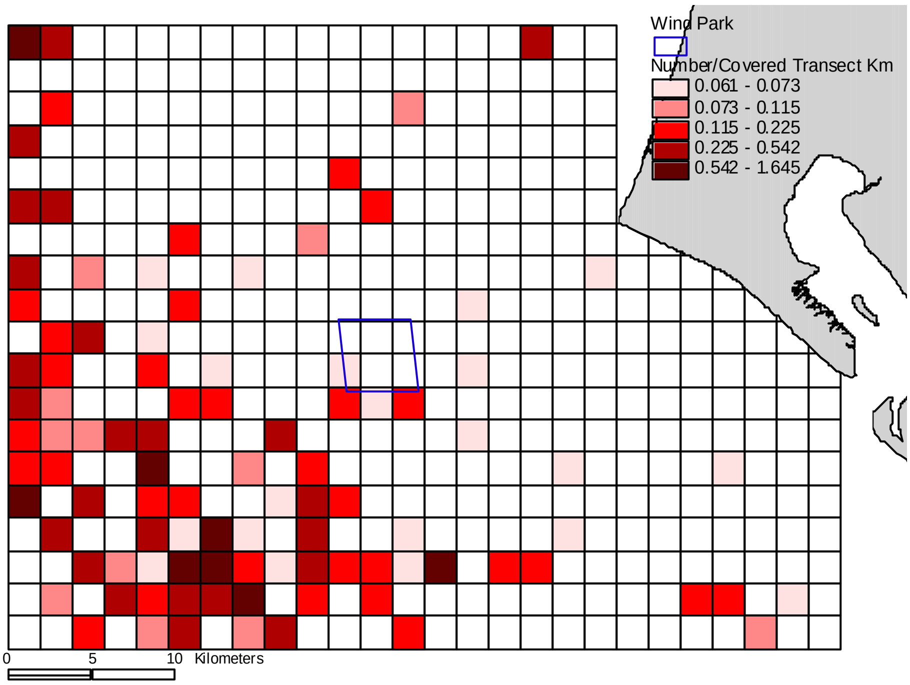


Fig. 17b

Fig. 17. The relative number of a) 838 alcids recorded in 8 aerial surveys during August-December 1999-2002, and b) 277 alcids recorded in 4 aerial surveys during January-February 1999-2002, corrected for coverage in each grid cell.

Common Gull (Larus canus)

A total of 288 Common Gulls was recorded during the study period. Common Gulls were observed throughout the annual cycle. Apart from a very high number recorded in August 1999, the seasonal and annual occurrence was comparable in all three years (Fig. 18). The annual average number of Common Gulls counted per transect kilometer did not change significantly between the three study years (Kruskal-Wallis test: $?^2 = 2.178$, df = 2, P = 0.337).

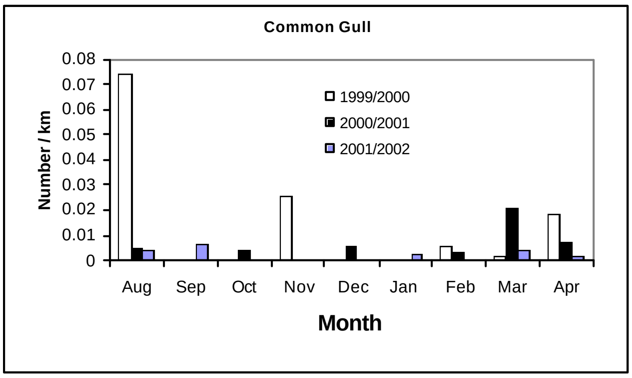


Fig. 18. The number of Gulls per transect kilometre recorded in 18 aerial counts during August 1999-April 2002.

The distribution of all 288 Common Gulls was variable with no consistent seasonal pattern. In general, the highest number of birds were recorded in the coastal parts of the study area around Blåvandshuk and Skallingen and in declining numbers with increasing distance from the coast (Fig. 19).

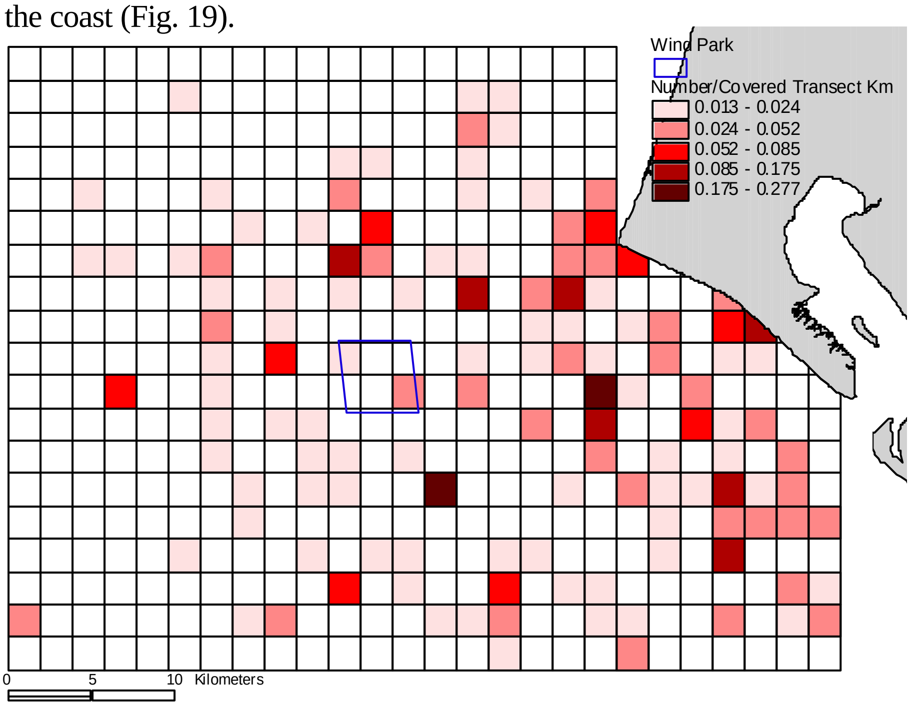


Fig. 19. The relative number of Common Gulls (N = 288) corrected for the coverage in each grid cell in the study area from 18 aerial surveys conducted during August 1999-April 2002.

Black-headed Gull (Larus ridibundus)

A total of 542 Black-headed Gulls was recorded during the study period. Black-headed Gulls were observed during February, March and April and during August and September. Highest numbers were recorded in April and August. Despite some variation in numbers, the seasonal and annual occurrence was comparable in all three years (Fig. 20). The annual average number of Black-headed Gulls counted per transect kilometer did not change significantly between the three study years (Kruskal-Wallis test: ?^{2} = 0.015, df = 2, P = 0.992).

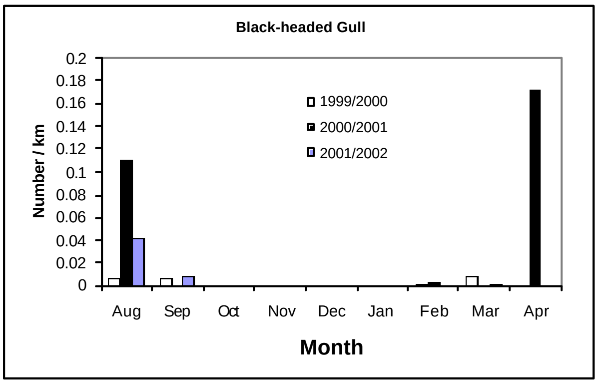


Fig. 20. The number of Black-headed Gulls per transect kilometre recorded in 18 aerial counts during August 1999-April 2002.

The distribution of all 542 Black-headed Gulls was variable with no consistent seasonal pattern. In general, the highest number of birds was recorded in the coastal parts of the study area around Blåvandshuk and Skallingen and in declining numbers with increasing distance from the coast (Fig. 21).

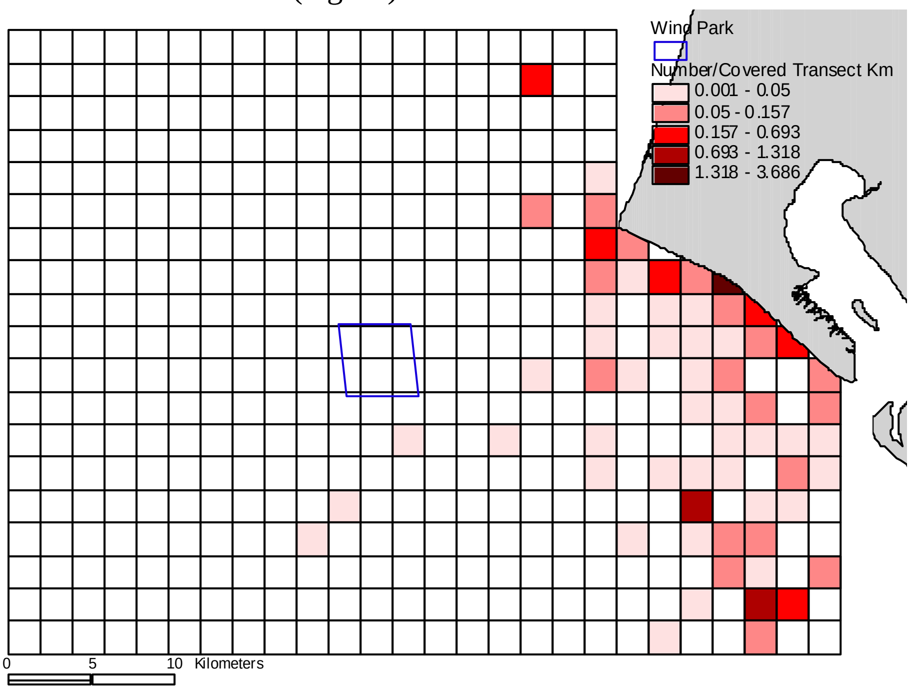


Fig. 21. The relative number of Black-headed Gulls (N = 542) corrected for the coverage in each grid cell in the study area from 18 aerial surveys conducted during August 1999-April 2002.

Herring Gull (Larus argentatus)

A total of 20,368 Herring Gulls was recorded during the study period. Herring Gulls were observed throughout the annual cycle with highest numbers in February, March and April and with lowest number during October-December. Except for a large number of Herring Gulls in February 2000, the seasonal and annual occurrence was comparable in all three years (Fig. 22). The annual average number of Herring Gulls counted per transect kilometer did not change significantly between the three study years (Kruskal-Wallis test: $?^2 = 1.163$, df = 2, P = 0.559).

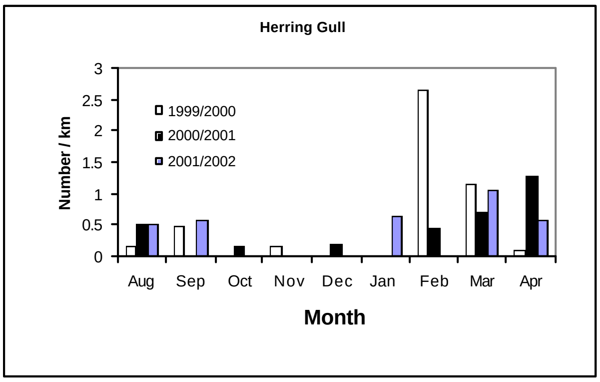


Fig. 22. The number of Herring Gulls per transect kilometre recorded in 18 aerial counts during August 1999-April 2002.

The distribution of all 20,368 Herring Gulls was variable with no consistent seasonal pattern. In general, the highest number were recorded in the coastal parts of the study area around Blåvandshuk and Skallingen and in declining numbers with increasing distance from the coast. On some occasions, aggregations of Herring Gulls around fishing vessels were observed far from the coast, especially in the area south and southeast of Horns Rev (Fig. 23).

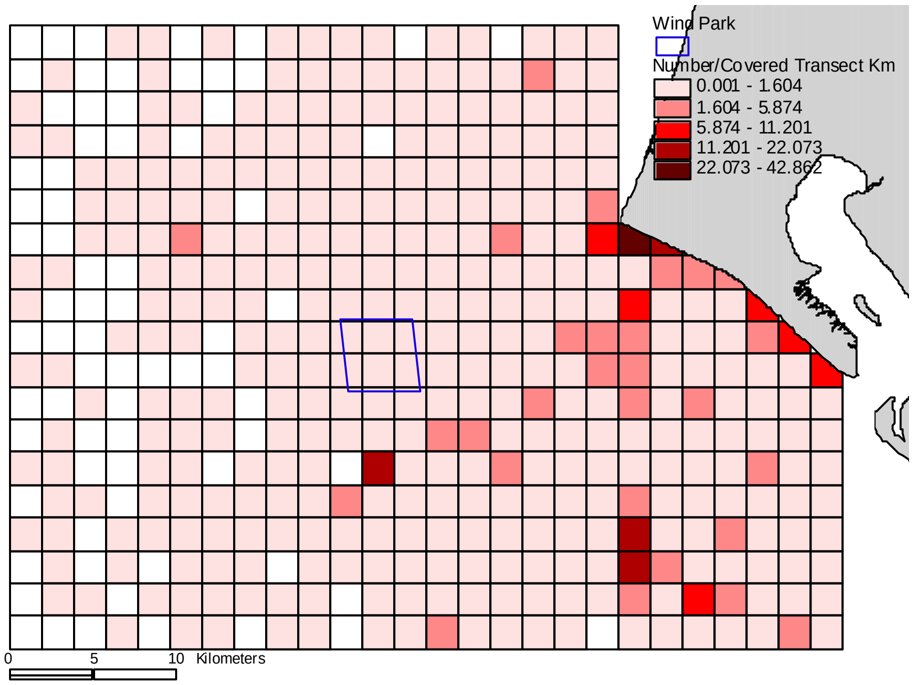


Fig. 23. The relative number of Herring Gulls (N = 20,368) corrected for the coverage in each grid cell in the study area from 18 aerial surveys conducted during August 1999-April 2002.

Great Black-backed Gull (Larus marinus)

A total of 579 Great Black-backed Gulls was recorded during the study period. The seasonal and annual occurrence was consistent during all three study years with highest numbers in August, September and April although some annual variation existed (Fig. 24). The annual average number of Great Black-backed Gulls counted per transect kilometer did not change significantly between the three study years (Kruskal-Wallis test: $?^2 = 1.182$, df = 2, P = 0.554).

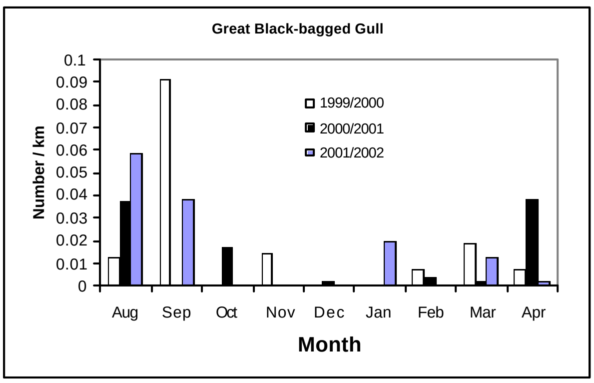


Fig. 24. The number of Great Black-backed Gulls per transect kilometre recorded in 18 aerial counts during August 1999-April 2002.

The distribution of all 579 Great Black-backed Gulls was variable with no consistent seasonal pattern. In some surveys the birds were distributed evenly over the entire area and in others the birds were recorded more concentrated. In general, the species was observed over the entire area with highest numbers in the eastern part of the study area (Fig. 25). Compared to the distribution of Herring Gulls, Great Black-backed Gulls seemed to occur more frequently in the offshore habitat being less associated with the coastal areas and shorelines (Figs. 23 & 25).

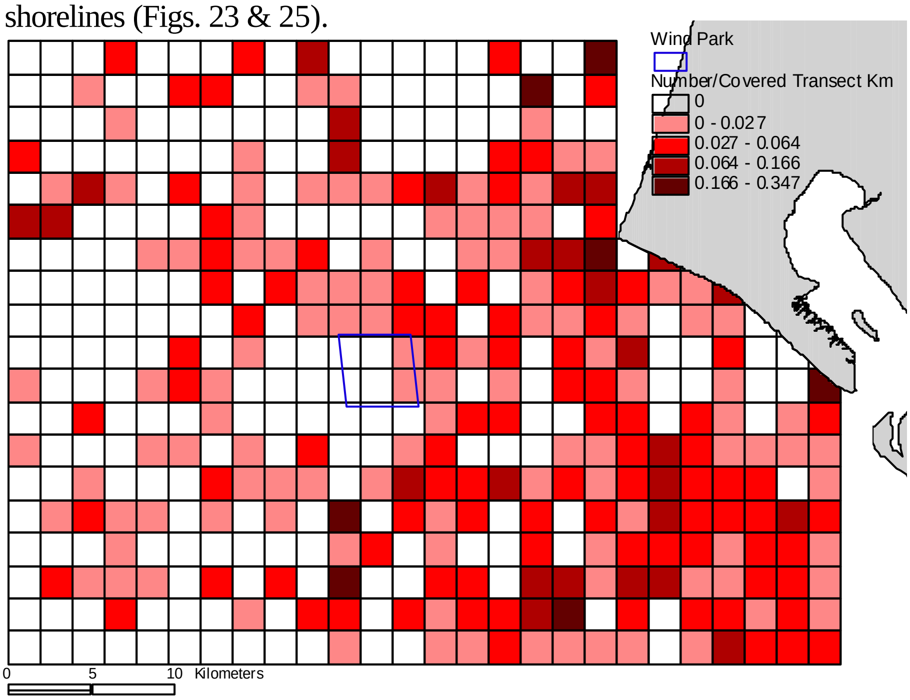


Fig. 25. The relative number of Great Black-backed Gulls (N = 579) corrected for the coverage in each grid cell in the study area from 18 aerial surveys conducted during August 1999-April 2002.

Kittiwake (Rissa tridactyla)

A total of 2,827 Kittiwakes was recorded during the study period. The seasonal and annual occurrence showed large variation with peak numbers observed at different times in the three study years. Kittiwakes were observed throughout the annual cycle but with most birds observed during August-November (Fig. 26). The annual average number of divers counted per transect kilometer did not change significantly between the three study years (Kruskal-Wallis test: $?^2 = 0.818$, df = 2, P = 0.664).

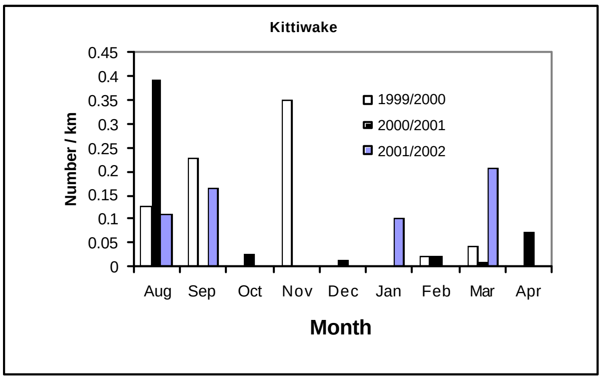


Fig. 26. The number of Kittiwakes per transect kilometre recorded in 18 aerial counts during August 1999-April 2002.

The overall distribution of all 2,827 Kittiwakes was variable with no consistent seasonal pattern. The species occurred over the entire study area with a tendency for highest numbers over the northwestern parts of Horns Rev and north of the reef and lowest numbers in the east and southeastern parts of the study area (Fig. 27).

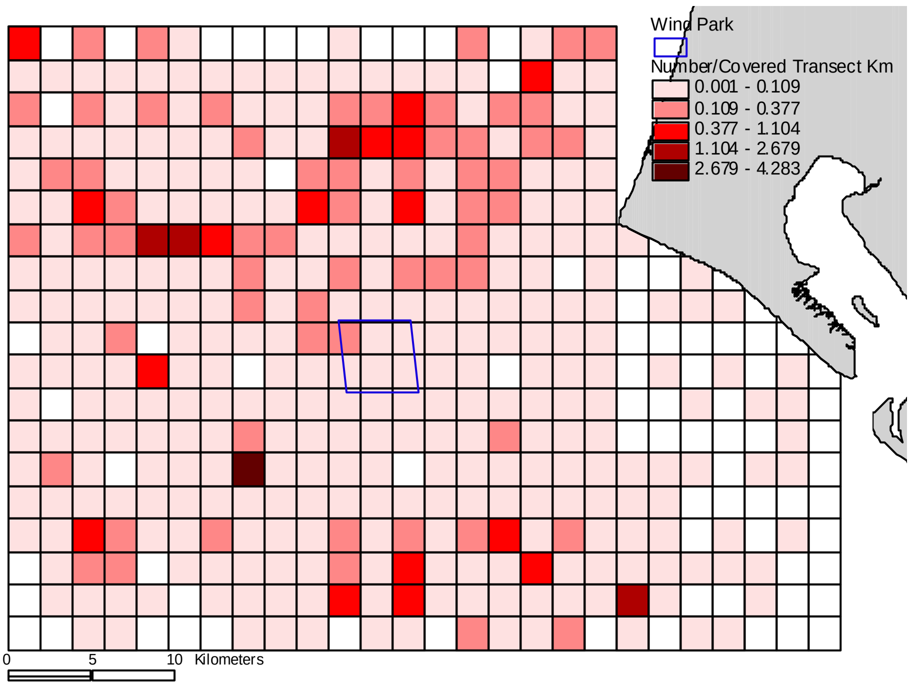


Fig. 27. The relative number of Kittiwakes (N = 2,827) corrected for the coverage in each grid cell in the study area from 18 aerial surveys conducted during August 1999-April 2002.

Little Gull (Larus minutus)

A total of 336 Little Gulls was recorded during the study period. The majority was observed during January-April (Fig. 28). Large year-to-year differences in the occurrence seem to exist, with a very high number recorded in the spring of 2002. Most birds were observed as solitary individuals or in small flocks in the offshore part of the study area. The annual average number of Little Gulls counted per transect kilometer did not change significantly between the three study years (Kruskal-Wallis test: ?^{2} = 3.577, df = 2, P = 0.167).

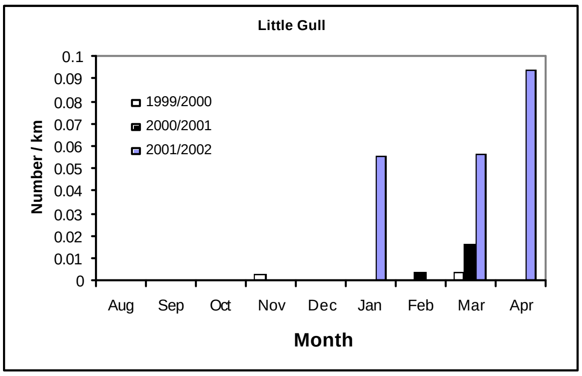


Fig. 28. The number of Little Gulls per transect kilometre recorded in 18 aerial counts during August 1999-April 2002.

The distribution of all 336 Little Gulls (Fig. 29) showed that most birds occurred north/northwest and south/southeast of the Horns Rev with very small numbers over the central part of the reef and in the wind farm area.

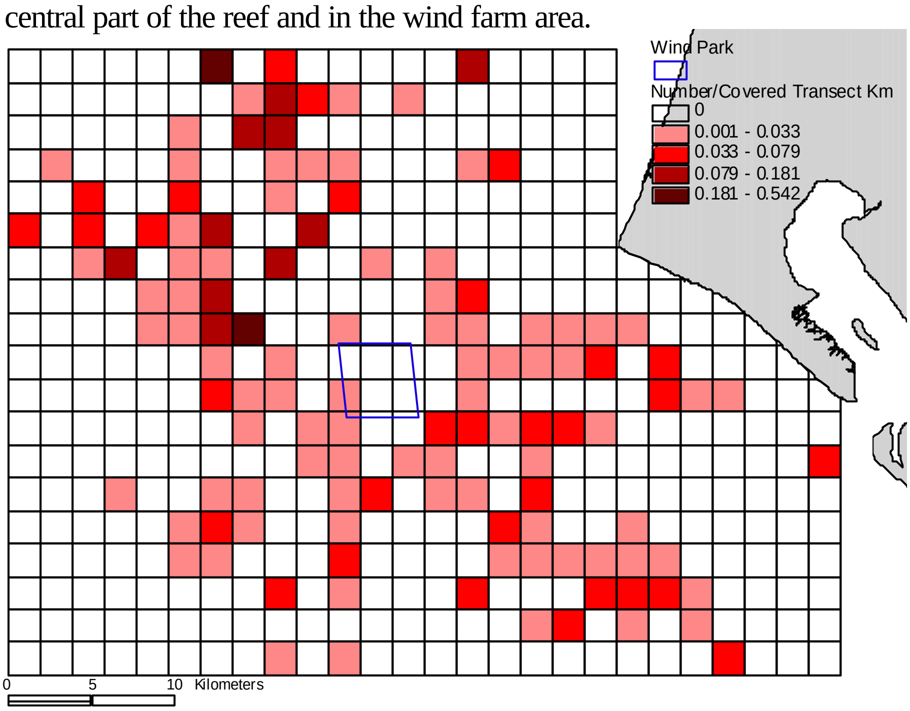


Fig. 29. The relative number of Little Gulls (N = 336) corrected for the coverage in each grid cell in the study area from 18 aerial surveys conducted during August 1999-April 2002.

Although numbers were small, Little Gull tended to show some seasonal difference in distribution. During January and March, most birds were recorded scattered south or southeast of the Horns Rev (Fig. 30a). In April, all birds were recorded in the northwestern part of the study area including the western part of Horns Rev (Fig. 30b).

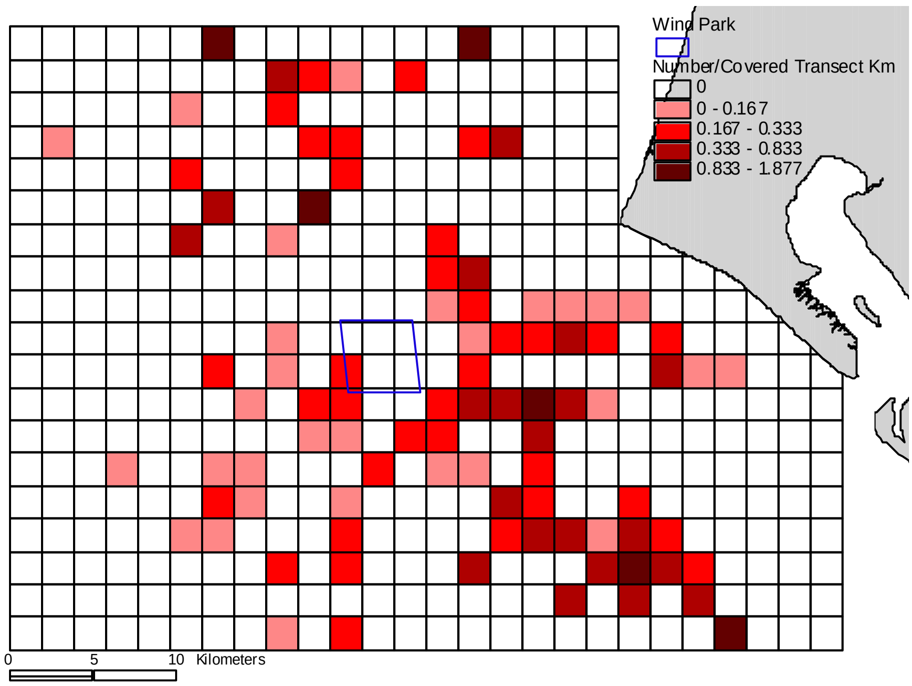


Fig. 30a

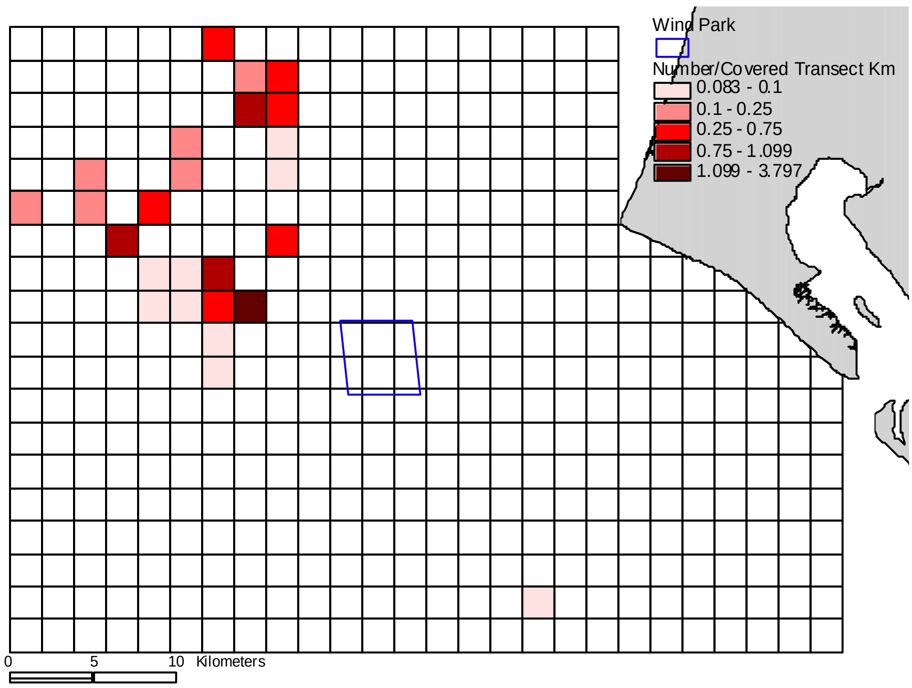


Fig. 30b

Fig. 30. The relative number of a) 208 Little Gulls recorded in seven aerial surveys during January-March 1999- 2002, and b) 128 Little Gulls recorded in three aerial surveys in April 1999-2002, corrected for the coverage in each grid cell.

Skuas (Stercorarius sp.)

A total of 43 skuas was recorded during the study period. Of these, 20 were recorded in August, 21 recorded in September, 1 in November and 1 in April (Table 2). Arctic Skua accounted for 37 of the skuas while six birds were not identified to species.

The overall distribution of all 43 skuas recorded occurred scattered throughout the study area and were observed as solitary individuals or as two birds together (Fig. 31).

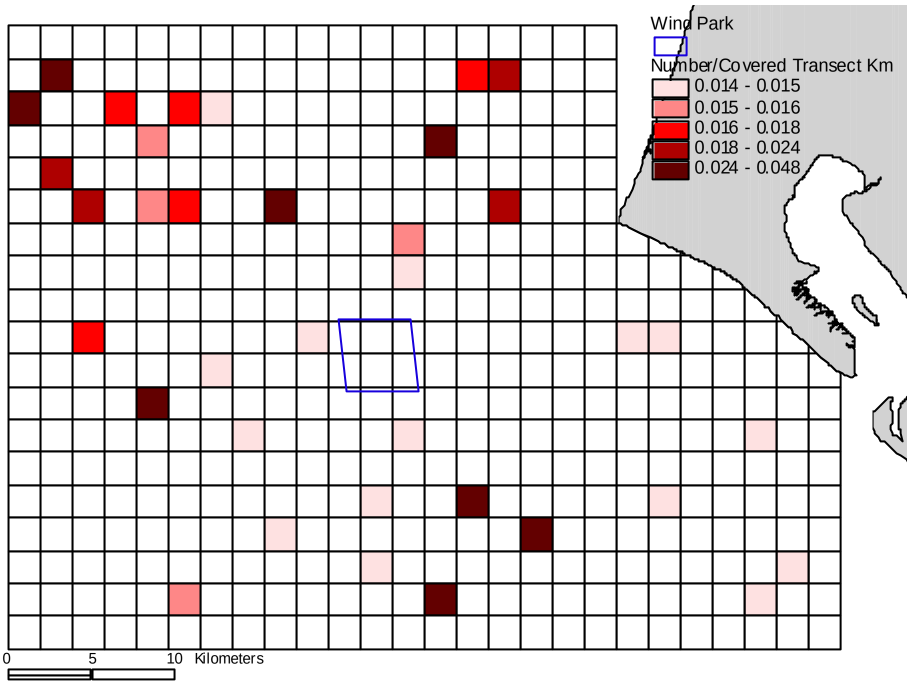


Fig. 31. The relative number of skuas (N = 43) corrected for the coverage in each grid cell in the study area from 18 aerial surveys conducted during August 1999-April 2002.

3.1.2 Species foraging on sessile benthic fauna

Eider (Somateria mollissima)

A total of 13,123 Eiders was recorded during the study period. Eiders were observed on all surveys except in August 1999. The seasonal occurrence showed a consistent pattern with highest numbers during mid-winter, whereas numbers fluctuated markedly between years (Fig. 32). The highest numbers were counted in December and February. The annual average number of Eiders counted per transect kilometer did not change significantly between the three study years (Kruskal-Wallis test: $?^2$ = 1.548, df = 2, P = 0.461).

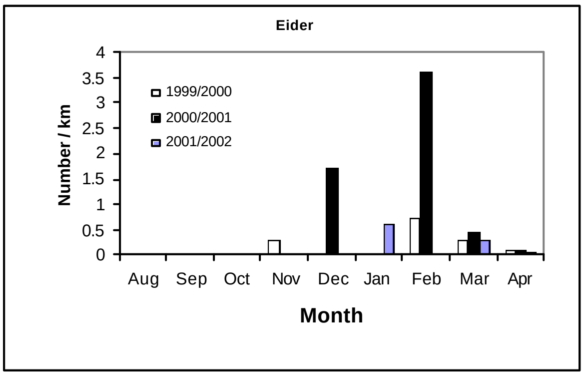


Fig. 32. The number of Eiders per transect kilometre recorded in 18 aerial counts during August 1999-April 2002.

The overall distributions of all 13,123 Eiders showed a very consistent pattern. In all surveys, the majority of Eiders were concentrated in the coastal parts of the study area at Blåvandshuk and along the coastline of Skallingen, but a few birds were regularly observed in the southeastern part of the study area (Fig. 33). The Eiders were generally recorded in large flocks of several hundred birds with solitary birds only observed on a few occasions.

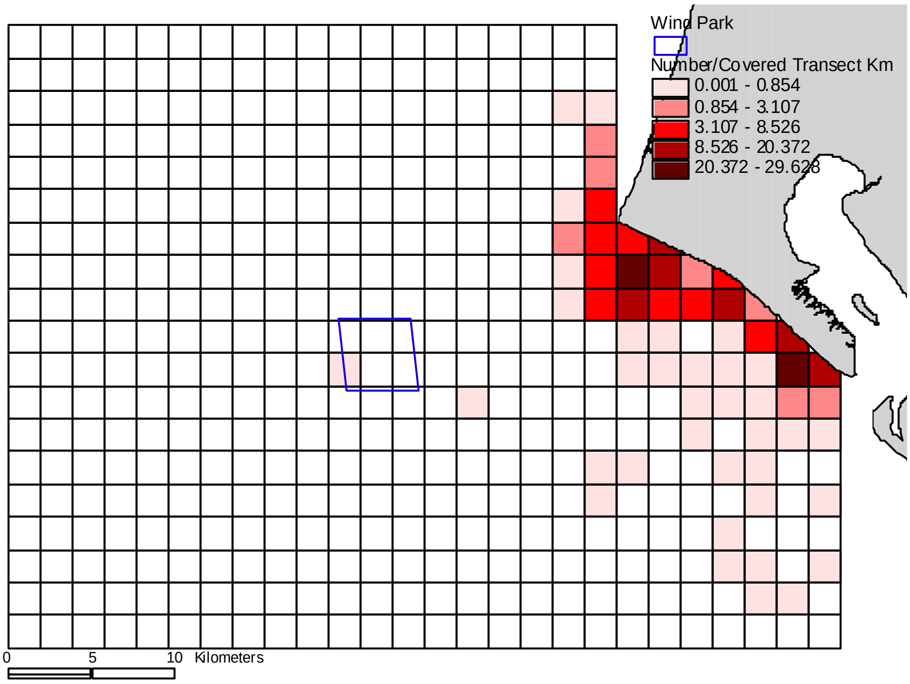


Fig. 33. Relative number of Eiders (N = 13,123) corrected for the coverage in each grid cell in the study area from 18 aerial surveys conducted during August 1999-April 2002.

Common Scoter (Melanitta nigra)

A total of 143,465 Common Scoters was recorded during the study period and was thus the most numerous species. Except for a high count in January 2002, the seasonal and annual occurrence of Common Scoters was rather consistent with highest numbers recorded during winter and spring. Some annual variation in numbers is evident at the time of spring migration in April (Fig. 35). The Common Scoters were generally recorded in larger flocks of several hundreds of birds. The annual average number of scoters counted per transect kilometer did not change significantly between the three study years (Kruskal-Wallis test: $?^2 = 1.829$, df = 2, P = 0.401).

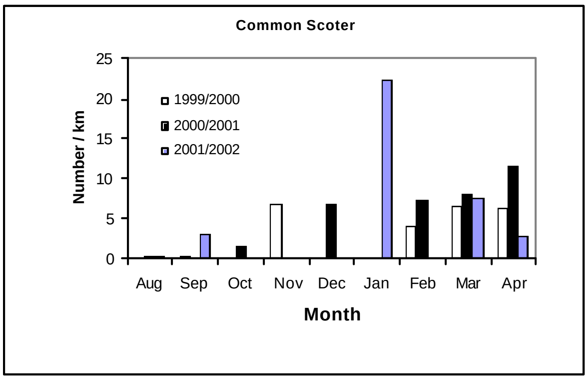


Fig. 34. The number of Common Scoters per transect kilometre recorded in 18 aerial counts during August 1999-April 2002.

The distribution of all 143,465 Common Scoters showed that the species occurred not only in the shallow coastal waters at Blåvandshuk and Skallingen, but also more offshore (Fig. 35).

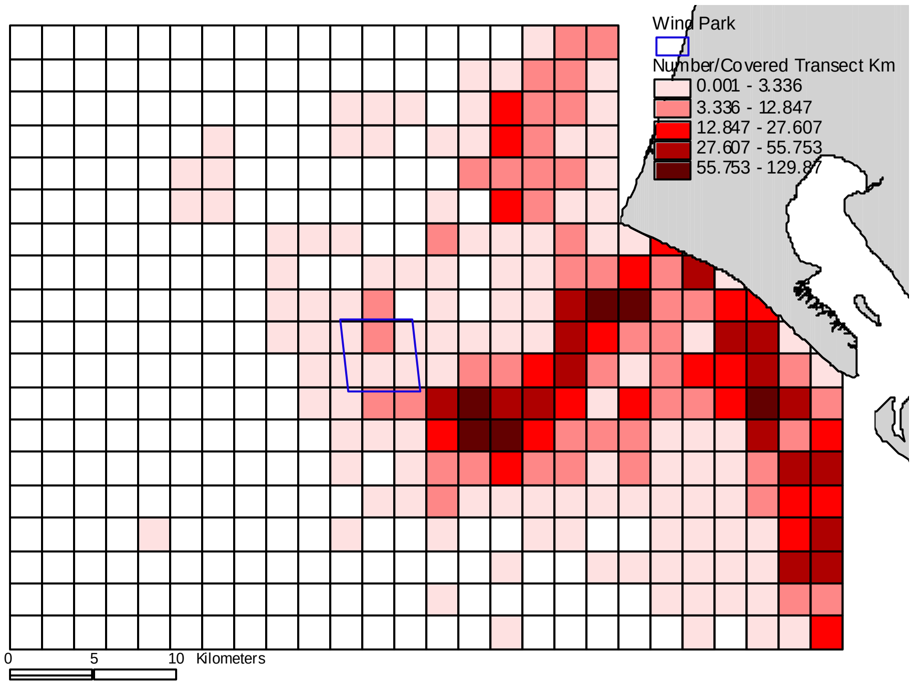


Fig. 35. The relative number of Common Scoters (N = 143,465) corrected for the coverage in each grid cell in the study area from 18 aerial surveys conducted during August 1999-April 2002.

The distribution of the Common Scoters showed consistent seasonal differences. During August-October, when numbers were low, the species occurred north and south of Blåvandshuk and Skallingen and in the southeastern parts of the study area (Fig. 36a). During November-January the species showed a similar distribution but with an increasing number of birds, especially building up in the area south of Blåvandshuk and Skallingen (Fig. 36b). During February-April the distribution changed markedly in all three study years, with an increasing number of birds occurring more offshore at the southeastern end of Horns Rev (Fig. 36c).

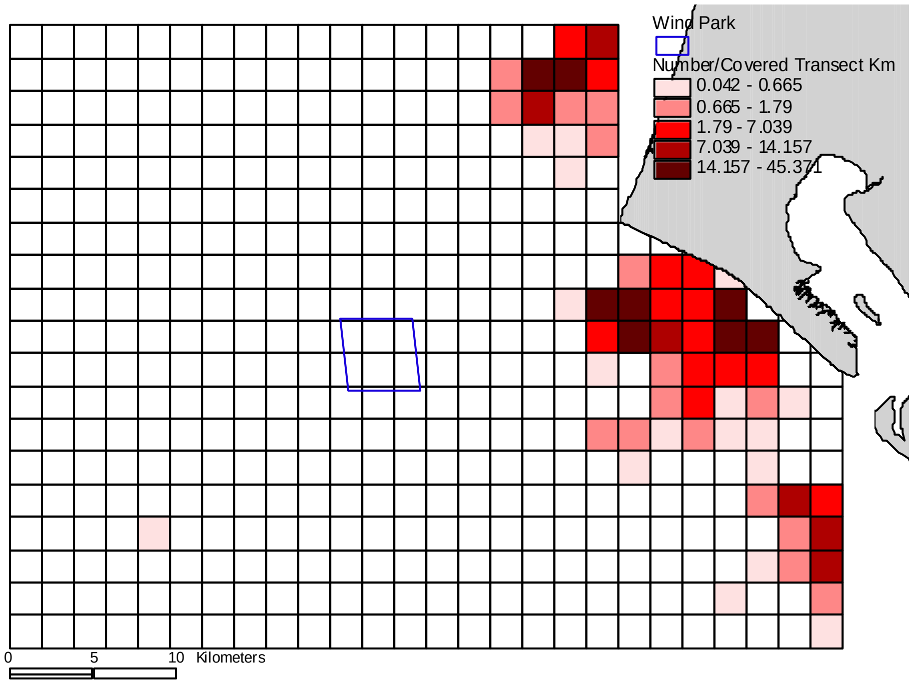


Fig. 36a

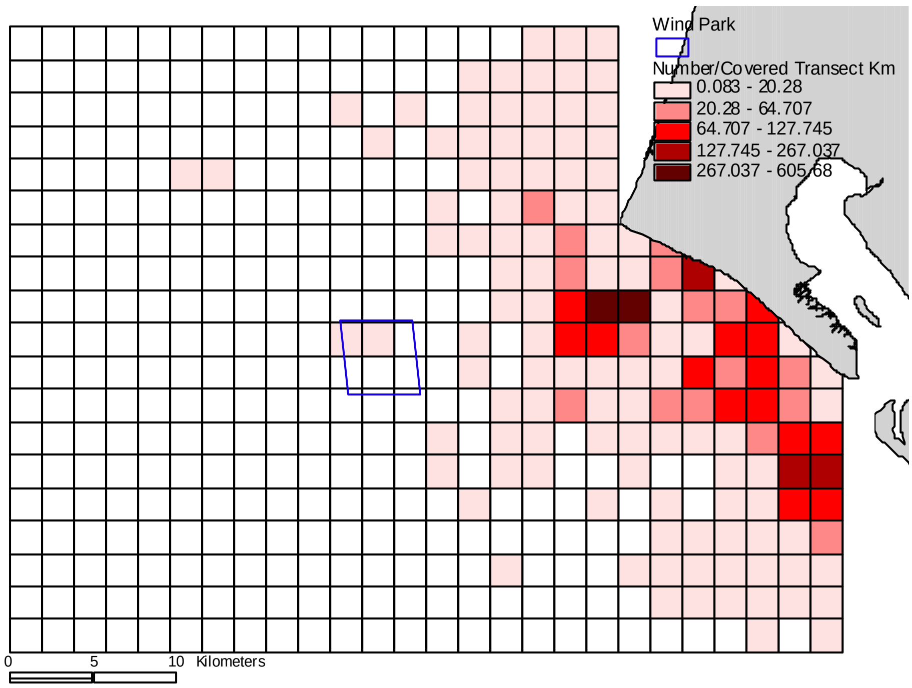


Fig. 36b

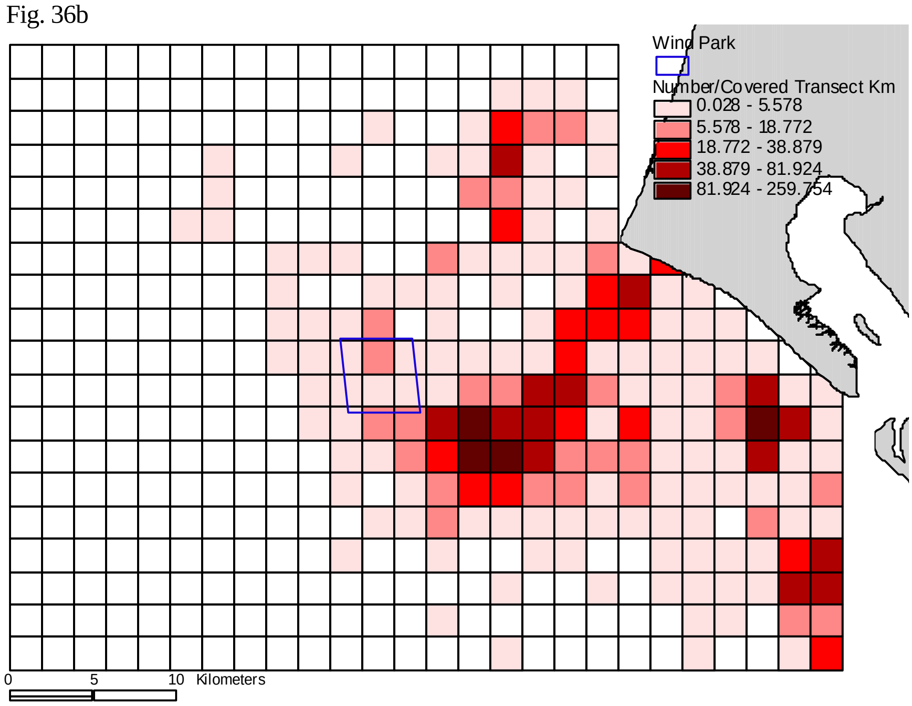


Fig. 36c

Fig. 36. The relative number of a) 7,658 scoters recorded in six aerial surveys during August-October 1999-2002, b) 49,150 scoters recorded in three aerial surveys during November-January 1999-2002, c) 86,657 scoter recorded in nine aerial surveys during February-April 1999-2002, corrected for the coverage in each grid cell.

3.2 Exploitation of the Horns Rev area during the base-line

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 from a geographical free distribution.

During the period prior to construction activities, August 1999-August 2001, most species showed a significant avoidance of the wind farm area and adjacent zones, as they occurred in lower than expected numbers (Table 3). Divers, Arctic/Common Tern and alcids occurred in expected numbers within the wind farm area and within one of two of the adjacent zones, while Gannet occurred in expected numbers within the zone comprising the wind farm area + 4 km. Only Common Scoter occurred in a significantly higher proportion than expected in the wind farm area +4 km. Consequently, as no species showed a specific preference for these areas, the wind farm area and adjacent+2 and +4 km zones did not seem, with the exception of the area of between 2 and 4 km from the wind farm for Common Scoter, to be of special importance to any of the species recorded.

Table 3. The percentage of the total number of individuals recorded prior to construction activities started (August 1999-August 2001) in the wind farm area (WF), in the wind farm area and an adjacent 2 km zone (WF +2), and in the wind farm area and an adjacent 4 km zone (WF +4). The size of each zone expressed as the percentage of transect kilometers counted within each area as a proportion of the total number of transect kilometer counted within the total study area is shown. The selectivity index of Jacobs (D) is given; negative values indicate that the species avoid the area in question, positive values that the species show preference for the area. N is the total number of individuals of the different bird species recorded during the 12 aerial counts. P is the probability values for ?^{2} one-sample test to compare values (WF column) with the values expected from a 'geographical free' distribution (*: P < 0.05; **: P < 0.01; ***: P < 0.001; ns: non significant; -: numbers to small to be tested).

Bird species/ Area	WF			WF +2 km			WF +4 km			Total
	%	D	p	%	D	p	%	D	p	
Divers	1.64	0.00	ns	5.00	0.01	ns	7.19	-0.17	**	1,279
Gannet	0.00	-1.00	**	1.98	-0.44	**	9.70	-0.01	ns	505
Arctic/Common tern	1.35	-0.10	ns	3.53	-0.17	*	8.14	-0.10	*	1,560
Sandwich tern	0.00	-1.00	*	1.83	-0.47	**	3.40	-0.51	***	382
Alcids	1.04	-0.23	ns	2.71	-0.30	**	9.18	-0.04	ns	959
Common scoter	0.55	-0.50	***	3.31	-0.20	***	11.13	0.07	***	93,642
Eider	0.01	-0.99	***	0.01	-1.00	***	0.01	-1.00	***	11,774
Skuas	0.00	-1.00	-	2.38	-0.36	-	7.14	-0.17	-	42
Common Gull	0.75	-0.26	-	1.12	-0.64	**	5.99	-0.26	*	267
Black-headed gull	0.00	-1.00	***	0.19	-0.93	***	0.19	-0.97	***	527
Herring gull	0.06	-0.94	***	0.33	-0.88	***	1.58	-0.74	***	16,236
Great Black-bagged gull	0.00	-1.00	**	1.49	-0.55	***	3.61	-0.49	***	471
Kittiwake	0.75	-0.38	**	3.01	-0.25	***	7.43	-0.15	***	2,127
Little gull	0.00	-1.00	-	2.00	-0.44	-	6.00	-0.26	-	50
Size of the area to the total area (% of transect km)	1.65			4.93			9.81			

3.3 Exploitation of the Horns Rev area during the period of construction and effects of construction activities

The preference analyses of birds in the wind farm area and adjacent +2 and +4 km during the period of construction are shown in Table 4. Including data from September 2001-April 2002, the analyses did not include Gannet, Arctic/Common Tern, Sandwich Tern, Common Gull and Black-headed Gull, which all have peak occurrence in August. However, for the remaining species, the analyses showed that the birds occurred in lower than expected numbers in the wind farm area. Considering the wind farm area +2 and +4 km zones, most species occurred in lower numbers than expected except for Herring Gull which occurred in significantly higher numbers than expected, and Great Black-backed Gull, which occurred in expected numbers.

Compared to the base-line results the preference analyses for data collected during construction indicated changed exploitation of the wind farm area and adjacent waters during this period for six bird species. Divers, alcids and Kittiwake showed a decrease in their exploitation (lower index-values) in both the wind farm area and wind farm area +2 and

+4 km zones during construction, while Herring Gull showed a consistent increase in the exploitation (higher index-values) of all zones (cf. Table 3 and 4).

Even though the preference values indicated some changes in bird exploitation of the wind farm area and adjacent +2 and +4 km zones during the period of construction, these changes was not supported by the associated statistics. Assessed from the test statistics on the preference indices, no significant changes in bird preference between the base-line period and the construction period was found for the wind farm area, e,g., a change from significant avoidance during the base-line to being non-significant or significantly attracted during the construction period. Consequently, since most species included in the analyses did not change the state of exploitation of the wind farm area significantly, nor showed the largest changes in preference-indices within the wind farm area, an impact of the wind turbines and/or associated construction activities was not be documented by this method.

Table 4. The percentage of the total number of individuals recorded during the construction period (September 2001-April 2002) in the wind farm area (WF), in the wind farm area and an adjacent 2 km zone (WF +2), and in the wind farm area and an adjacent 4 km zone (WF +4). The size of each zone expressed as the percentage of transect kilometers counted within each area as a proportion of the total number of transect kilometers counted within the total study area is shown. Data are analysed as described in Table 3.

Bird species/ Area	WF			WF +2 km			WF +4 km			Total
	%	D	p	%	D	p	%	D	p	
Divers	0.31	-0.66	-	0.62	-0.78	***	3.73	-0.46	***	322
Alcids	0.00	-1.00	-	0.00	-1.00	**	0.00	-1.00	***	207
Common scoter	0.76	-0.33	***	3.27	-0.21	***	5.11	-0.33	***	49,823
Eider	0.00	-1.00	***	0.00	-1.00	***	0.00	-1.00	-	1,349
Herring gull	0.56	-0.47	***	6.15	0.12	***	15.13	0.25	***	4,131
Great Black-bagged gull	0.00	-1.00	-	2.78	-0.29	ns	10.19	0.03	ns	108
Kittiwake	0.43	-0.56	*	0.57	-0.80	***	2.29	-0.64	***	700
Little gull	0.00	-1.00	-	1.05	-0.66	**	3.85	-0.45	**	286
Size of the area to the total area (% of transect km)										
	1.51			4.89			9.57			

To evaluate a potential disturbance or attraction effects related to construction activities, we applied a ?^{2}-two sample tests to the number of birds recorded during each base-line year on numbers recorded during the construction period in the wind farm area and in the wind farm +2 and +4 km zones respectively (Table 5). Due to low numbers of Gannet, Arctic/Common Tern, Sandwich Tern, Eider, Common Gull, Black-headed Gull and Little Gull the analysis did not included these species and was therefore restricted to the six species/groups showing changes in exploitation of the wind farm area and in adjacent +2 and +4 km zones. However, since even some of these species occurred in very small numbers in wind farm area, the tests were not completely reliable for assessments of disturbance effects in this specific area. Hence, we also evaluated changes in actual numbers in the assessment of potential disturbance effects. The results of the ?[2] analyses are shown in Table 6.

Table 5. The total number of birds recorded within the total study area and within the wind farm (WF), in the wind farm area +2 km zone (WF +2 km) and in the wind farm + 4 km zone (WF +4 km) during the base-line years and during the period of construction. Birds recorded during August 2001 are not included.

Bird species	Period		Total	WF	WF +2km	WF +4km
Divers	Base-line	1999/00	773	11	32	48
	Base-line	2000/01	504	10	32	45
	Construction	2001/02	322	1	2	12
Gannet	Base-line	1999/00	306	0	6	40
	Base-line	2000/01	136	0	1	5
	Construction	2001/02	12	0	0	0
Arctic/Common Tern	Base-line	1999/00	1,343	9	33	94
	Base-line	2000/01	217	0	3	7
	Construction	2001/02	5	0	0	0
Sandwich Tern	Base-line	1999/00	73	0	5	6
	Base-line	2000/01	298	0	2	2
	Construction	2001/02	54	0	0	1
Alcids	Base-line	1999/00	608	3	15	53
	Base-line	2000/01	334	7	11	33
	Construction	2001/02	207	0	0	0
Eider	Base-line	1999/00	3,331	1	1	1
	Base-line	2000/01	8,441	0	0	0
	Construction	2001/02	1,349	0	0	0
Common Scoter	Base-line	1999/00	41,158	4	9	55
	Base-line	2000/01	52,165	513	3,089	10,369
	Construction	2001/02	49,823	378	1,629	2,546
Common Gull	Base-line	1999/00	191	1	2	10
	Base-line	2000/01	70	1	1	6
	Construction	2001/02	21	1	1	1
Black-headed Gull	Base-line	1999/00	37	0	1	1
	Base-line	2000/01	421	0	0	0
	Construction	2001/02	15	0	0	0
Herring Gull	Base-line	1999/00	10,509	2	38	136
	Base-line	2000/01	4,905	4	11	80
	Construction	2001/02	4,131	23	254	625
Great Black-bagged Gull	Base-line	1999/00	229	0	1	9
	Base-line	2000/01	145	0	2	3
	Construction	2001/02	108	0	3	11
Kittiwake	Base-line	1999/00	1,161	11	35	83
	Base-line	2000/01	783	5	27	66
	Construction	2001/02	700	3	4	16
Little Gull	Base-line	1999/00	13	0	0	1
	Base-line	2000/01	37	0	1	2
	Construction	2001/02	286	0	3	11

The number of divers was lower in the wind farm area and in the wind farm +2 and +4 km zones during the year of construction than during the base-line (Table 5). Assessed from the ?[2] analyses, the number in the wind farm area was, however, not significantly lower during the period of construction than during the base-line seasons, whereas a significant decline was found in the wind farm area +2 km zone during construction (Table 6). The number of divers in the wind farm area +4 km was significantly lower compared to one base-line year, but not the other. Without a significant decline in the number of divers in the wind farm area there is no evidence of a disturbance effect from construction activities on the distribution of divers. However, as the lack of a significant decline in the number of divers in the wind farm area was related to the observation of one individual bird on 12 March 2002, when construction activities were related to one ship operating in the wind farm area approximately 2.5 km from the location of the bird, it may be possible that the distribution of divers to some extent may have been affected by the construction activities.

No alcids were recorded closer than 4 km from the wind farm during the construction period (Table 5), and numbers were thus lower than during the both base-line years. In the wind farm area and the wind farm area +2 and +4 km zones, the number of alcids was significantly lower during the year of construction, except in comparison with one base-line year in the wind farm area (Table 6). Considering that no alcids were observed within and close to the wind farm and numbers were significantly lower in most comparisons to the base-line years, the distribution of alcids may reflect a disturbance effect to construction activities. However, this interpretation is somewhat constricted by the lack of an October or November survey during construction, a period when alcids occurred most abundant and most scattered during the base-line period.

The number of Common Scoters recorded during the year of construction was intermediate to the numbers recorded during the two base-line years (see Table 5) and differed significantly to the base-line numbers in all comparisons (Table 6). Thus, as a result of the highly different numbers recorded during the base-line years the number recorded during the period of construction showed both a significant attraction and a significant avoidance to the wind farm and wind farm area +2 and +4 km zones when compared to the base-line result. Given this inconsistency it could not be assessed whether the distribution of Common Scoters during the period of construction was affected by construction activities.

Herring Gulls were recorded in higher numbers in the wind farm area and in the wind farm area +2 and +4 km zones during the year of construction than during both base-line years (see Table 5). Compared to the base-line numbers the increase was significant in all comparisons (Table 6). Thus, Herring Gulls showed a consistent attraction towards the wind farm area during the year of construction.

During the year of construction the number of Great Black-backed Gulls recorded in the wind farm and in the wind farm area +2 and +4 km zones were comparable to numbers recorded during the base-line (Table 5). As the number of Great Black-backed Gulls only showed an inconsistent significant attraction in the wind farm area + 2 and +4 km (Table 6), construction activities were not found to have affected the distribution of Great Black-backed Gull.

Kittiwakes were recorded in low numbers in the wind farm and in the wind farm area +2 and +4 km zones during the year of construction (Table 5). In the wind farm area, numbers did not deviate significantly from numbers recorded during the base-line years (Table 6). In the wind farm area +2 km and in the wind farm area +4 km a significant lower number was recorded during construction. However, as no effect was recorded within the wind farm area during construction and the number of Kittiwakes observed during the base-line years varied, there is no reason to believe that disturbance effects from construction activities have affected the distribution of this species.

Table 6. Results of frequency analyses (two-sample ?^{2}, df=1 in all comparisons) of the numbers recorded within and outside the wind farm area, the wind farm area + 2km and the wind farm +4 km during the base-line years (99=1999/2000 and 00=2000/2001) and during the year with construction activities (01=2001/2002). In cases of more than 25% of the cells have expected values less than 5, Fisher's Exact test (F) was applied. Whether higher or lower numbers are recorded during the year of construction compared to the base-line year is indicated for each comparison as either low or high. ns = non-significant, * = P<0.05, ** = P< 0.01, *** = P<0.001.

Area			WF		WF +2		WF +4	
Bird species	Years compared	Numbers in last year	?^{2}	P	?^{2}	P	?^{2}	P
Divers	99 vs. 01	low	F	ns	8.30	**	2.31	ns
	00 vs. 01	low	F	ns	15.03	***	7.60	**
Alcids	99 vs. 01	low	F	ns	F	*	20.26	***
	00 vs. 01	low	F	*	F	**	21.78	***
Common Scoter	99 vs. 01	high	298.63	***	1,381.74	***	1,995.33	***
	00 vs. 01	low	15.34	***	376.98	***	5,073.17	***
Herring Gull	99 vs. 01	high	44.90	***	418.68	***	1,006.25	***
	00 vs. 01	high	14.54	***	228.83	***	489.10	***
Great Black-backed Gull	99 vs. 01	high	-	-	F	*	2.320	ns
	00 vs. 01	high	-	-	F	ns	4.383	*
Kittiwake	99 vs. 01	low	1.90	ns	12.75	***	16.74	***
	00 vs. 01	low	F	ns	14.99	***	22.89	***

3.4 Detectability of permanent effects

The main objective of the base-line study of bird numbers and distribution in the Horns Rev area has been to provide a data set to which future changes in the occurrence of birds can be compared.

In the present study we applied a ?^{2} two-sample test to detect changes in bird occurrence within and close to the wind farm area during the period of construction. We applied the same test in assessing the power to detect changes in the distribution of birds after the wind farm is in operation. In these analyses we only include species which have occurred in reasonable numbers in the vicinity of the wind farm area or otherwise are considered to be of interest in relation to the wind farm, i.e., species that may be susceptible to collision risk.

To assess the disturbance/attraction effects within the wind farm area and in the wind farm area +2 km and +4 km zones we compared the numbers recorded in separate base-line years against reductions and increases in bird numbers. To assess the magnitude of decreases in bird numbers (disturbance) that would be significant compared to the base-line numbers we tested the numbers of birds recorded during each base-line year against reductions of 10%, 25%, 50%, 75% and 100% in the wind farm area and in the wind farm area +2 and +4 km zones, respectively. To assess the magnitudes of increase (attraction) that would be significant compared to the base-line we tested the base-line numbers against actual increases in bird numbers, as proportional increases could not be applied as several birds had not been recorded within the areas of interest during the base-line period. Assessments of significant attraction were only made for the wind farm area.

Generally the results were not consistent for the analyses made on separate base-line years, as the numbers recorded in these years varied considerably. This was especially evident in species that mainly occur in the Horns Rev area during migration and do not stage for extended periods in the study area.

3.4.1 Disturbance effects

The wind farm area

With a number of divers recorded during one year of wind farm operation that is comparable to the number recorded during the base-line years, a reduction in numbers in the wind farm area during wind farm operation should be 100% in order to demonstrate a significant disturbance effect. For Arctic/Common Tern, alcids and Kittiwakes reductions should be 75%-100% compared to the numbers recorded during one of the two base-line years to turn out significant. Compared to numbers in the other base-line year no significant reductions would be found for these species. Likewise, a reduction of 10%-25% in the number of Common Scoter compared to numbers in one base-line year would turn out significant, whereas no significant result was obtained even by a reduction of 100% of the number recorded in the other base-line year. Herring Gulls occurred in too low numbers in the wind farm area during the base-line years to allow meaningful tests of reductions. - In terms of actual numbers, significant decreases in bird numbers in the wind farm area would involve reductions of not more than 12 individuals of each of the analysed species, except for Common Scoter which should be reduced by at least 130 individuals.

The wind farm area +2 km

Detection of significant reductions was more consistent in the wind farm area +2 km zone. For this area, reductions in bird numbers of 25-50% would be significant for divers, Arctic/Common Tern, Herring Gull and Kittiwake compared to the numbers recorded during both base-line years. For alcids significant reductions would concern 50-75% and 75-100% of the base-line numbers respectively, while reduction in the number of Common Scoter would be significant with reductions of 75-100% and <10% compared to numbers recorded during separate base-line years. - For the wind farm area +2 km zone, significant reductions would involve at least 310 Common Scoters and not more than 20 individuals of all remaining species.

The wind farm area + 4 km

In the area comprising the wind farm +4 km zone, reduction of 25-50% of divers, Arctic/Common Tern, alcids and Kittiwake during wind farm operation would be significant. Significant reductions in the number of Herring Gull and Common Scoter in this area were different for the two base-line years, being 10-25% and 25-50% for Herring Gull and 25-50% and <10% for Common Scoter, respectively. - For the wind farm area +4 km zone, significant reductions would involve at least 1,050 Common Scoters and 24 - 68 individuals of the other species.

3.4.2 Attraction effects

Attraction of divers to the wind farm during operation should include an increase by 100-150% (at least 16 individuals) compared to the number recorded during the base-line study to demonstrate a significant effect. Similarly, attraction of other species to the wind farm during operation compared to the base-line numbers include 10 - 16 individuals of Gannet, Arctic/Common Tern, Sandwich Tern, alcids, Common Gull, Black-headed Gull, Herring Gull, Great Black-backed Gull and Kittiwake in order to be significant. The number of Common Scoter should increase by at least 100 individuals to demonstrate a significant attraction effect.

4. Discussion and conclusions

4.1 Data representability

The study of bird occurrence and distribution in the Horns Rev area during the period August 1999-April 2002 relies on 18 aerial surveys performed during single days at selected times of the year. The count dates were selected to cover periods in which the number of migrating and/or staging bird species was present in high numbers. On these days, however, the surveys only provide a 'snap-shot' of the distribution of the different bird species. Likewise, with a total of 5-7 surveys per year, the base-line study can only provide a coarse picture of the general phenology of bird species present at Horns Rev and not establish a detailed view of the natural seasonal variation in bird occurrence.

As discussed by Noer et al. (2000), aerial surveys were considered the most effective method to record data on bird occurrence and distribution. However, the practical performance of aerial surveys puts on some constraints on the collected data that needs to be mentioned.

Firstly, aerial surveys are performed on calm and clear days with a wind speed of less than 6 knots to enable observers to detect birds sitting on the water. This dependency on calm weather conditions has resulted in some variation in the timing of planned surveys leading to some month being covered only one or two times during the study period. Consequently, for some periods, especially during the autumn, the results may not provide a proper picture of the natural variation in bird numbers that may occur at these times. However, the observed number of the different species recorded during the base-line study is generally comparable to the phenology of these species recorded at Blåvandshuk since 1963 (Kjær 2000, Jacobsen in prep). Thus, the number and timing of occurrence of seabird species recorded during the three study years is considered representative in so far the present data do not deviate from what is considered as normal variation.

Counts performed during calm weather conditions may also lead to non-representative count results of the number of some pelagic seabird species. During periods of strong westerly winds, species like skuas, Gannet and Fulmar are known to occur in higher numbers in the eastern parts of the North Sea and along the west coast of Denmark than during calm periods. In the present study these species are recorded in very low numbers probably reflecting the calm weather conditions used in the present aerial surveys.

Secondly, aerial surveys have normally been conducted between 10 a.m. and 6 p.m. on individual count dates. The results thus in general reflect the number and distribution of bird species present in the area during mid day. Thus for some species which have peak periods of foraging activity during early morning and evening, the count results do not necessarily reflect the distribution of these species during periods of foraging.

4.2 Base-line results

4.2.1 Within-year and between-year variation in bird numbers at Horns Rev

Large within-year and between-year fluctuations in seabird abundance as well as in distribution is well known in both migrating and wintering species occurring in Danish waters (e.g., Laursen et al. 1997, Pihl et al. 2001). Although much variation in the number of migrating and wintering birds is known to be related to variation in environmental factors such as severity of winter and the onset of spring and autumn, bird numbers may also be influenced by factors affecting breeding success in breeding areas far from Danish waters.

The within-year variation recorded in the most abundant species during the base-line study did not show any major deviation from what could be expected from comparison with the seasonal occurrence of these species at Blåvandshuk 1963-1999 (Kjær 2000, Jacobsen in prep.). Marked within-year variation in numbers was found in species with distinct migration periods, e.g., Kittiwake, Arctic/Common Tern, Sandwich Tern and Black-headed Gull, with high numbers during spring and autumn migration. The Common Scoter showed a marked within-year variation during 2001/2002 (Fig. 34) with a high number recorded in January 2002 following a cold period in December 2001. High numbers of both Common Scoter and Eider at Blåvandshuk during mid-winter are normally observed in cold winters when these species leave inner Danish waters and move to the Wadden Sea (Jacobsen in prep) although the high number of Common Scoter was not matched by high number of Eider in 2002.

Marked year-to-year variation in the abundance of the birds in the Horns Rev area during the base-line study was generally found in species that migrated through the area, e.g., terns, Gannet and Kittiwake with less pronounced variation found in staging and wintering species, e.g. divers, Herring Gull and Common Scoter.

Although no species in the present study showed significant year-to-year variation in numbers, some variation existed. Most markedly, variation was found in migrating species in which the timing and intensity of migration may be influenced by varying weather conditions. Likewise peak migration may vary in relation to the timing of aerial surveys resulting in variable count results, e.g., the recorded variation in the occurrence of Gannets may reflect different timing of the survey to the short and intense peak migration period of Gannets in autumn (mainly September) or reflect differences in weather conditions prior to the surveys, as the local occurrence of Gannets in the Horns rev area may be influenced by weather (cf. Jacobsen in prep.). Of the wintering species, both the Eider and Common Scoter showed pronounced between-year variation. As previously mentioned the abundance of these species in the Wadden Sea area are known to vary in relation to severity of the winter.

4.2.2 Seabird use of the Horns Rev area

Assessed from the numbers and spatial distributions of birds obtained during the two base-line years, the Horns Rev area in general, and the wind farm area in particular, was found not to be important to the bird species recorded. Most species were recorded in very low numbers or in low proportions within the wind farm area and showed no preference for this area at all. Only divers, Arctic/Common Tern and alcids were found within the wind farm area in numbers that could be expected from a free geographical distribution (see Table 3). All other species showed a negative preference for the wind farm area. Including the adjacent zones around the wind farm, divers were recorded in expected numbers within the wind farm area +2 km and Gannet and alcids were recorded in expected numbers in the wind farm area +4 km. The only species that was recorded in higher than expected numbers was the Common Scoter, which showed significant preference for the wind farm area +4 km (see below).

There was a clear difference in the spatial pattern between species foraging on fish and pelagic invertebrates and species foraging on sessile benthic fauna. Species foraging on fish and pelagic food were generally distributed in the offshore parts (more than c. 2 km from the coast) of the study area. These species were generally dispersed throughout the study area. Species foraging on sessile benthic fauna (Eider and Common Scoter), were much more restricted in their distribution and occurred more coastal. In most cases these species were observed close to Blåvandshuk and Skallingen, although a relatively high number of Common Scoters consistently exploited the area south-east of Horns Rev, especially during the late winter and early spring.

The relatively high number of Common Scoter at a distance between 2 km and 4 km from the wind farm during late winter and spring occurred consistently in both base-line years although most markedly during the last year, and also during the year of construction. It is not known why the Scoters concentrate in this area. Located at the edge of the reef proper, this area may offer some profitable foraging conditions in early spring, e.g., the species may exploit the bristle worms community at the reef (Bio/consult/Carl Bro 2000) at this time, or potentially feed on fish or eggs from spawning fish that may concentrate in this area by updwelling currents. Alternatively, the Common Scoter may gather in this area as part of a social pattern in the timing of spring migration.

4.3 Effects of construction activities

The overall numbers of all bird species recorded in the total study area during the period of construction did not deviate from the numbers recorded during the base-line years. Even though some species recorded within the wind farm area and the wind farm area +2 km and +4 km zones showed changes in their exploitation of these areas during the period of construction, statistical analyses did not find any consistent significant reductions in the observed bird numbers which indicate a disturbance effect from the construction activities. An increase in the number of Herring Gulls was, however, consistently significant compared to the base-line results, which strongly suggested that Herring Gulls were attracted by the construction activities.

In general, the low and variable number of birds consistently recorded within the wind farm and adjacent +2 and +4 km zones makes assessments of potential disturbance effects very tentative as accidental occurrence of even a few individual birds may change the test results. Likewise, the varying levels and extent of actual construction activities on the different survey dates does not constitute a uniform source of disturbance to which data can be compared, and to which different species may react differently and even possess seasonal variation in sensitivity. Furthermore, assessments of disturbance effects were restricted for several species, as data during the period of construction was not obtained in the period of peak occurrence of these species.

Despite the present programme was unable to generate data sufficient to produce statistical detection of disturbance effects from the construction activities, the number of divers and alcids within and close to the wind farm area was consistently higher during the base-line years than the numbers recorded during the period of construction. During construction, one diver was recorded in the wind farm area compared to 11 and 10 individuals during the two base-line years, respectively. This individual was observed more than 2.5 km from the closest construction activities in the wind farm area (one active ship) and more than 3 km from the scaffolds of the transformer station in March 2002, at which time no turbines or turbine foundations were erected. In April 2002 when the construction activities concerned a much larger area and several turbines were erected, no diver was observed closer than 2 km from the wind farm area. Thus for divers, an avoidance due to construction activities can not be ruled out.

During the period of construction, no alcids were recorded closer than 4 km from the wind farm area and only one bird was recorded within a distance of 6 km from the wind farm. However, an assessment of disturbance effects from construction activities on the distribution of alcids is greatly hampered from the lack of data from October-November, as the occurrence of alcids peak during this period. The base-line study demonstrated during autumn the most variable distribution with maximum numbers recorded within and close to the wind farm area. Despite the lack of data from this period, a complete avoidance of especially the areas comprising the wind farm area and 2 km and 4 km zones during the period of construction suggests, that the construction activities and even the presence of the poles and associated scaffolds for the transformer station, may have affected the distribution of alcids.

In Herring Gull an attraction effect was found during the period of construction. Throughout the study period the Herring Gull has generally been recorded in high numbers around ships in the study area. Thus the high number recorded within and close to the wind farm area during the period of construction may be an immediate effect of increased ship activity in the area as well as the erection of turbine foundations may have provided platforms used for perching.

In conclusion, the present analyses only found statistical evidence for an attraction effect on Herring Gulls to construction activities at Horns Rev. For species showing a decrease in numbers in the area within and close to the wind farm area, no consistent change in the occurrence of birds could be documented that would indicate a disturbance effect related to construction activities.

Effectively, a disturbance effect from the operating wind farm should for all species, except the Common Scoter, result in a complete abandonment of the wind farm area before any conclusive assessments concerning disturbance effects can be made. However, to safeguard interpretations of disturbance effects even in the case of a complete abandonment of the wind farm area, a significant disturbance effect should preferably also be detected at least in the wind farm +2 km zone in order to elude the high probability of recording no birds in the wind farm area. An attraction effect to the wind farm, on the other hand, seems for most species to be readily detectable, as such an effect is dependent on a relatively low increase in the number of most species.

Considering that disturbance effects from the operating wind farm results in a complete abandonment of the wind farm area, and birds even abandon the wind farm of up to 2 km, the number of birds affected will be so low that it probably has no biological relevance to these species. Of species recorded within and close to the wind farm (divers, terns, alcids and Common Scoter) the numbers that potentially would be affected are inferior compared to the total populations or flyway populations of the species comprising thousands or tens of thousands of birds in this part of Danish waters (cf. Noer et al. 2000). Likewise, the habitat loss associated with a complete abandonment of the wind farm corresponds to an area of c. 20 km^2 that previously was of no major importance to bird species occurring in the Horns Rev area. Consequently, even if the ongoing programme will be able to detect significant disturbance effects from the operating wind farm, the small number of birds and low importance of the wind farm area suggests that such potential effects will be of no biological or ecological significance to bird species occurring in the area.

4.4 Statistical power of the monitoring programme

In the present report, the power to detect changes in the numbers and distributions of species occurring within the wind farm, the wind farm area +2 km and the wind farm area +4 km, was assessed using ?^{2}-tests comparing base-line numbers to varying decreases and increases. Although the low and variable number recorded within and close to the wind farm during the base-line years made assessments of significant reduction tentative, the present analyses demonstrated that for most species, and with the exception of Common Scoter, a complete abandonment of the wind farm area would effectively be detectable with statistical confidence. In the wind farm area +2 and +4 km zones, detectable reductions would in general comprise reductions of between 25% and 50% of the base-line numbers.

As this test relies on the number of birds included, the present results of the estimations of detectable changes are sensitive to variation in bird numbers to be recorded during the annual surveys. In general, an increased number of birds included will lead to a higher power, detecting smaller changes in the number of birds in the areas in question with statistical significance.

The original number of six annual surveys each covering periods dominated by different bird species have been considered as a minimum number to describe the number and distribution of bird species occurring at Horns Rev during the annual cycle. Likewise, the low numbers of birds generally recorded within the study area during each survey and specifically within and close to the wind farm emphasise that six annual surveys are at a minimum. Thus, a reduction in the number of annual surveys will inevitably reduce the number of birds recorded and specifically of species having peak occurrence in the periods that will not be covered.

Increasing the number of birds to be recorded within the wind farm area, and thus the power of detecting changes, can be done by increasing the annual number of aerial surveys during the coming years. However, to fully benefit from an increased frequency of aerial surveys from the present average of six surveys per year, the numbers of surveys should at least be doubled to cover the periods of peak occurrence of all relevant species.

The ‘uncoordinated’ timing of aerial surveys and occurrence of birds generally resulted in more variable numbers recorded of species that migrate through the area and more stable numbers of staging and wintering species. Consequently, an increased survey effort will be most beneficial when targeted at staging and wintering species. At Horns Rev, an optimal survey strategy may be to increase the number of surveys in periods with high numbers of staging species, e.g., divers, alcids and Common Scoter, and decrease the number of surveys in periods dominated by migrating species, e.g., terns and Gannet. Such changes in the present programme are currently under consideration.

4.5 Conclusions

Based on data of bird occurrence obtained during the base-line period, August 1999-April 2001, and during the year of wind farm construction, August 2001-April 2002, in the Horns Rev area, the following conclusions can be made:

1. The planned wind farm area, representing c. 1.2% of the study area, was of no particular importance to bird species recorded in the Horns Rev area. Bird numbers were generally very small in the wind farm area and in the adjacent 2 km and 4 km zones.

   In consequence, a disturbance effect from the operating wind farm on bird exploitation of the area within and close to the wind farm is expected to be limited. If the birds totally avoid exploiting the wind farm area due to disturbance, less than 1% of the different species in the study area will be affected, except for divers (1.64%), Arctic/Common Tern (1.35%) and alcids (1.06%). If the birds should totally avoid the wind farm and the adjacent 4 km zone this will affect c. 11% of the Common Scoter, c. 10% of the Gannet, 6-9% of the divers, Arctic/Common Tern, alcids, skuas, Common Gull, Kittiwake and Little Gull, while the corresponding proportions of the remaining species in the study area will range between 1-4% (cf. Table 3). Compared to the size of the total populations or flyway populations of the species known to occur in the Horns Rev area, the number of bird that may be affected constitute an inferior proportion, implying that the habitat loss is of no biological relevance.

2. The distribution of birds in the study area showed distinctive differences. Fish-eating species (divers, alcids and gulls) generally showed a variable and widespread occurrence in the offshore part of the study area. Species foraging on sessile benthic prey (Eider and Common Scoter) showed much more constant and restricted distributions associated with the coastal zone with shallow water.

   Several species showed a consistent seasonal pattern in their distribution in the study area. Most strikingly was the aggregation of Common Scoter at the southeastern slope of the Horns Rev during spring, resulting in the relatively high number recorded especially at a distance of between 2 and 4 km from the wind farm. The reason for the exploitation of this area by the Common Scoter is unknown.

3. Based on the low and variable numbers of birds recorded within and close to the wind farm during the base-line study, the power to detect changes in bird numbers was somewhat tentative. The probability of detecting a disturbance effect from the operating wind farm would effectively need a complete abandonment of the wind farm area, but even in that case the low number of birds makes any assessment of disturbance effects very provisional for this area. Considering the wind farm area +2 km and +4 km zones, the analyses proved more reliable due to higher number of birds included. In these areas a reduction in the number of birds of between 25-50% would in general be detectable with statistical confidence.

4. Compared to the occurrence of birds during the base-line, slight differences in bird exploitation of the wind farm area and wind farm +2 km and +4 km zones were found during the construction phase. However, the analyses showed that the bird numbers within and close to the wind farm area were not consistently and significantly reduced during this period. Assessed from the actual numbers observed in the wind farm area and the wind farm +2 and +4 km zones, divers and alcids occurred in markedly lower numbers at a distance of more than 2.5 km to actual construction activities suggesting that these species avoided these activities.

   The Herring Gull showed a significant attraction to the wind farm area and to the wind farm +2 and +4 km zones during the construction phase. This species generally aggregates around ships in the offshore habitat and may have been attracted both by ship activities and/or by the possibility to rest on turbine foundations erected in the wind farm area.

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Appendix 1. Constructions activities on days with aerial bird surveys August 2001-April 2002.

Bird surveys	Transformer station		Wind turbines		
	Type of activity		Type of activity	Activity on turbine no.[1]	Erected turbine foundations[1]
22 August 2001	No activity				
26 September 2001	Installation of basic frame (Rambiz)				
7 January 2002	No activity				
12 March 2002	No activity		Deposition of erosion cover	01, 11	
9 April 2002	Mounting of poles		Deposition, ramming of poles and mounting of turbines	01, 42, 45, 46, 47, 58, 61, 91	01, 41, 51, 61, 71, 81, 91

1 Numbers refer to turbine number. Turbine 01 is located at the northwestern corner of the wind farm with 02, 03 to 08 located on a line to the south; turbine 91 is located at the northeastern corner with 92 to 98 located on a line to the south.

Appendix 2. Birds observed at Horns Rev during 18 aerial surveys during August 1999-April 2002. The list includes both identified species and birds identified to groups.

Species/Date of survey	19990803	19990903	19991112	20000217	20000221	20000319	20000427	20000821	20001006	20001222	20010209	20010320	20010421	20010822	20010926	20020107	20020312	20020409	Total
Red-/Black-throated Diver (Gavia stellata/arctica)	23	5	56	314	106	129	113	6	23	38	192	149	87	2	3	54	126	138	**1564**
Red-throated Diver (Gavia stellata)			15			12					9								**36**
Black-throated Diver (Gavia arctica)																	1		**1**
Great Northern Diver (Gavia immer)/White Billed Diver (Gavia adamsii)					1														**1**
Red-necked Grebe (Podiceps griseigena)								1											**1**
Great creasted Grebe (Podiceps cristatus)													1						**1**
Grebe sp. (Podiceps sp.)																4			**4**
Fulmar (Fulmarus glacialis)	3	16						1	38			1			1	3			**63**
Gannet (Sula bassanus)	25	266	2			6	7	33	42			1	60	63	10		1	1	**517**
Cormorant (Phalacrocorax carbo)	3	2	1				2	80			1	20	2	25	32				**168**
Whooper swan (Cygnus cygnus)										13									**13**
Greylag goose (Anser anser)																		44	**44**
Pink-footed goose (Anser brachyrhyncus)													25						**25**
Brent goose (Branta bernicla)							9								15				**24**
Canada goose (Anser canadensis)								2											**2**
Shelduck (Tadorna tadorna)																		1	**1**
Mallard (Anas plathyrynchos)				2		2	4												**8**
Teal (Anas crecca)													4						**4**
Widgeon (Anas penelope)															31				**31**
Pochard (Aythya ferrina)									1										**1**
Goldeneye (Bucephale clangula)											1								**1**
Long-tailed duck (Clangula hyemalis)											5	1							**6**
Eider (Somateria mollissima)		5	458	2114	181	476	97	37	42	2062	5438	763	99	2	3	823	448	75	**13123**
Common Scoter (Melanitta nigra)	68	119	10231	7190	3861	10459	9230	283	2208	8436	11041	13295	16902	319	4661	30483	10877	3802	**143465**
Velvet Scoter (Melanitta fusca)			28				16		1	19	58	148	343	2	2	4	5	5	**631**
Red-breasted merganser (Mergus serrator)				3		1						2	2		12				**20**
Oystercatcher (Haematopus ostralegus)			1					39					2						**42**
Lapwing (Vanellus vanellus)					1														**1**
Grey Plover (Pluvialis sqatarola)	5								8										**13**
Golden Plover (Pluvialis apricaria)						2				55									**57**
Bar-tailed Godwit (Limosa lapponica)								14											**14**
Redshank (Tringa totanus)								1											**1**
Turnstone (Arenaria interpres)							2												**2**
Sanderling (Calidris alba)			19				9							10					**38**
Dunlin (Calidris alpina)			20																**20**
wader sp. (Calidris sp.)	16																	15	**31**
Great Skua (Stercorarius skua)	1	1	1				1												**4**
Arctic Skua (Stercorarius parasiticus)		20	1											15	1				**37**
Arctic/Pomarine/Long-tailed skua							1	5											**6**
Common Gull (Larus canus)	110		38		13	3	27	7	6	7	5	34	11	6	10	3	6	2	**288**
Herring Gull (Larus argentatus)	254	699	236	4025	3327	1857	112	775	193	230	672	1169	1866	822	856	918	1553	804	**20368**
Lesser Black-backed Gull (Larus fuscus)	9	1				3	1	39	3				1	29	6			2	**94**
Great Black-backed Gull (Larus marinus)	19	129	21	4	14	31	11	55	24	2	5	3	56	97	60	27	18	3	**579**
Black-headed Gull (Larus ridibundus)	8	13		1	1	14		164	1		3		253	69	13	1	1		**542**
Little Gull (Larus minutus)			8			5				5	5	26	1		1	76	82	127	**336**
Kittiwake (Rissa tridactyla)	186	324	520	18	41	70	2	579	35	17	30	14	108	183	251	145	304		**2827**
Gull sp. (Larus sp.)		13		2	4	1		16	30	3			670		5				**744**
Common Tern (Sterna paradisea)			5					2											**7**
Arctic Tern (Sterna hirundo)	692	100				1	545												**1338**
Common/Arctic Tern (Sterna paradisea/hirundo)								175					40	844	4			1	**1064**
Sandwich Tern (Sterna sandvicensis)	48	12				1	12	67					231	11	37		4	2	**425**
Terns sp. (Sterna sp.)								47				3	24	3				2	**79**
Little Auk (Alle alle)									3								3		**6**
Razorbill (Alca torda)			9		3		2			1			1			5			**21**
Guillemot (Uria aalge)		4	3	3	4	2		12	18			2	1	1					**50**
Guillemot/Razorbill (Uria aalge/Alca torda)		59	372	59	67	18	3	48	162	35	32	14	8	16	36	104	60	3	**1096**
Puffin (Fraternica arctica)									1										**1**