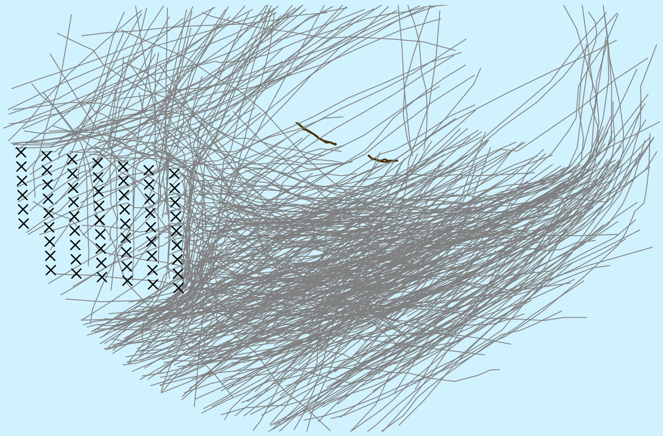
National Environmental Research Institute
Ministry of the Environment · Denmark

Investigations of birds during construction and operation of Nysted offshore wind farm at Rødsand

Annual status report 2003

Report Commissioned by Energi E2 A/S 2004



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Data sheet

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Information Note

This information note summarises the framework for the three annual status reports for 2003, concerning bird studies in relation to the offshore wind farms at Nysted in the Baltic Sea and Horns Rev in the North Sea.

The three reports are:

Christensen, T. K., Hounisen, J. P., Clausager, I. & Petersen, I. K., 2004: Visual and radar observations of birds in relation to collision risk at the Horns Rev offshore wind farm. Annual status report 2003. - 48 pp.

Kahlert J., Petersen I. K., Fox A. D., Desholm M. & Clausager I. 2004: Investigations of birds during construction and operation of Nysted offshore wind farm at Rødsand. - Annual status report 2003. – 82 pp.

Petersen, I. K., Clausager, I. & Christensen, T. K., 2004. Bird numbers and distribution in the Horns Rev offshore wind farm. - Annual status report 2003. - 36 pp.

Bird studies are to be carried out at Nysted and Horns Rev during the period 1999-2006 under the permitting tems for wind farm construction at the two sites, granted by the Danish authorities. The bird studies are carried out before, during and after construction of both wind farms.

The installation of wind turbines was finished in autumn 2002 (Horns Rev) and summer 2003 (Nysted). Hence, the annual status reports for 2003 merely represent data from one year or less during the initial operational phase of the wind farms. Thus, natural variation between years, seasons, species and sites and the possible habituation effects during the operational phase could not be considered. Therefore, it must be emphasised that the tendencies, suggested by the results in all three annual status reports are to be considered as preliminary, and must await further compilation of data, before firm conclusions can be drawn with respect to impact on birds.

The final environmental impact assessment for the two wind farms is planned to be undertaken upon termination of the environmental monitoring programmes in 2006.

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Synopsis

This report presents data on monitoring investigations of birds carried out during spring and autumn 2003 in relation to the Nysted offshore wind farm at Rødsand.

Information presented covers the spring migration period of 2003 during which the wind farm was under construction. Observations therefore reflect the reactions of migrating birds to the presence of foundations and the support ships in the vicinity.

Data are also presented for autumn 2003 by which time all the turbines had been erected and were in operation.

Migration routes were mapped using the same techniques as those used during the base-line investigations of 1999-2002, combining radar techniques by day and night with specific species identification during daylight hours using telescopes. Radar tracks were entered to a GIS platform to compare the base-line with subsequent monitoring results. Emphasis was placed upon three key variables:

1) the orientation of autumn migration routes for waterbirds and terrestrial species to measure potential avoidance responses and response distances,

2) the probability that waterbirds will pass through the wind farm area during autumn and spring, to measure waterbird responses to the entire wind farm,

3) migration intensity, measured by the number of bird flocks that pass the eastern and northern edge of the wind farm area, to measure the effect of avoidance responses on the volume of migration within the wind farm area.

Comparisons of these key variables between individual base-line years were undertaken by controlling for various factors such as weather conditions, season and time of day using multi-factor ANOVA and regression analyses.

In addition, the distribution and abundance of waterbirds, which included spring migrants and wintering birds, were monitored in and around the wind farm by sequential aerial surveys as during the base-line years.

The wind farm area is situated on a major waterbird migration route, used by up to 300,000 individuals in autumn. The intense migration of waterbirds was confirmed by base-line observations in 1999-2002 and during the construction and operational phases in 2003.

Autumn migrating waterfowl showed significant differences in their mean orientation within the approaching area of the wind farm between all four years of investigation. The analyses of the orientation of individual bird flocks in relation to their distance from the wind farm showed that the year-effect differed across years dependent on the distance from the wind farm. Due to small sample sizes and certain wind conditions the wind effects found in the baseline studies could not be incorporated into the 2003 analyses. It was therefore not possible to demonstrate a convincing change in migration orientation at a specific distance from the wind farm following construction of the wind farm. However, the standard deviation of migration orientation increased significantly during the daytime at distances closer than 3000 m to the wind farm in 2003 and closer than 1000 m during the night. These results support the hypothesis that migrating birds show a response to the wind farm, specifically reacting by increased lateral avoidance to the north and south of the wind farm. They also conform to the predictions under the hypotheses that (i) the deflection will occur close to the wind farm and (ii) that the deflection will occur closer to the wind farm at night than during the day.

Observations in autumn 2003 offered no support for a severe avoidance response to the wind farm, in terms of a substantial reverse migration of birds turning back eastwards from the eastern edge of the wind farm compared with the base-line.

Base-line studies showed that between 24% (2002) and 48% (2000) of tracks registered in autumn by radar passed the eastern border of the proposed wind farm area. After the wind turbines were erected in 2003, significantly less (9%) tracks of waterbird flocks registered by radar passed the eastern border. This result was confirmed controlling for the effects of cross-winds, time of day (4-7% by day compared to 11-24% by night) and latitudinal position.

Generally, the major spring migration route of waterbirds lies north of the wind farm area. During spring 2003, 11% of all migrating waterfowl tracks passed the eastern edge of the wind farm area, less than in 2001 (16%) and 2002 (25%), but the difference was not significant during the day. Hence, during daylight hours there was no support for the hypothesis that birds avoided the wind farm area during the construction phase in spring 2003.

Data relating to migrating land birds are not discussed in any great detail in this report. Temporary suspension of the studies in autumn 2002, extremely low spring migration intensities of raptors, pigeons and passerines in all years provide insufficient information for a full analysis of the effects on these species during construction and operation of the wind farm.

Waterbird migration intensity within the wind farm area varied considerably with weather conditions both locally and on a flyway scale making predictions at a local scale difficult to model, and statistical comparisons complex. Nevertheless, the results from spring and autumn 2003 clearly demonstrated reduced intensity of migration in the wind farm area, based on density of radar tracks. These responses were undoubtedly partly the results of the "shadow effects" cast on the radar screen by individual turbines. However, because many of the tracks appear beyond such turbines shadow and emerge from the outer side of the wind farm, the intensity of migration in the area between the erected turbines was considerably less than at outside and compared with base-line years. This is confirmed from individual tracks identified to species, which showed that many flocks and individuals take avoidance action and fly around the park without ever venturing between the turbines. Furthermore, those that do continue into the wind farm adjusted their flight trajectories and tended to fly down the visually clear corridors between the rows of turbines. Both these features combine to explain the overall reduction in migration track densities within the wind farm.

Despite general support for the hypotheses outlined above, it is important to stress that these results provide little evidence for or against the effects of the construction of wind turbines on migrating waterbirds. The data were collected in just one year and construction phase of the turbines extended over a relatively short period. It is therefore difficult to draw many reliable conclusions from the single case study. Although the results suggest substantial avoidance (and provide data on the nature of that avoidance) by autumn migrating waterbirds of the newly constructed wind farm, it is important to stress that these results come from one single monitoring year. They are gathered under the particular conditions prevailing in that year and before any likely effects of longer-term habituation or other behavioural responses to its presence.

Four aerial surveys of staging and wintering birds were conducted in the study area in 2003, one in each of the months of January, March, April and December. Thus a total of 25 surveys has been performed since August 1999.

The main construction phase of the Nysted windfarm was defined to commence by January 2003 and the operational phase by August 2003. Thus the three early surveys of 2003 represented the construction phase data set, while the December survey comprised the first data set from the operational phase of the wind farm.

At the time of the January 2003 survey ice cover was observed in large parts of the survey area, causing changes in bird distribution patterns. Therefore data from this survey were excluded from part of the data analyses.

The most numerous species recorded in 2003 were Tufted Duck (12,205), Eider (3,142), Mute Swan (2,882) and Long-tailed Duck (2,797). Of these only Eider and Long-tailed Duck occurred frequently in the offshore areas.

To ensure maximum compatibility between base-line data and construction data only data from March and April of the base-line phase were used to analyse construction activity impact on bird distributions. Given the small number of surveys during construction, no firm conclusion can be drawn about the construction phase. However, long-tailed duck and eider showed reduced preference for the wind farm area during construction, whereas the relative number of herring gulls increased slightly in the wind farm area.

Since only one survey exists during operation of the wind farm results must be supported by further surveys before conclusions concerning habitat loss for staging and wintering birds at Nysted Wind Farm can be drawn.

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1 Introduction

1.1 Background

In June 2001, the Danish Ministry of Energy licensed Energi E2 to construct the offshore Nysted wind farm situated in the Baltic Sea, south of Lolland and Rødsand (Fig. 1). The off-shore construction of the wind farm commenced in June 2002 when the first excavations for foundations were carried out. In September 2002, the cabling was laid between the offshore transformer station and Lolland. In October 2002, the first foundation was placed off-shore. Intensive work on establishing foundations was carried out during spring 2003. Subsequently, 72 turbines each with a performance of 2.3 MW were erected May to July 2003. Turbines came gradually into operation from July to Mid-September. During autumn 2003, an operational test was conducted. The test period included frequent servicing of the turbines, which also involved temporary cessation of turbines in one or more rows. The test period terminated by 1 December 2003, when commercial operation was initiated.

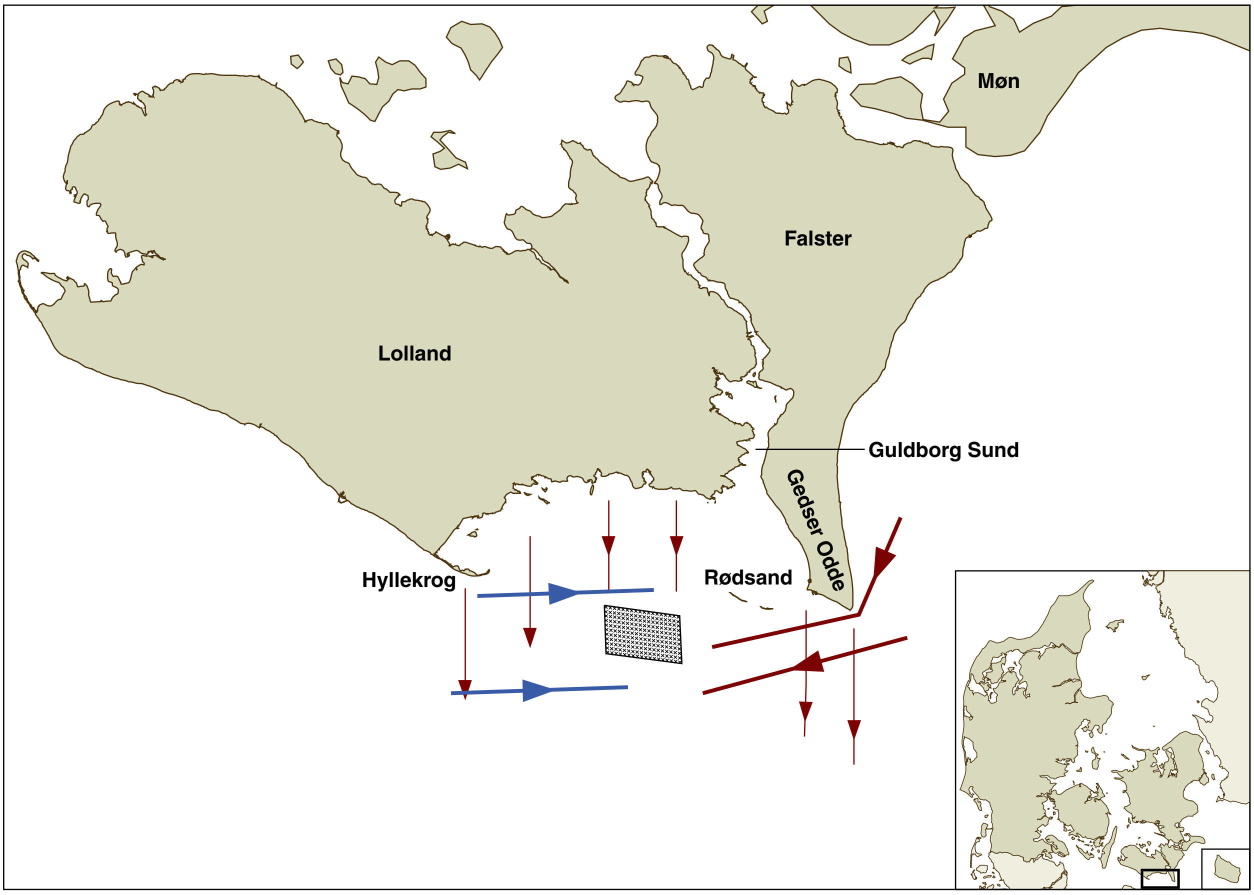


Figure 1. The wind farm area and study area south of Lolland and Falster in southeastern Denmark. Names of locations referred to in the text are indicated. The hatched area represents the wind farm area, thin and thick arrows indicate the schematic direction of terrestrial and waterbird migration, respectively. Blue arrows indicate spring migration and red arrows autumn migration.

The entire project has been organised as a demonstration project to assess the technical, economic and environmental constraints on the future development of electric power production in Danish offshore environments. For detailed background information, see SEAS Distribution A.m.b.A. (2000).

Within the framework of the environmental programme, bird investigations have been carried out since 1999. Based on the progress and extent of construction activities, bird studies have been divided into three phases in this report:

1) Base-line investigations before erection of the wind farm, 1999-2002
2) Monitoring during the main construction phase, January - July 2003
3) Monitoring during the first provisional operational phase of the wind farm, August - December 2003.

This report presents results compiled during 2003 and deals with the first preliminary analysis of effects on birds present at the Nysted wind farm during construction and operation of the wind farm. The results from 2003 will be supported by further studies in the years to come.

The potential effects of the wind farm on birds are considered under three main headings:

1) Disturbance effects (displacement, equivalent to habitat loss);
2) Physical changes due to construction (physical habitat loss, change of bottom fauna and new opportunities for resting on the static superstructure);
3) Risk of collision (mortality).

1) The displacement of staging birds as a result of wind farm construction has been demonstrated for different bird species (Tulp et al. 1999, Larsen & Madsen 2000). In relation to staging waterbirds, the turbines can scare birds away from the immediate vicinity of the wind farm area. This in turn could have two consequences: either a loss of foraging areas which could ultimately reduce the population size if feeding areas are limited, or a shift in foraging area with no measurable effects on the overall population size if alternative feeding areas exist elsewhere.

2) Physical changes of the habitat were judged to be of minimal and temporal importance, and it was estimated that resettling of bottom fauna on foundations of the turbines would exceed the loss of bottom fauna caused by the establishment of turbines (DHI 2000). Furthermore, cormorants and gulls may use the static turbine superstructure for resting.

3) It is known that wind turbines represent a risk of bird mortality (e.g. Barrios & Rodrígues 2004). Studies of the collision risk were not possible prior to the construction of the turbines. Nevertheless, the subject has been given attention in the present report as collision risk is highly dependent on a number of factors, in which insight can be gained by compiling data before and after the erection of the wind farm. This includes the avoidance response by flying birds, which may either deflect laterally as they approach a wind farm or may

climb to attain height to avoid it attitudinally. Such avoidance responses are likely to be species-specific, which may result from the differing ability of different species to manoeuvre, their sensitivity to the presence of large offshore constructions and interactions with weather factors. Furthermore, displacement from regular migration patterns will indirectly affect the collision risk, as the precise position of the local migration routes is a major determinant of the number of potential encounters.

Collisions increase the mortality of bird populations. At the level of a flyway population, the sensitivity to additional mortality caused by collisions with wind turbines will depend on the population dynamics of the species. Long-lived species with a low reproduction rate such as many waterbirds are likely to be more sensitive to small changes in adult mortality compared to passerines that suffer a high annual mortality (in some species more than 50%) and have a correspondingly high reproductive output (Noer et al. 1996, Morrison et al. 1998).

A separate project, which deals with the development of reliable methods to estimate collision frequency at the Nysted wind farm, is currently being undertaken. So far it has been concluded that recordings from video cameras using infrared sensing are likely to be a feasible way to estimate the collision frequency at offshore wind turbines (Desholm et al. 2001, Desholm 2003).

1.2 Base-line investigations

Data from the base-line investigations have been collected over a number of years (1999-2002) to assess the extent of inter-annual variation. During the construction phase and after the erection of the turbines a 2-3 year monitoring programme is planned, to form the basis of a comparison with the base-line data in order to determine possible effects of the construction activities and of the wind farm itself on birds.

The initial base-line study confirmed the importance of the area around Rødsand, which holds relatively large numbers of staging waterbird species throughout the year. In addition, Gedser Odde, which is situated east of the wind farm area, acts as a geographical barrier during autumn where migrating waterbirds and terrestrial bird species concentrate as they pass through the area. During spring, substantial numbers of birds (mostly waterbirds) pass along the southern coastline of Lolland and Falster and thus through the wind farm area (see Fig. 1). The significance of the area for staging and migrating waterbirds has been confirmed through extensive studies, carried out since 1999 by the National Environmental Research Institute (NERI) (Kahlert et al. 2000, Desholm et al. 2001, Kahlert et al. 2002, Desholm et al. 2003), and commissioned by SEAS Wind Energy Centre (SEAS) on behalf of Energi E2.

During the autumns of 1999-2002, the majority of terrestrial bird species migrated from the tip of Gedser Odde and Lolland in southerly directions, whereas the waterbirds rounded Gedser Odde heading west and southwest (Kahlert et al. 2000, Desholm et al. 2001, Kahlert et al. 2002, Desholm et al. 2003; see Fig. 1). Time of day, season and wind direction had significant effects on the migration pattern in the study area.

Of the total waterbird migration at Gedser Odde, 16-48% passed the easternmost edge of the wind farm area in 1999-2002, dependent on season.

An area is recognised as being of international importance to a species if 1% of its flyway population is present regularly at a site at some time during the annual cycle (Prater 1981, and see also http://www.ramsar.org/key_criteria.htm). Based on this 1%-criterion the selected study area around Rødsand was classified as being of international importance to staging cormorants *Phalacrocorax carbo*, red-breasted merganser *Mergus serrator* and moulting mute swans *Cygnus olor* (Desholm et al. 2001).

In the autumns of 2000 and 2002, analyses of the distribution of the three species for which the study area was considered of international importance showed that red-breasted merganser occurred in extremely small numbers. Cormorants and mute swans significantly avoided the wind farm area although cormorants visited it during social foraging movements. These movements consisted of flocks of up to 5,000 cormorants, which may make up a potential high-risk of collisions with wind turbines in the future.

1.3 Monitoring programme

The bird investigations carried out during the monitoring of the construction and operation of the wind farm in 2003 followed the procedures used in the base-line investigations (Desholm et al. 2001, Kahlert et al. 2002, Desholm et al. 2003). However, adjustment of the monitoring programme was done in accordance with the conclusions obtained during the base-line study. The study of spring migration of dark-bellied brent geese *Branta bernicla* in late May was not carried out in 2003 as in previous years. Three years of base-line results did not show any significance of the wind farm area for this species as the migration route was consistently situated north of the wind farm area close to the mainland coasts (Desholm et al. 2003). In addition, aerial count surveys were not carried out during autumn 2003, as the area during this season was shown to be of little importance for staging waterbirds, except for cormorant. However, monitoring of cormorants was continued under the studies of migratory birds (radar studies), which included counts and description of flight trajectories.

In accordance with the base-line studies three variables were derived to analyse potential lateral changes in migration routes for birds approaching the wind farm area. The three variables are: 1) orientation of migration (only during autumn), 2) probability of passing through the wind farm area, and 3) migration intensity in the wind farm area. Aerial counts of staging waterbirds were carried out during December - April to cover the winter and spring period, which appeared to be of greatest importance for staging waterbirds.

2 Methods

2.1 Study area

The wind farm is located south of Rødsand, ca. 10.5 km west-southwest of Gedser Odde and ca. 11.5 km south of Lolland at water depths of 6-9.5 m (Fig. 2). The wind farm comprises 72 turbines placed in 8 north-south orientated rows with 9 turbines in each row. The distance between rows is 850 m, whereas the distance between turbines within a row is 480 m. The upper tips of the wings reach 110 m whereas the lower tips start at 30 m.

For flight safety reasons, synchronised red flashing lights have been mounted on top of turbines at the fringe of the wind farm. Light intensity is 32 Cd at visibilities more than 5 km and 2000 Cd when less than 5 km. Permanent red lights with an intensity of 32 Cd are placed on the inner turbines. For ship navigation the wind farm was fitted with flashing lights on each of the corner turbines, on two turbines at the northern and southern fringe, respectively, and on one turbine at the eastern and western border of the wind farm. All flashing lights are synchronised and should be visible at a distance of 5 nautical miles. For further description of the wind farm see SEAS Distribution A.m.b.A. (2000).

The observations of migrating birds at Rødsand were conducted from an observation tower placed 6 km south-west of Gedser Odde and 5 km north-east of the wind farm area. From this position it was possible to monitor bird migration by performing both visual and radar observations. Visual observations of birds were undertaken along a transect south of the observation tower. Registration of bird flocks by radar was done within a circular area of 388 km^2 around the observation tower (see Fig. 2). In Fig. 2 and the following figures related to radar observations, are only turbines within the radar range depicted.

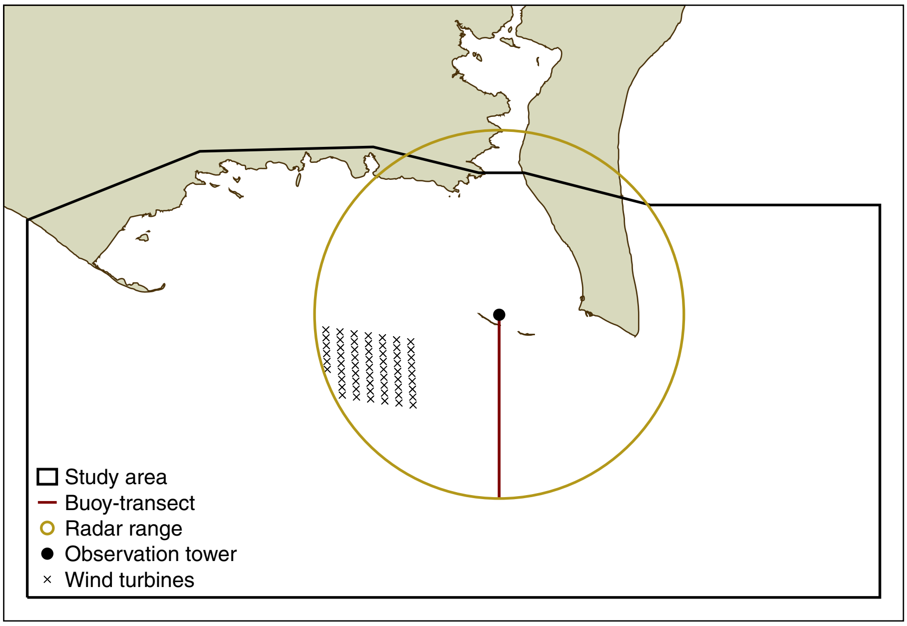


Figure 2. Location of the Rødsand study area covered by aerial surveys, the observation tower on which the radar was mounted, radar range, wind farm area and the Buoy-transect.

The study area for mapping of staging waterbirds using aerial surveys extended over an area of ca. 1,350 km^2 including the planned wind farm of ca. 23 km^2 (see Fig. 2).

The total study area is referred to as the reference area, whereas the area in which the turbines were erected subsequently will be called the wind farm area.

The Rødsand sandbars cover an area of between 0.1 and 6.3 km^2, depending on the highly variable water level.

The eastern parts of the bay have shallow, sheltered waters with a number of islets. The offshore parts range to water depths of approximately 30 m.

2.2 Monitoring of migratory birds 2003

Observations of the bird migration intensity, species composition, flock size and migration routes were performed day and night during 16 March - 15 April (four weeks) and 30 August - 31 October (eight weeks). These periods coincide with the main migration period of a substantial number of the species of waterbirds and raptors. Two days of effective observations were conducted each week from the observation tower where two observers were present to ensure maximum effectiveness, and for safety reasons.

During 2003, visual data were collected during the day based upon the 6.9 km long transect (referred to as the Buoy-transect) placed between the observation tower and the buoy 'Schönheyders-Pulle' (see Fig. 2). A telescope (30x) was used, and data were recorded by 15-minute periods.

To compile spatial data on bird migration at long distance and during periods of poor visibility due to fog or darkness a ship-radar (Furuno FR2125) was used. Each echo on the radar monitor corresponded to a flock of birds in the study area, and in this way the spatial migration pattern could be described both during day and night. Sunset and sunrise defined the grouping of bird data into day and night. The distance from the observation tower to the periphery of the study area covered by the radar was 11 km. Data were provided as the lateral position of objects, their migration speed and course. During autumn, the westerly-orientated migration of waterbirds was followed in the area between Gedser Odde and the wind farm area, and the southerly-orientated migration of terrestrial species was followed in the area between southeast Lolland and Gedser Odde (see Fig. 1). During spring, the easterly-orientated migration of waterbirds was monitored from the wind farm area to Gedser Odde. No significant migration of terrestrial bird species occurred during spring.

The migration routes were mapped by tracing the course of bird flocks from the radar monitor on to a transparency. Only tracks longer than 5 km (arbitrary value) were included in the analysis, thereby excluding short tracks of local movements. When possible, species and flock size were recorded. Afterwards, the transparencies were digitised and entered into a GIS-database.

Time of day, season and wind direction have previously been shown to have significant effects on the migration patterns in the study area (Kahlert et al. 2000, Desholm et al. 2001, Kahlert et al. 2002). In addition, the response pattern of birds to operating wind turbines was hypothesised to be affected by visibility. However, in this preliminary assessment of effects caused by the Nysted wind farm, the effects of restricted visibility were only analysed in comparisons between daylight and darkness. Periods with fog or severe haze occurred at a very low frequency in the study area during the base-line (1999-2002) and 2003 was no exception to this pattern (Fig. 3). For example, less than 1% of the time visibility was less than 3 km during autumn 2003. Periods of poor visibility occurred at a higher frequency during spring (visibility was lower than 3 km during 11% of the time). Nevertheless, it has proven extremely difficult to make local predictions on visibility and plan radar observation bouts to coincide with foggy weather conditions. For this reason, little bird data could be compiled during periods of poor visibility in 2003. However, it may still be possible to gather sufficient data by compiling data over several years under the monitoring programme to make reliable assessments on this particular issue.

2.2.1 Lateral change in migration routes

Hypothesis: In previous studies, lateral avoidance has been considered the most frequent bird response to established wind farms (Winkelman 1992). An alternative hypothesis would be that birds are attracted for example by illumination of wind turbines (for a review on the illumination topic, see Lensink et al. 1999), a phenomenon that only relates to nocturnal migrants. It is also possible that gulls and cormorants will use the static turbine superstructure as a resting platform during both day and night, resulting in relatively high numbers of radar tracks of birds moving towards and into the wind farm. The present study of migration routes is, however, designed as to detect attraction effects also.

Based on the main hypothesis that migratory birds show a lateral avoidance response to the wind farm, the following predictions are made:

1) A gradual and systematic deflection of the migration route will occur with significant changes in the flight direction close to the wind farm after the turbines have been erected;

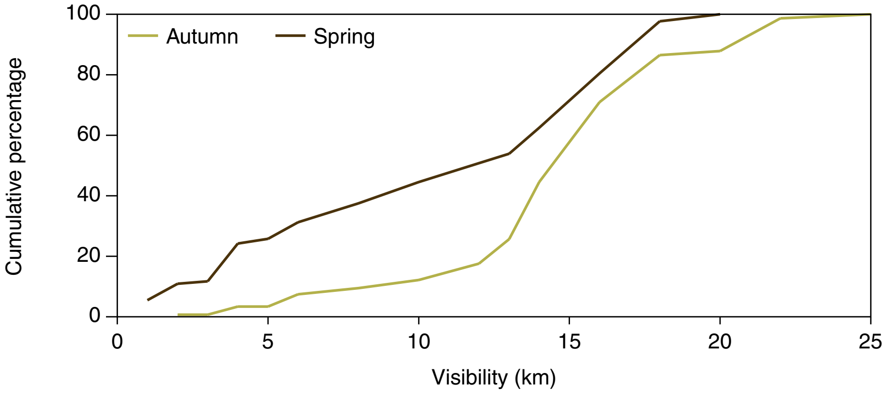


Figure 3. Cumulative percentage of observations in relation to visibility (km) measured at Gedser. Observations were made every six hours during the spring period 15 March – 15 April and the autumn period 25 August – 31 October, 2003.

2) The change in flight direction will occur closer to the wind farm at night and during periods of poor visibility than during daytime and periods with good visual conditions;

3) In case of a severe avoidance response to the wind farm in autumn, it may be predicted that the proportion of eastward-migrating birds (reversed migration) at the Buoy-transect south of the observation tower would increase after the erection of turbines due to a higher number of individuals returning either to gain altitude before passing the wind farm or to find alternative migration routes lateral to the wind farm area.

Based on the alternative hypothesis that migratory birds show a lateral attraction response to the wind farm the following prediction is made:

4) A gradual and systematic deflection towards the wind farm will occur with significant changes in the flight directions close to the wind farm area after the turbines have been erected.

Methods: During autumn, westward-directed waterbird migration tracks were traced by use of radar from just south of the observation tower and until they had passed the wind farm area to determine the migratory routes of waterbirds. Of 3,098 migration tracks recorded during autumn 2003 (Fig. 4), 46 were extracted for the analysis of lateral change in migration routes. This was the result of removal of all those tracks that did not pass the 15 transects placed in parallel with and east of the most easterly row of turbines (Fig. 5a), and those that crossed the north and south lines depicted in Fig. 5a. This selection of data ensured that the analysis focused on bird flocks approaching and passing through the wind farm area at the easterly row of turbines, and the associated response distance of migratory birds towards individual wind turbines. In total 486 tracks were included in the analysis for 2000, 2001, 2002 (base-line) and 2003 (operation of the wind farm).

Figure 4. Radar registrations of 3,098 waterbird flocks migrating at Rødsand during autumn 2003. Flocks that were not determined visually to species were classified as waterbirds on the basis of their radar signal and/or migration speed exceeding 50 km/hour. All flocks presented were migrating in a westerly direction.

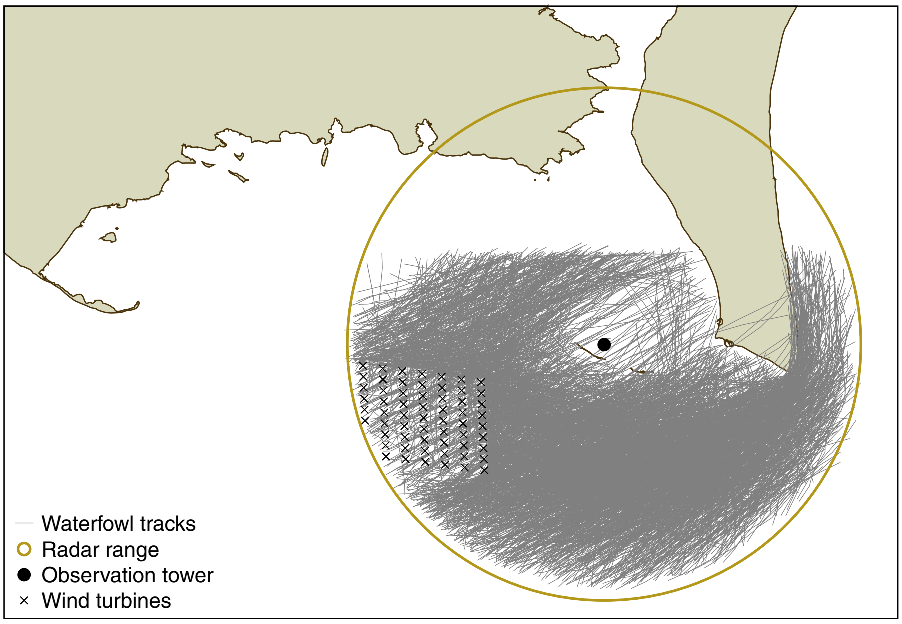
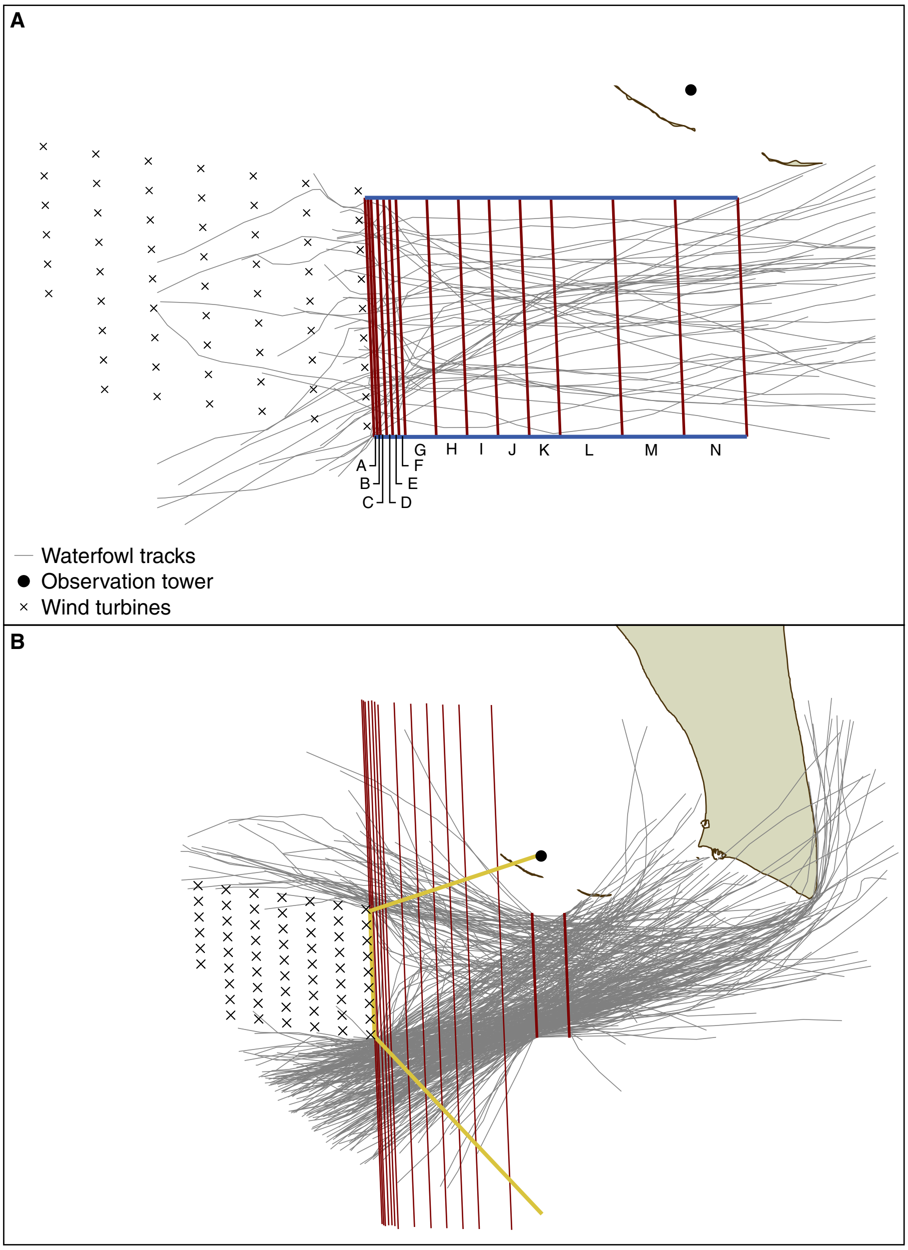


Figure 5. Tracks of autumn migrating waterbird flocks, which were used in the analyses of the orientation of migration routes at the observation tower and the Rødsand, wind farm area. The letters A - N indicate the 14 sectors between the transects. Flocks that crossed the eastern border of the wind farm (A) and flocks that passed north or south of the wind farm (B).



In 2003, the positions of turbines as they appeared on the radar monitor were used as a reference to the tracks of migratory birds. The transects used during the base-line study were also used in the present report and referred to the geographical coordinates of the turbines. This led to some minor discrepancy between the eastern gate of the wind farm and the most westerly transect, which may possibly derive from distortion of the radar-image and from the digitalisation process of tracks and turbines.

For this reason five tracks appeared as if they passed south of the wind farm in Fig 5a, which may not necessarily be the case or if so they passed very close to the most southeasterly turbine. Hence, the aim of the analysis to investigate the response patterns of birds to individual turbines was not compromised.

A parallel analysis was carried out on the flocks (N = 288), which have passed the two easternmost transects 5 and 6 km east of the wind farm but definitely passed either north or south of the wind farm. This parallel analysis was carried out to investigate whether those flocks, that did not cross the wind farm area in 2003 (operation of wind farm), showed any change in flight pattern compared to 2000, 2001 and 2002 (base-line) (Fig. 5B). In this analysis it was assessed that no response towards the wind farm occurred at a distance 5-6 km from the wind farm.

In both analyses, the 15 transects were positioned 0, 50, 100, 200, 300, 400, 500, 1,000, 1,500, 2,000, 2,500, 3,000, 4,000, 5,000 and 6,000 metres from the most easterly row of turbines, respectively, and had the same orientation and length as this row. For each track 14 migration courses were calculated, one for each interval between two adjacent transects, as the course between the intersections of the migration track and the two adjacent transects. For each transect interval the mean migration course of the tracks was calculated.

The unequal intervals between the transects were originally considered to be a provisional solution, aiming in the first instance at detecting all the possible changes in migration routes and to estimate the response distance to the wind farm, even if it is very short or very long (e.g. A versus C in Fig. 6).

The mapping of migration routes gives the opportunity to test potential changes in the mean orientation at different distances from the wind farm area, and to test whether a systematic change in migration route has occurred. For example, if most birds avoid the wind farm by making lateral adjustments to the north, the mean track orientation will differ as a result of this lateral reorientation. If data from all sectors are normally distributed and show equal variance, the differences in the mean course at a specific distance can be tested using a t-test after establishment of the wind farm. However, if birds show lateral response differences in the distributions of migration courses with respect to distance to the wind turbines, e.g. a deflection of individuals both to the north and to the south of the wind turbines, this could result in a bimodal distribution close to the wind farm, but an unimodal distribution further away where the deflection has not yet

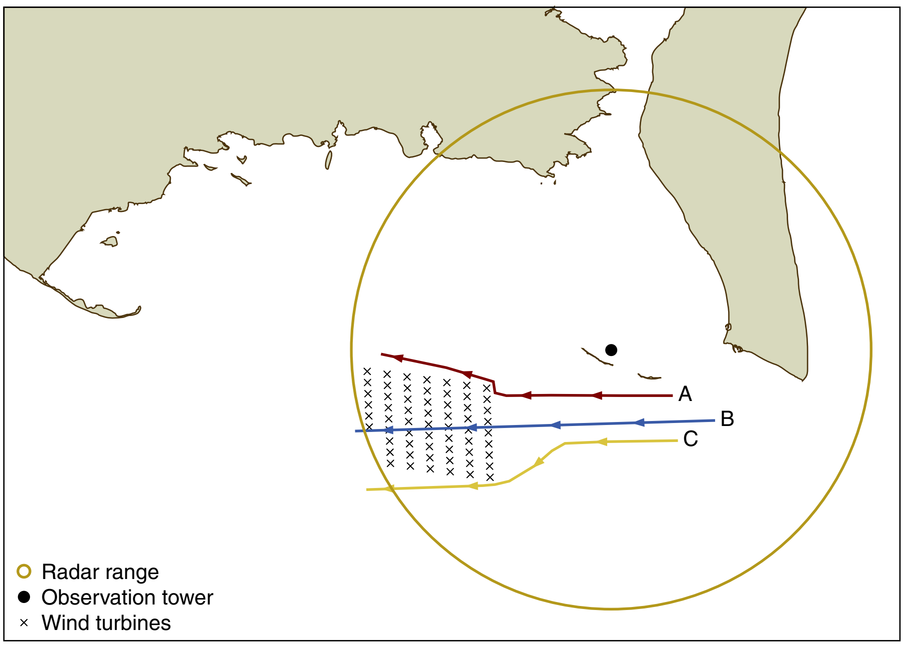


Figure 6. Schematic presentation of possible lateral avoidance responses shown by flocks of autumn migrating waterbirds to the Nysted wind farm: A) deflection with a short avoidance distance, B) no deflection and C) deflection with a long avoidance distance.

begun. In this case, one could expect no significant difference in mean orientation, but a significant increase in the standard deviation of the mean.

Northerly and southerly winds can displace westward-migrating flocks to the south and north, respectively. Time of day (day and night) may affect the spatial placement of migration routes, especially after the wind turbines have been erected (*cf.* predictions from the hypothesis). The effects of wind direction, time of day, distance to the wind farm and year on the orientation of migration was tested using repeated measures ANOVA.

Reversed migration, which may be a relevant factor in the case of a severe response from the birds to the wind farm, was studied by daytime telescope observations. These observations included recordings of species, number of birds and flock size, and were carried out simultaneously with radar observations to derive species specific data on the migration patterns through the study area. The observations by telescope were undertaken along the first 6.9 km of the Buoy-transect (measured from the north; see Fig. 2), which covered the autumn migration approach routes of waterbirds. For each observation it was noted whether the birds were flying towards the west or the east, and hence, the proportion of the east migrating flocks could be computed on the species level.

'Orientation of migration' and 'proportion of reverse migration' are only relevant for bird flocks approaching the area designated for the wind farm during autumn. The approach of bird flocks during spring migration could not be described, as the area to be covered was beyond the maximum range (Fig. 7), which is appropriate to use for detection of bird flocks with the present radar equipment.

2.2.2 Probability of passing the wind farm area

Hypothesis: In relation to the main hypothesis, that migratory birds show a lateral avoidance response to the wind farm, it is further hypothesised that the probability of passing the wind farm area after

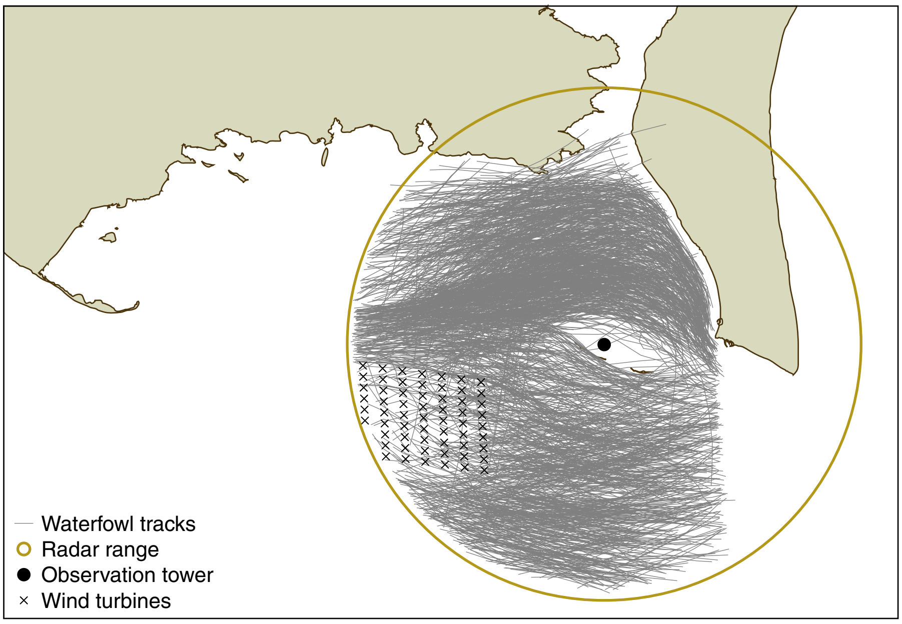


Figure 7. Radar registrations of 1,599 waterbird flocks migrating at Rødsand during spring 2003. Flocks that were not determined visually to species were classified as waterbirds on the basis of their radar signal and/or migration speed exceeding 50 km/hour. All flocks presented were migrating in an easterly direction.

erection of turbines will decrease. Following the methods of the base-line study, data were collected in 2003 for both autumn migrating bird flocks flying south of Rødsand towards the west and for spring migrating bird flocks south of Lolland flying in an easterly direction.

<u>Methods used for autumn analysis:</u> Of the 3,098 migration tracks recorded during autumn 2003, 779 were extracted for analysis by excluding those that were orientated in westerly direction and did not pass the line due south of the observation tower and the eastern transect (the Buoy-transect; see Fig. 2), as these radar tracks represent the bird flocks which may show a lateral avoidance response to the wind farm.

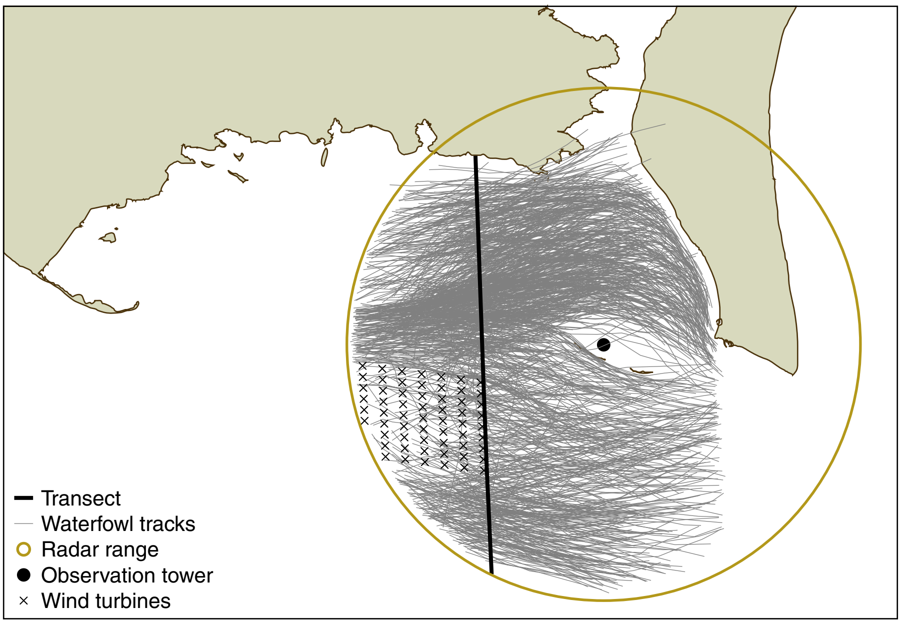
Flocks (radar echoes) were followed to see whether they crossed the eastern edge of the wind farm area or not, and the proportion of flocks that actually did so was calculated. Thus, the grouping of flocks has been slightly changed. During the base-line study, proportions of flocks, which crossed the wind farm area at any place, were calculated, i.e. birds that crossed the northern or southern edges of the wind farm area were also included. However, the northern and southern edges are parallel with the main orientation of bird migration and particularly during the base-line flocks may have crossed these edges by coincidence as a result of minor adjustments of the flight direction and inflicted data with some random variation. In addition, radar detection of flocks may in particular be reduced at the southern edge of the wind farm because the radar beam has to cross the entire wind farm before it reaches the southern edge (shadow effect). For this reason, it has been considered to be a more robust approach to estimate the proportions of flocks crossing the eastern edge, exclusively. It must be emphasised that estimates, which were calculated during the base-line study, were only slightly changed (less than 3%) using the revised method. In order to describe the migration pattern in detail, logistic regression models were used to describe the probability of passing the wind farm area incorporating the following four factors:

1) north-south placement of the track (latitudinal), measured as the distance from the observation tower to the intersection between the migration track and the Buoy-transect,
2) time of day (day and night),
3) wind (northerly and southerly winds), and
4) year (2000, 2001, 2002 and 2003).

<u>Methods used for spring analysis</u>: Of 1,599 migration tracks recorded during spring 2003 (see Fig. 7), 1,055 were extracted for analysis by excluding the observations that did not pass the transect due south of Lolland (Fig. 8).

The proportion of migration tracks that passed the eastern edge of the wind farm area in 2003 was calculated and compared with the situation before the erection of the wind turbines. The effect of cross winds (classified into northerly and southerly wind directions) and time of the day (day and night) were analysed using a logit model, i.e. the response variable was binary (presence/absence at the eastern edge),

Figure 8. The 1,055 tracks of spring migrating waterbird flocks at Rødsand, which were used in the analysis of the probability of passing the wind farm area in 2003.



and the explanatory variables were all assigned to categories (Kristensen et al. 1986)

2.2.3 Migration intensity in the wind farm area

Hypothesis: In relation to the main hypothesis, that migratory birds show a lateral avoidance response to the wind farm, it is further hypothesised that migration intensity in the wind farm will decrease after erection of the turbines. Assuming that it will be more difficult for migrating birds to detect the wind farm at night than by day (depending on the attraction effect of turbine illuminations), it is predicted that the decrease in migration intensity in the wind farm will be most pronounced during the day.

Methods: Systematic counts of the number of bird flocks per 15-minute period were carried out using radar (see Kahlert et al. 2000). During autumn 2003, bird flocks that entered the wind farm area from the north or east were counted at the two transects simultaneously (Fig. 9). One transect was positioned between the north-west and north-east corner of the wind farm (northern gate), the other transect between the north-east and the south-east corner (eastern gate). It has previously been concluded that migration tracks passing the northern gate from the north were mainly terrestrial birds and potentially geese migrating from the mainland areas. Tracks passing the eastern gate from the east could mainly be ascribed to migratory waterbirds, mainly eiders (Kahlert et al. 2000). Only flocks flying into the wind farm area with the main heading of autumn migration (towards the west and south) were included in the analysis.

During spring 2003, the number of individuals passing per 15-minute period was counted on the same transects as during autumn. Because the main heading of migration during spring is towards the east and north, only bird flocks that flew out of the wind farm area at the eastern and northern gates were analysed.

Figure 9. Location of the northern and eastern gates at the Nysted wind farm used for estimating the migration intensity in the wind farm area.

As previous studies (Kahlert et al. 2000) have demonstrated that migration intensity is influenced by several abiotic factors, it was decided to split the data set in relation to season and wind conditions based on those divisions, which had the highest explanatory power for changes in the migration intensity. The migration intensity data were divided into two periods: spring (16 March - 15 April) and autumn (30 August – 31 October). In the present report, between-year variation of the average number of flocks per 15-minute period was presented for each season, time of day and wind direction. Wind conditions were divided into four categories also to include head- and tailwinds to the prevailing orientation of the migration: 1) northeasterly winds (1°-90°), 2) southeasterly winds (91°-180°), 3) southwesterly winds (181°-270°) and 4) northwesterly winds (271°-360°).

Also based on radar observations, the lengths of radar tracks (bird flocks) were calculated in squares of 0.1 km^2. In 2003, lengths of tracks divided by total number of tracks were compared in the eastern part of the wind farm area (Fig. 10) with the results obtained during the baseline study (2000-2002). By dividing the length of tracks with total number of tracks in each year (onwards referred to as track density), the between year variance in observation effort was taken into account. The area of comparison (10.8 km^2) was arbitrarily chosen. However, it was set as criteria that the area should be of limited extent (to reduce effects of the distance-related variation in detection rate) and that an appropriate reference area of the same size just outside the wind farm area could be defined. Since the same tracks of waterbirds may occur both in the reference area and in the eastern part of the wind farm area repeated measures were included in the Analysis-of-Variance.

It must be recognised that the variation in migration intensity in the wind farm area may be influenced by the overall migration volume (data not available). Hence, conclusions should be drawn with caution, in so far as a decrease in the overall volume of migration in a single year should not affect the conclusions made for the local migration patterns at Rødsand.

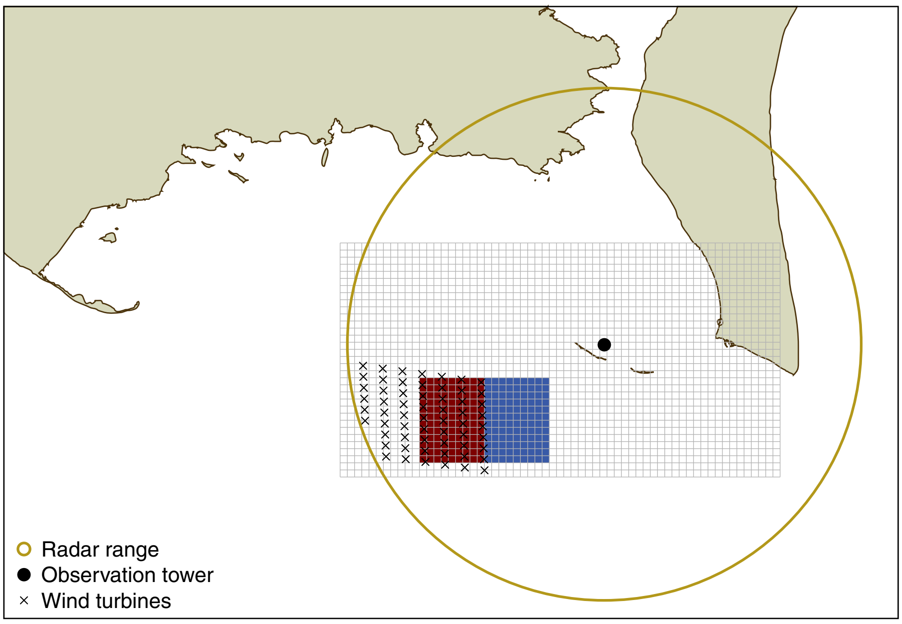


Figure 10. Location of the eastern wind farm area (red) and the reference area (blue) used for comparisons of track densities.

2.2.4 Species composition, numbers and flock size

The results obtained from the daytime telescope observations made possible a species specific description of the abundance and phenology. The telescope observations thereby contributed importantly in the assessment of potential impacts and their consequences at a species level. Information on species specific abundance and phenology can also be used in the decisions about the design of the future bird programme in the years to come. The mean number of birds passing the Buoy-transect per 15-minute period (migration intensity) during five periods are presented for: early September (1-15 September), late September (16-30 September), early October (1-15 October), late October (16-31 October) and spring (16 March - 15 April). As the species specific distributions of migration intensity and flock sizes differed markedly from normal distributions, log-transformation of data was undertaken when calculating the mean migration intensity and the 95% confidence limits. This approach is generally less sensitive to extreme observations of very large flocks, which may occur at a very low frequency, compared to calculation of simple averages.

2.2.5 Migration speed

Methods: Data on ground speed of migrating birds will not be included directly in any before-and-after study, and thus, no hypothesis on this subject is put forward. However, this parameter is a useful tool for species determination in radar investigations. No results from this part of the investigation are presented in this report (but see Desholm et al. 2001, Kahlert et al. 2002 and Desholm et al. 2003).

2.3 Surveys of staging, moulting and wintering birds

The presence (number and species composition) and distribution of staging and wintering birds in the study area (see Fig. 11) was recorded by four aerial surveys during January – December 2003. The data were collected to detect possible impacts of the wind farm on

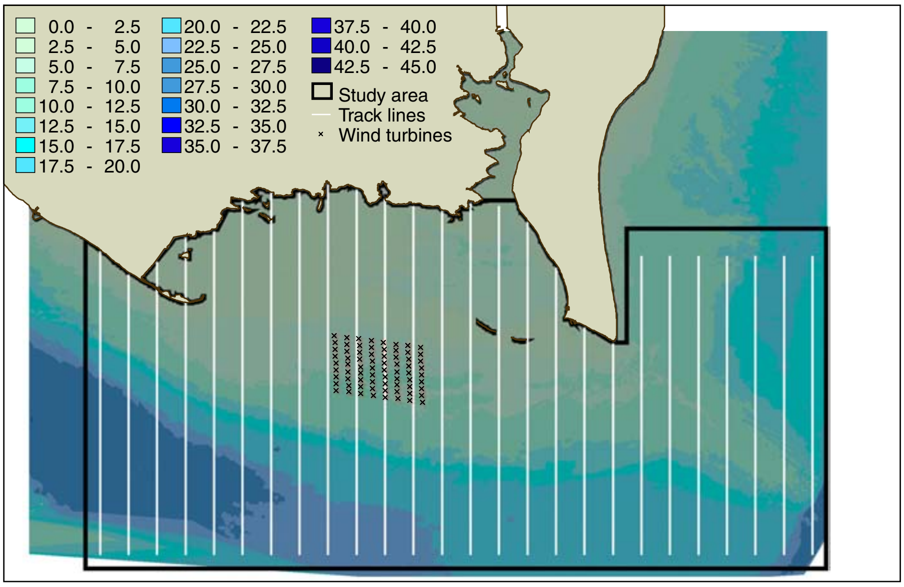


Figure 11. The Rødsand study area for aerial surveys with positions of the wind turbines, and with the ideal survey transect lines and bathymetric profile shown.

birds during the construction phase and subsequently the operational phase. The number of recorded birds during the four surveys was used to describe distribution and relative numbers of the most numerously appearing bird species in the survey area.

The survey area was covered by 26 north-south orientated, parallel transects separated by a distance of 2 km and a total length of 579 km. Transect endpoints were entered into the aircraft GPS as waypoints, used for navigation along the transect tracks.The surveys were conducted from a high winged, twin-engine Partenavia P-68 Observer, designed for general reconnaissance purposes with a flight altitude of 76 m (250 feet) and a cruising speed of approximately 180 km/h (100 knots).

At the time of the December survey in 2003 the wind turbines were installed. With a survey altitude of 76 m, collision with the turbines had to be avoided by slightly modifying the survey track lines. This was done by creating way points along the original track lines approximately 3 km north and south of the wind farm area, and from these positions adjust the track lines through the wind farm half way between turbine rows. Once through the wind farm area the track line was adjusted back to the original track line. Thus, the track line adjustment increased the length by only 89 m.

During the surveys, two observers covered one side of the aircraft each. All observations were continuously recorded on a dictaphone, including information on species, number, transect band and time (see Kahlert et al. 2000). The majority of the observations were considered accurate within four seconds, i.e. each observation was given the exact time ± 4 seconds, and consequently, the positional accuracy on the longitudinal axis was within 206 m (see Kahlert et al. 2000).

After completion of each survey, tables of observation data (species, number, time, transect band and side of aircraft) and flight track data were created from the transcription. A combination of GIS tools and Turbo Pascal software was used to add a position to each record of observation data.

Distribution maps were produced for each of the relevant bird species showing the location and relative size of the observed bird flocks.

The comparative analysis to be conducted by the end of the before-and-after study is likely to be based on pooled data from the aerial surveys. A total of 21 surveys conducted between August 1999 and August 2002 comprises the base-line phase. Three surveys from January to April 2003 comprise the construction phase, while a survey in December 2003 comprised the first survey under the operational phase of the wind farm.

The development of spatial modelling tools to generate estimates of densities and total numbers of birds in the survey area is in a final stage (Fox et al. 2003). The data requirements for the survey data are different from the present format, and the data from this study area has not yet been through this process. Therefore survey data from 2003 will be presented in the same general format as in the previous reports. In order to correct for the coverage of the study area, data are presented as the number of individuals observed, by species, relative to the covered transect length in a grid net of cells 2x2 km each.

Jacobs selectivity index (Jacobs 1974) was adopted to describe the waterfowl (staging, moulting and wintering) preference for different zones in or around the wind farm area compared to their preference for the whole study area. The waterfowl preference for the following zones were computed: 1) the wind farm area, 2) the wind farm area + a 2 km zone around it, and 3) the wind farm area + a 4 km zone around it. Previously a zone comprising the wind farm + a 275 m zone around it was included in this analysis. This zone was combined with the wind farm + 2 km zone in the present report.

The D-value which expresses Jacobs selectivity index varies within –1 (no birds inside the wind farm area) and +1 (all birds inside the wind farm area), and was calculated as:

$$D = \frac{(r - p)}{(r + p - 2rp)} \qquad (1),$$

where r = percentage of birds in the area of interest compared to the birds in the whole study area, and p = the percentage 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 percentages was tested as the difference between the observed number of birds in the wind farm area and the expected number in the area of interest relative to the share of the length of transects in the wind farm area (one-sample χ^2-test).

In January 2003 large parts of the study area was ice covered. This obviously caused a change in the distribution of most bird species in the area. Therefore, data from this survey was omitted from comparisons between base-line and construction phase. The two surveys performed during the construction phase in March and April were compared to data from the base-line period. The construction zone in the wind farm area was defined for individual surveys, according to construction progress.

Based on the surveys in March and April 2003, a distance to nearest wind turbine or wind turbine foundation was calculated for each bird record to calculate frequency distributions of birds for each 500 m intervals. Frequency distributions were generated for 1999, 2000, 2001 and 2002 (base-line) and 2003 (construction) and compared.

For further details on the methods of the aerial surveys, see Kahlert et al. (2000), Noer et al. (2000).

2.4 Weather data

Weather conditions were included in the documentation of effects of the wind farm on migration routes to increase confidence of the conclusions. Energy E2 collected data on wind force (at 7.9 m a.s.l.) and wind direction (at 25 m a.s.l.) every 10 minutes at a weather station positioned (54°32.372 N, 11°44.554 E) in the wind farm area. Before the study period in 2003, the Danish Meteorological Institute ceased to compile data on visibility at Gedser Odde. Hence, data on visibility were kindly provided by Gedser Havudkik. Data from the Meteorological Institute and Gedser Havudkik were compatible, although data were compiled less intensively in 2003 (every 6 hours). As during the base-line study, an observation of visibility was assigned to bird observations 1½ hour before and after the time of measurement.

2.5 Quality control

All observations were recorded either in a notebook, on transparencies (investigations of migrating birds) or on a dictaphone (investigations of staging birds). Unusual data were underlined or commented to make a later exclusion of erroneous data possible. After having stored data in databases the original data were checked once again. Analysis of data was performed mainly by using the statistical package (SAS 1999) and ArcView (GIS).

The following quality control procedures were imposed on this report:

- External review
- Internal editorial and linguistic revision
- Internal proof-reading
- Layout followed by proofreading
- Approval by project managers.

3 Results

3.1 Migratory birds

The total distribution of autumn migration tracks of all birds (Fig. 4) and waterbirds (Fig. 12) are presented here. Where migrating waterbirds have been visually determined to species or species groups, these have been plotted separately (common eider Fig. 13, pintail/wigeon Fig. 14, ducks not determined to species Fig. 15 and geese Fig. 16). The grid-based relative density of tracks (expressed as the total sum of track metres within each grid cell) is shown in Fig. 17. The high concentration of westbound tracks rounding Gedser Odde and the general patterns observed in autumn 2003 closely resembled those observed during the base-line study. It is evident, however, that the density of tracks was lower in the wind farm area compared to previous years (Fig. 17) – for further analysis, see section 3.1.4.

In 2003, the eastbound spring migration (mainly waterbirds) in the study area complied with the patterns observed in 2001 and 2002 (Kahlert et al. 2000), (Fig. 7, but see also Fig. 18 for eider migration specifically). The main route occurred north of the wind farm area, but in general massive eastward migration all took place within the entire radar range (Fig. 19). Density of tracks in the wind farm area tended to be lower than during the base-line study (Fig.19a-c) even though only the foundations had been established at the time of the spring bird observations. However, intense ship traffic occurred in the wind farm area during this period.

In the following sections the patterns of flight trajectories from 2003 are analysed in further detail.

3.1.1 Lateral change in migration routes

Autumn migration of waterbirds

In this section, overall lateral responses of bird flocks as they approached the wind farm were tested to determine the preliminary response distance where avoidance occurs. Two parallel analyses of flight trajectories were carried out: 1) those passing the eastern gate of the wind farm, and 2) those passing north or south of the wind farm.

Firstly, for waterbirds migrating towards the wind farm in a westerly direction (hereafter referred to as approach area) and passing the eastern gate, the mean orientation varied between 264.1 and 268.7 degrees in 2003 (a range of 4.6 degrees difference - see Fig. 20). This pattern was generally consistent with the results observed during the base-line study in 2002 (e.g. Fig. 18 in Desholm et al. 2003), which was more southerly compared to observations in 2000 and 2001 (Desholm et al. 2001, Kahlert et al. 2002). An overall analysis (repeated measures ANOVA including year and time of the day) showed a significant difference between four years of the investigation (Table 1). Both factors (year and day/night) and the interaction between the two terms (Table 1) explained some of the variation in orientation.

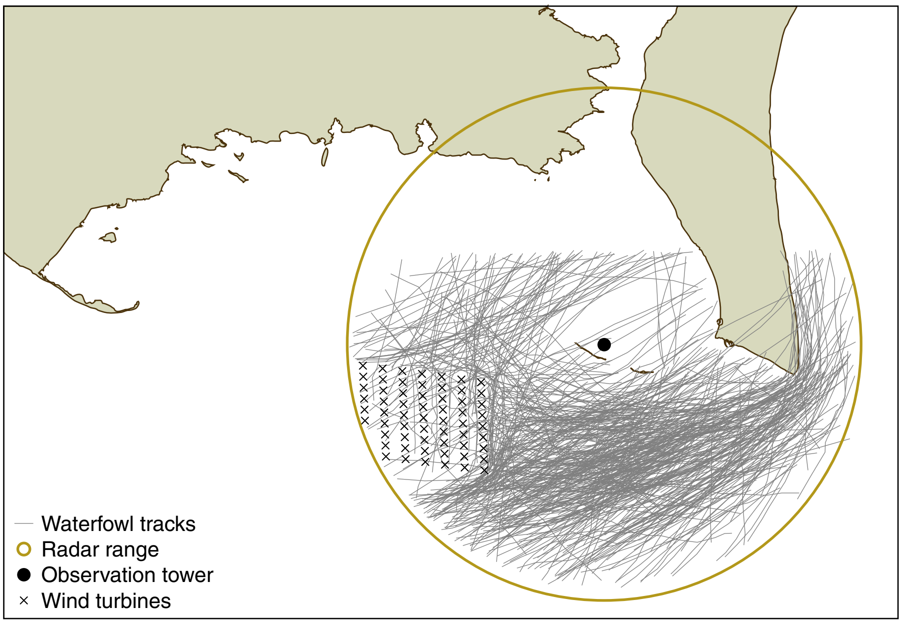


Figure 12. Radar registrations of 508 waterbird flocks determined visually migrating at Rødsand during autumn 2003.

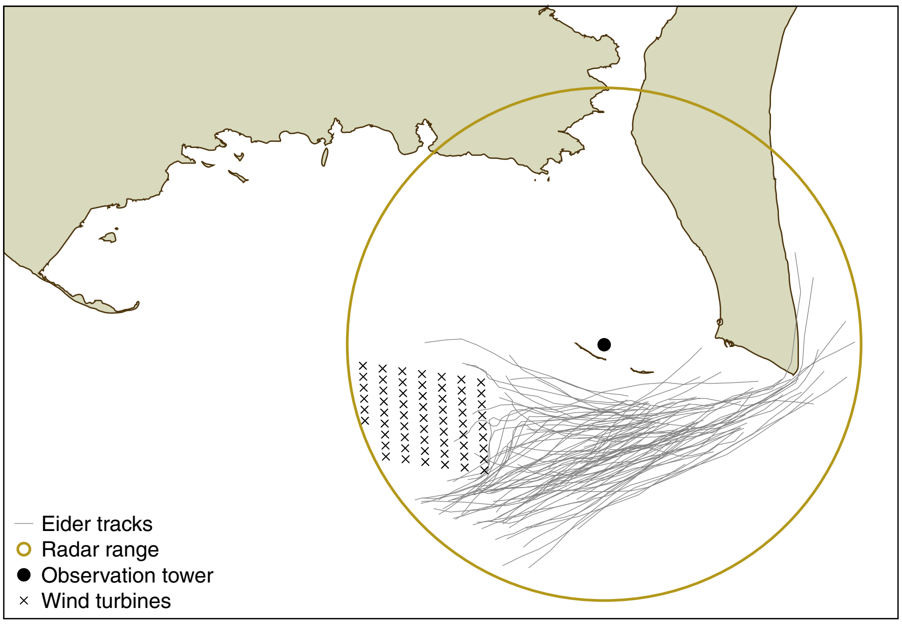


Figure 13. Radar registrations of 84 flocks of migrating eiders determined visually at Rødsand during autumn 2003.

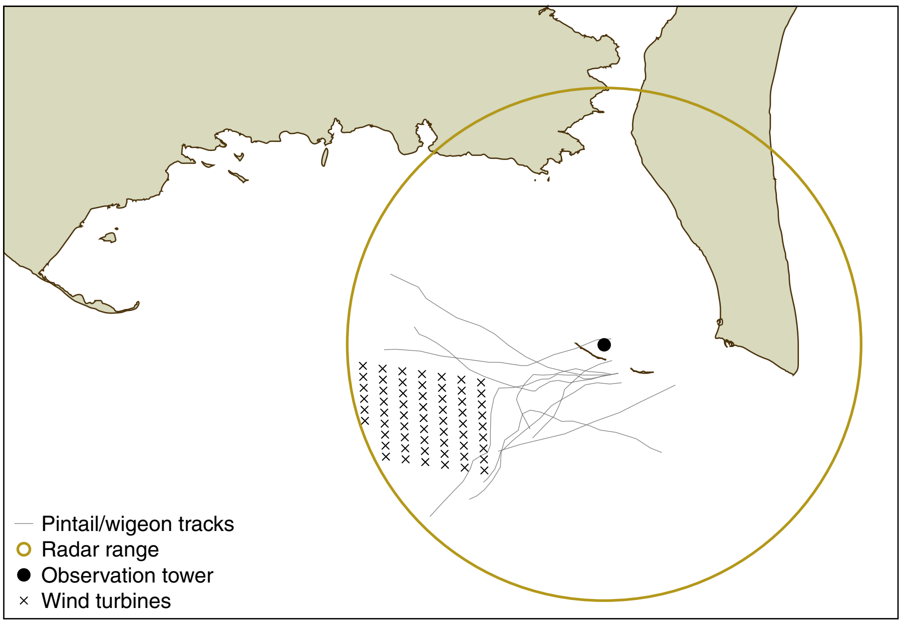


Figure 14. Radar registrations of 9 flocks of migrating pintail or wigeon determined visually at Rødsand during autumn 2003.

Figure 15. Radar registrations of 143 flocks of migrating ducks determined visually (but not to species) at Rødsand during autumn 2003.

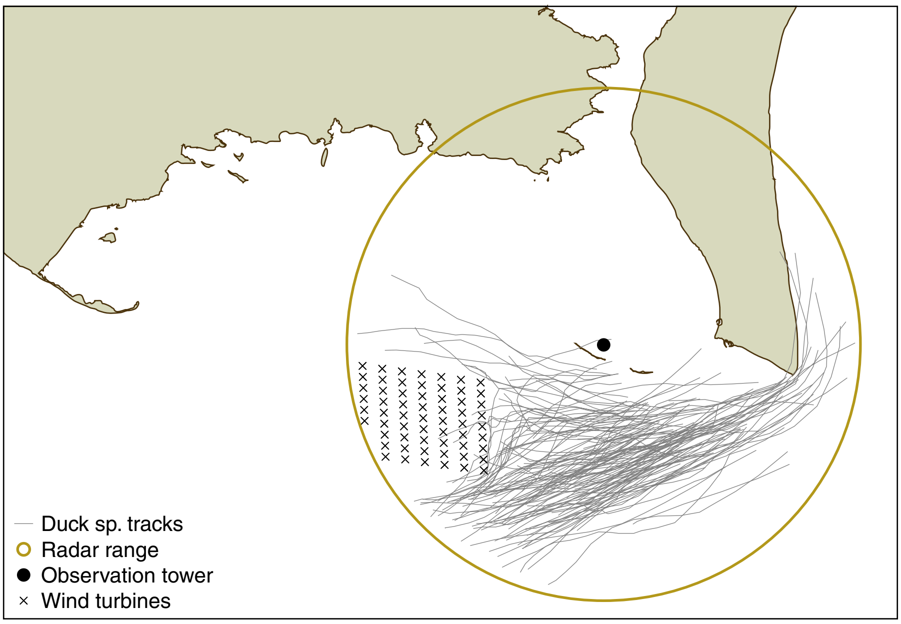
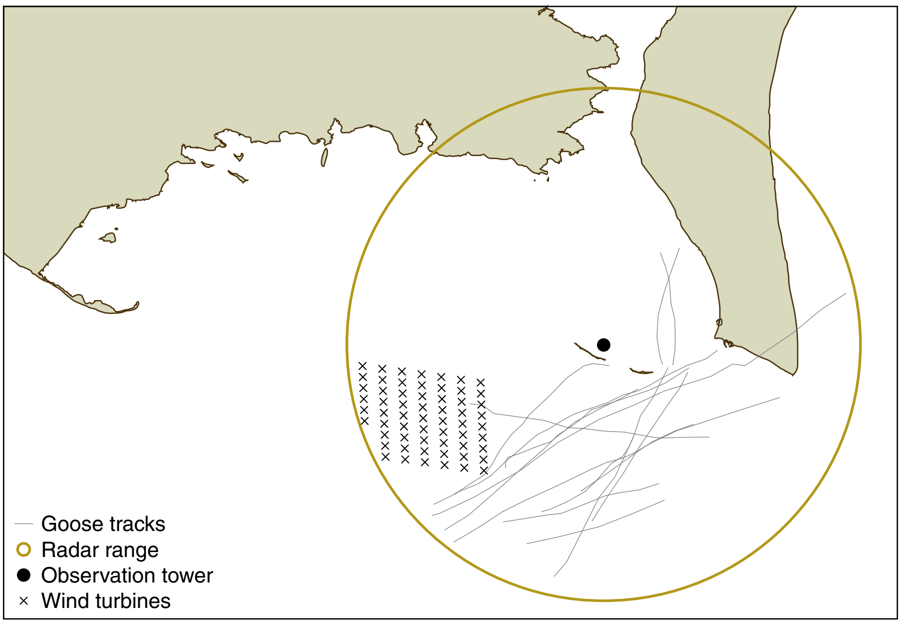


Figure 16. Radar registrations of 16 flocks of migrating geese determined visually (but not to species) at Rødsand during autumn 2003.



In addition, a repeated measurement analysis on the orientation of individual bird flocks in relation to their distance to the wind farm in the approach area showed that the year-effect differed across years, dependent on the distance to the wind farm (Table 2). Note that the wind effects found in earlier studies could not be incorporated into this analysis, since during the course of 2003, there were only three observations available during the day with southerly wind conditions. Hence, in this particular year it was not possible to include both time of the day and wind in the analysis in order to elucidate their potential effects on migration routes caused by the wind farm. The preferred model included the parameter time of the day, as this factor was more likely to affect the response of bird flocks towards the wind farm. In order to investigate specific effects of the operation of the wind farm, a comparison between the orientation of the flight trajectories in 2003 and the base-line years 2000-2002 was carried out.

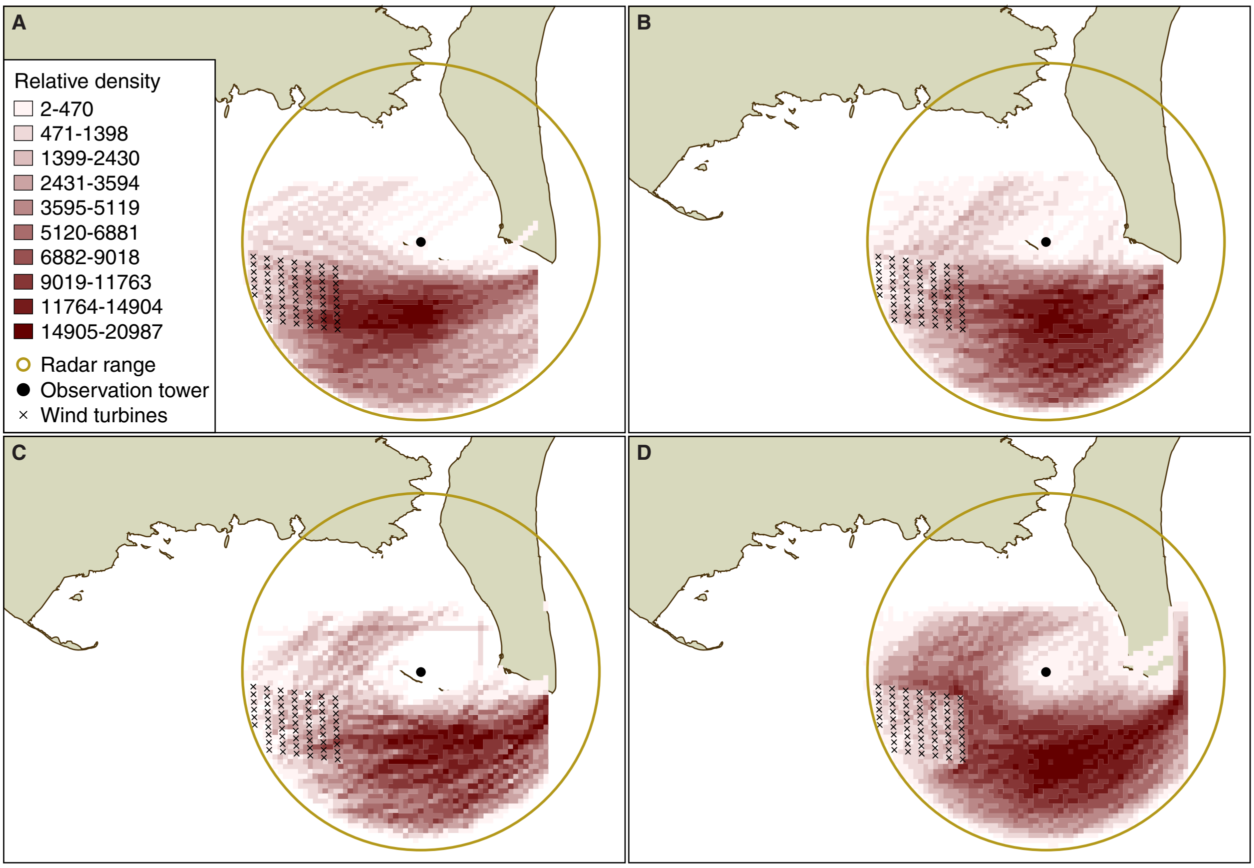


Figure 17. Spatial migration density of waterbird flocks migrating at Rødsand during autumn. The density is indicated by the total length of tracks in metres within each grid cell. Maps are presented for 2000 (A), 2001 (B), 2002 (C) and 2003 (D).

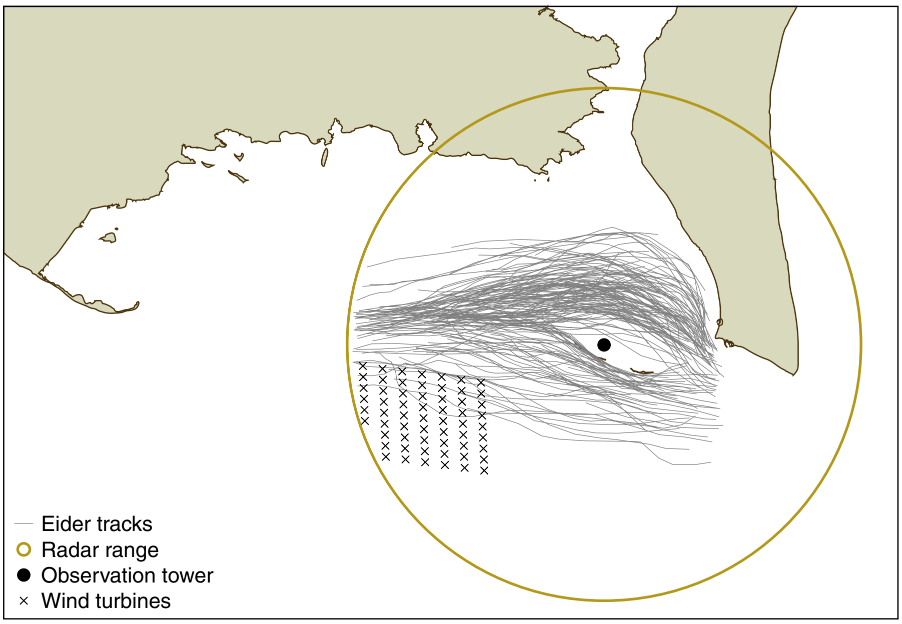


Figure 18. Radar registrations of flocks of migrating eiders determined visually at Rødsand during spring 2003.

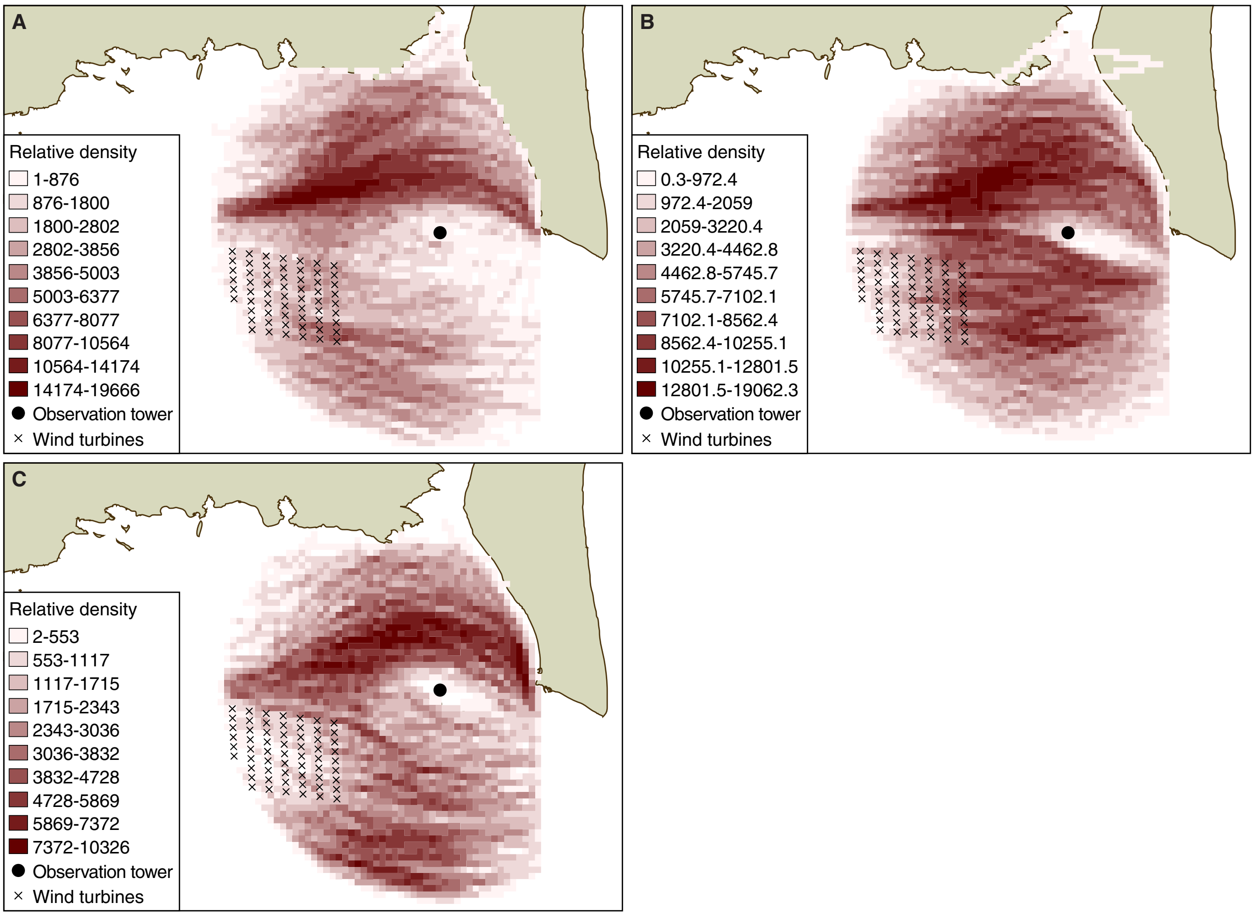


Figure 19. Spatial migration density of waterbird flocks migrating at Rødsand during spring. The density is indicated by the total length of tracks in metres within each grid cell. Maps are presented for 2001 (A), 2002 (B) and 2003 (C).

The observations showed that birds adjusted their orientation to laterally avoid the wind farm both to the north and to the south as they approached the wind farm, hence, comparisons of the means was unlikely to be the most sensitive variable (Figs. 4 and 21A and 21B). It was apparent that although the distributions showed enhanced variance between 1000 m and 500 m in front of the wind farm, the overall mean direction did not change.

Because of this, rather than compare means, standard deviation (s.d.) was considered as a more appropriate variable to test in order to demonstrate a significant change in direction of migration and the distance at which it occurred.

Table 1. Repeated measures analysis of variance of the mean orientation of waterbird flocks approaching the wind farm and the effect of year, time (day/night) and the combined effect of the two factors (between term effects, N = 478).

Factor	DF	F	P
Year	3	7.43	<0.001
Time	1	9.13	0.003
Year*Time	3	3.32	0.020

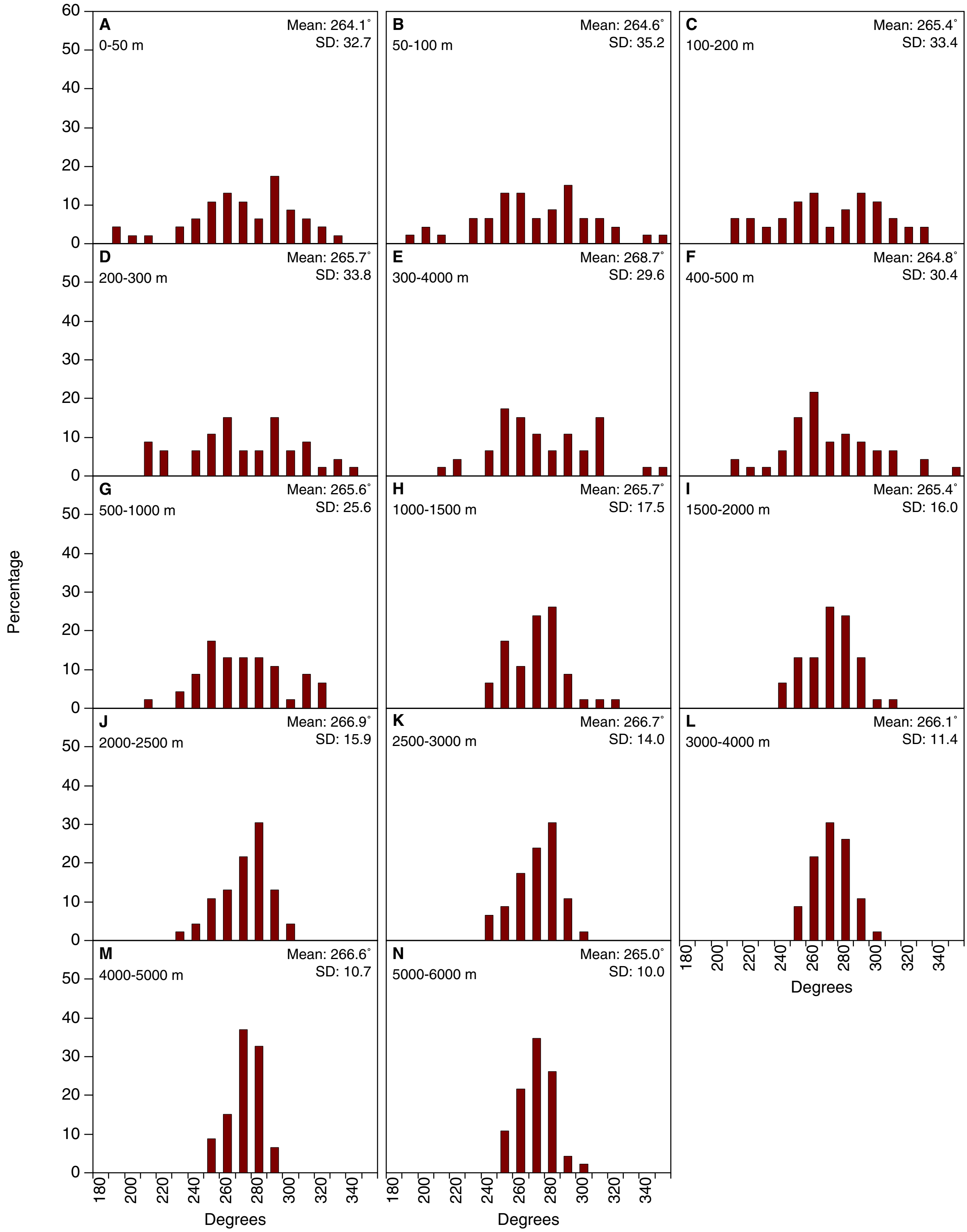


Figure 20. Frequency distributions of the orientation of the autumn migrating waterbird flocks at Rødsand for each of the 14 sectors A-N (see Fig. 5). Mean course and standard deviation for each sector are given in the graphs.

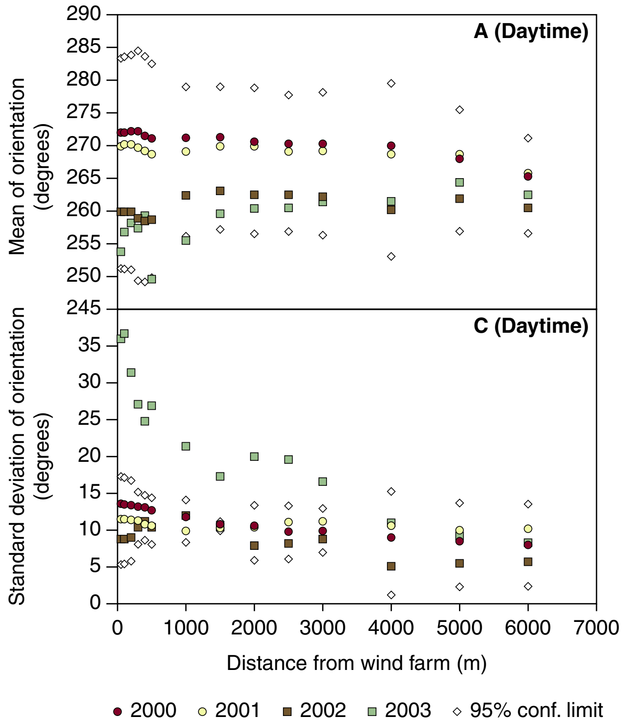


Figure 21. Orientation of tracks of autumn migrating waterbird flocks, which crossed the eastern edge of the wind farm at Rødsand during 2000-2003. Annual mean values with upper and lower 95% confidence limits for the base-line period 2000-2002 are presented for each distance class out from the eastern gate during daytime(A) and nighttime (B). Annual standard deviation values with upper and lower 95% confidence limits for the base-line period 2000-2002 are presented for each distance class out from the eastern gate during daytime (C) and nighttime (D).

This variable was considered more sensitive to changes in migration course when birds show simultaneous adjustment in both a northerly and southerly direction. S.d. of the orientation changed dramatically across the approach area in 2003 (Fig. 21C and 21D). At distances between 4,000 m and 6,000 m there was no difference in s.d. between 2003 data and those obtained during the base-line study by day or by night, i.e. the 95% confidence limits of the base-line s.d. overlapped with the s.d. in 2003. However, daytime observations showed more than twice the s.d. at distances closer than 3000 m to the wind farm in 2003 than during the base-line (well above 95%-confidence limits), and in particular at distances closer than 1,000 m s.d. was markedly higher during operation of the wind farm compared to the results obtained during the base-line study.

Table 2. Repeated measures analysis of variance of the mean orientation of waterbird flocks approaching the wind farm at various distances and the effect year, time (day/night) and the combined effect of the three factors (within term effects, N = 478).

Factor	DF	F	P
Distance	13	1.55	0.090
Distance*year	39	1.70	0.004
Distance*time	13	1.71	0.053
Distance*year*time	39	1.21	0.170

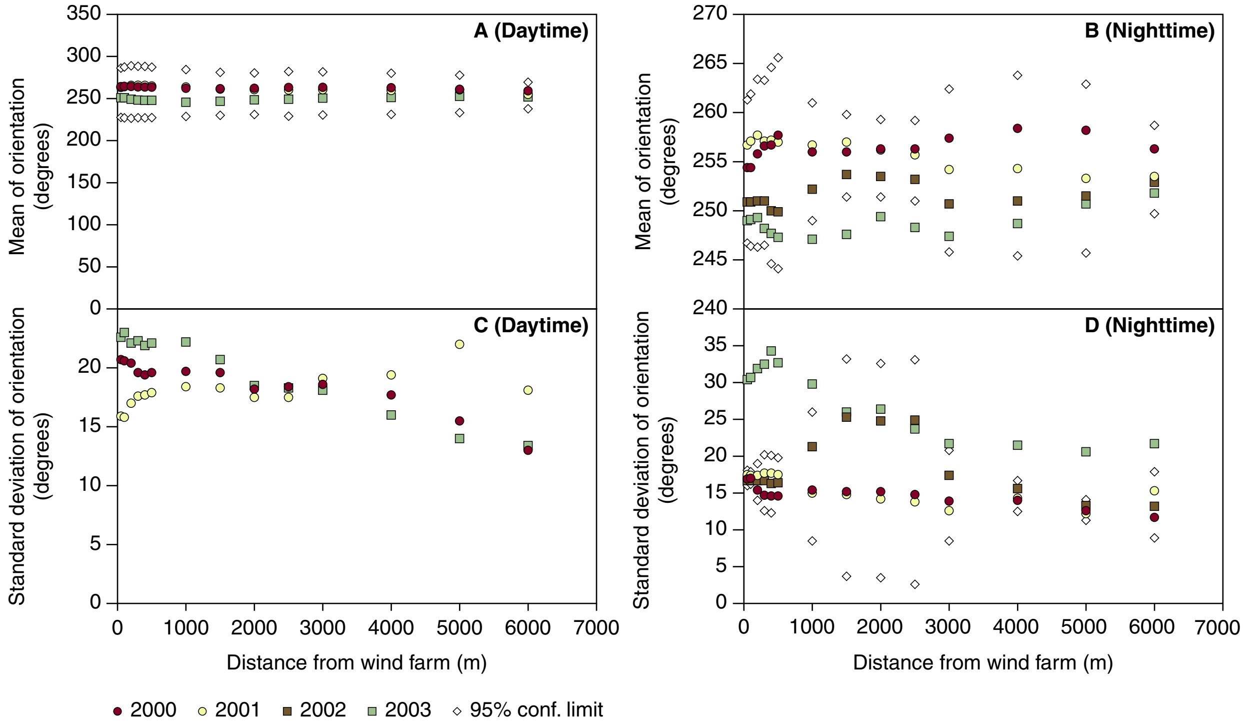


Figure 22. Orientation of tracks of autumn migrating waterbird flocks which passed north or south of the wind farm in autumn at Rødsand during 2000-2003. Annual mean values with upper and lower 95% confidence limits for the base-line period 2000-2002 are presented for each distance class out from the eastern gate during daytime(A) and nighttime (B). Annual standard deviation values with upper and lower 95% confidence limits for the base-line period 2000-2002 are presented for each distance class out from the eastern gate during daytime (C) and nighttime (D).

This suggests that bird flocks changed their orientation as they approached the wind farm at such distances, and this may represent the first observed response of migrating waterbirds at the Nysted wind farm. During the night, the response distance over which a significant increase in s.d. occurred was at 1,000 m (Fig. 21D). This suggested that birds came markedly closer to the wind farm at night before they adjusted their course.

It is therefore concluded that mean values of bird flock orientation as they approach a wind farm may not be an adequate measure of a response *per se* or the response distance. The results from 2003 at Nysted Wind Farm show that it is extremely important to consider changes in the variance as well as the mean direction taken by migrating birds at different distances from the wind farm.

The second analysis included those bird flocks that passed either north or south of the wind farm. Mean orientation during daytime varied little between the years 2000, 2001 and 2003 (Fig. 22A) – note that only eight tracks were available in 2002, and for this reason daytime observations were omitted from this year and no confidence limits for the base-line study was calculated. During nighttime, birds were orientated further to the southwest (225°) compared to the base-line study (Fig. 22B).

S.d. of orientation, which was suggested to be a measure of response distance, tended to be higher during daytime at distances closer than 1,000 m to the wind farm compared to s.d. further east of the wind farm (Fig. 22C). However, this pattern was not as marked as for the birds, which crossed the eastern gate (see Fig. 21C). During night-time, s.d. converged to values which in 2003 was approx. twice the base-line results (2000-2002) at distances closer than 1,000 m to the wind farm (Fig. 22D). This suggested that birds adjusted their course to a larger extent within this distance to the wind farm during operation of the wind farm than they did before the wind farm was erected.

Hence, the results from the data set, only including those birds, which had a course towards the wind farm at a distance of 5-6 km, but passed either north or south of the wind farm tended to support the results obtained from the birds which passed the eastern gate of the wind farm. Thus, at a distance of 3,000 m but most markedly at 1,000 m birds adjusted their flight course likely to be a response towards the wind farm.

Autumn migration of terrestrial birds

Autumn migration orientated towards the northern gate of the wind farm was assumed mainly to represent terrestrial bird species such as passerines and raptors. So far, data collection of radar tracks from terrestrial birds has proven difficult. In 2003, only 20 radar tracks corresponded with the definition established for terrestrial bird tracks. Only in one year during the base-line (2001) were sufficient numbers of tracks (130) compiled to carry out further analysis. The small size of most terrestrial birds, especially passerines, is likely the main reason why terrestrial birds are difficult to detect on the radar. Establishing an observation platform closer to the northern gate of the wind farm could enhance detectability. Although this was considered during the base-line, there were several other factors that constrained the position of the observation platform to its present one. It was therefore decided to focus upon waterbirds and their approach at the eastern gate of the wind farm, because this particular group of birds was considered to be most sensitive to the extra mortality, which the wind turbines may impose on bird populations. There was also a number of practical and logistical reasons for using the present position of the observation platform. Evidently, terrestrial birds may be cited as a major issue in future offshore wind farms. In such cases, the distance between the proposed wind farm and the main observation area is an important key factor to be considered in the design of a bird programme.

As a result of the low number of tracks the flight trajectories can only be reviewed in a descriptive manner and conclusions should only be considered as tentative and preliminary (Fig. 23). The few available southbound tracks at the northern gate of the wind farm showed that bird flocks assumed to be terrestrial birds were able to discern the wind turbines and pass through in the corridors between the north-south orientated rows of turbines. The suggestion that birds are capable of detecting the turbines at some distance and adjust their migration route accordingly is supported by at least some of the tracks, which showed fine-grained adjustments as they approached the wind farm. However, it cannot be excluded that some of the straight south-

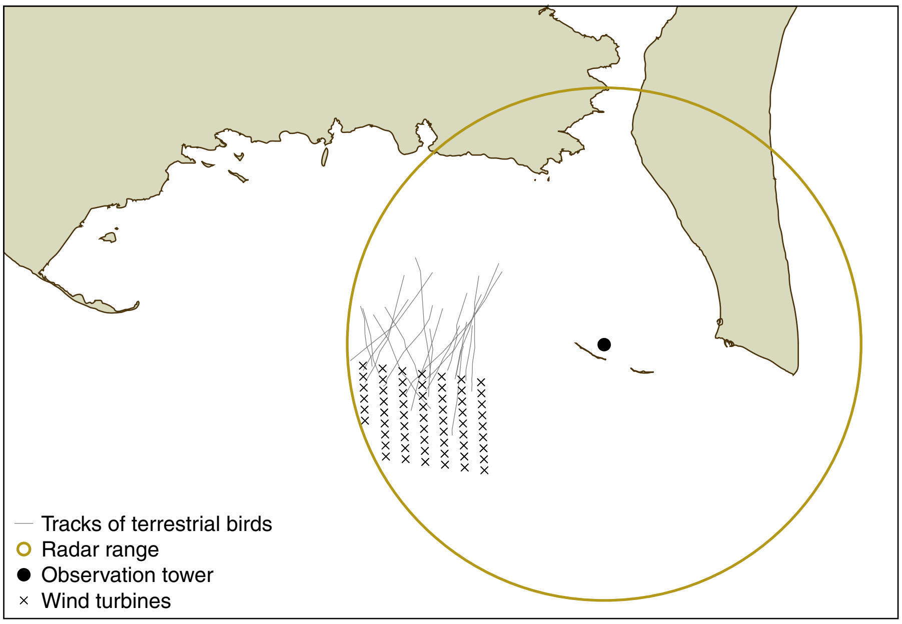


Figure 23. Radar registrations of 20 flocks of migrating terrestrial birds at Rødsand during autumn 2003.

bound tracks were actually flocks which migrated at high altitude above the upper tips of the turbine blades (> 110 m) and could therefore take the optimal straight course without any adjustments.

3.1.2 Probability of passing the wind farm area

Autumn migration of waterbirds

In order to describe the probability of bird flocks passing the wind farm area in further detail, logistic regression models for different years (2000-2003), wind situations (northerly and southerly) and by day and night were computed incorporating distance to the observation tower when passing the Buoy-transect. The last measure corresponded to the spatial distribution of the westerly-orientated migration route taken by waterbirds along a north-south longitudinal axis as they approached the wind farm area.

All factors incorporated into the model could significantly explain the variation in the probability that bird flocks would pass the eastern gate except for time of the day (day/night) (Table 3). However, time of the day would be allowed entry in the model at $P = 0.07$, i.e. very close to the applied significance level ($P = 0.05$)

The year effect indicated that the probability that bird flocks would pass the eastern gate differed between years (Table 3). Overall, the probabilities were in 2000: 48.1%, 2001: 35.2% and 2002: 23.9% and 2003: 8.9%). This means that after the wind turbines were erected in 2003, a flock of birds that approached the wind farm was significantly less likely to pass the eastern gate compared to base-line years (i.e. in the absence of turbines). Note that estimates were slightly changed due to use of a revised method (see section 2.2.2). Radar observations of flocks approaching from the east in the vicinity of the eastern gate also showed flight patterns, which suggested that avoidance of the wind farm occurred (Fig. 24).

Table 3. Significance of Maximum Likelihood Estimates of parameters in a stepwise logistic regression model, predicting the probability that bird flocks pass the wind farm area as a function of year (2000-2003), the distance in metres to the observation tower, wind direction (northerly/southerly), and first order interactions between the factors. Only significant factors are presented entry and stay in model at P = 0.05. Model Goodness-of-Fit Tests were carried out according to Hosmer & Lemeshow (SAS 1999). N = 2,179).

Factor	DF	χ^2	P
Year	3	301.36	< 0.001
Distance	1	558.57	< 0.001
Wind	1	9.09	0.003
Distance*Year	3	18.71	<0.001
Distance*Wind	1	80.59	< 0.001
Year*Wind	3	8.70	0.034
Goodness-of-Fit	8	56.91	< 0.0001

The distance effect confirmed the results from previous years that birds (Table 3), which migrated at the same latitude as the wind farm, would have a higher probability of passing the eastern gate than birds approaching at a latitude north and south of the wind farm (Desholm et al. 2001, Kahlert et al. 2002, Desholm et al. 2003).

The wind effect was consistent with that of previous years, i.e. migration routes were positioned further to the north during periods with winds from the south compared to situations with northerly winds (Table 3). During northerly winds, 6.8% of tracks were detected in the northernmost sector of the buoy-transect (distance to tower 0-3 km) compared to 16.2% during southerly winds (averages during the period 2000-2003). The further to the north (equivalent to a shorter distance to the tower) the lower the probability of crossing the eastern edge of the wind farm (Desholm et al. 2001, Kahlert et al. 2002, and Figs. 25C and 25D this report).

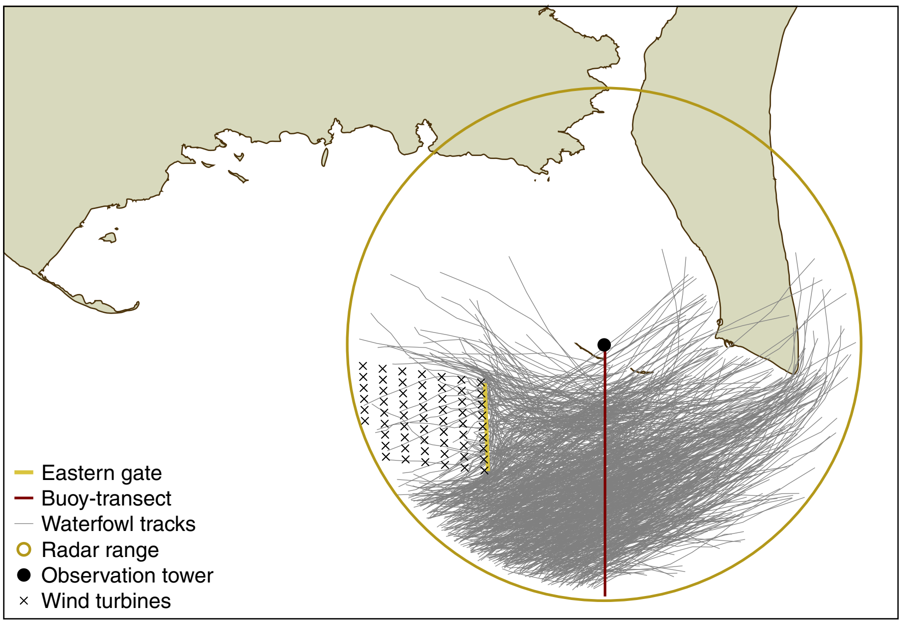


Figure 24. Radar tracks of migrating waterbirds at Rødsand during autumn 2003. For a track having crossed the buoy-transect, there was a probability of 8.9% of passing the eastern gate of the wind farm.

Given the predominant westbound migration the two cross wind scenarios evidently affected the probability that bird flocks would pass through at the eastern gate of the wind farm. In addition, the crosswind effect varied between years (i.e. the significant combined year and wind effect in Table 3).

The effect of distance also differed between years (combined year and distance effect in Table 3). Finally, the magnitude of the distance effect was dependent on wind direction (combined year and wind effect in Table 3).

On the basis of the flight trajectories compiled during 2000-2003, it can be concluded that the main migration route of waterbirds appeared to be relatively constrained, showing a main heading to the west. However, when the course of the flight trajectories was investigated on a more fine-grained scale, i.e. compared to the position of the wind farm area, the nature of flight corridors turned out to be quite complex and influenced by several factors.

For this reason, more detailed analysis has been carried out, in particular to determine whether any general avoidance response occurred during autumn 2003 after the erection of the wind turbines. This analysis showed that the probability that bird flocks would pass the eastern gate in 2003 was reduced considerably compared to the base-line years (2000-2002). This result was obtained under all combinations of cross wind regimes and time of the day when controlling for their latitudinal position as the bird flocks approached the wind farm (distance to tower) (see Figs. 25A-E).

With one exception, the differences in probabilities between 2003 and the base-line years were significant (Tables 4 and 5). The insignificant result was obtained in the comparison between 2001 and 2003, during daytime at southerly winds at distance intervals between 0 and 4,000 m (Tables 4 and 5). This comparison held the lowest sample size of all comparisons (N = 42), and this may explain why a marked graphical difference (see Fig. 25c) failed to attain statistical significance. In addition, most first-order interactions (comparisons of slopes) were significant in the model, indicating that the rate of change in probability over distances was markedly different in 2003. Graphically, the most notable examples can be found in Fig. 25d.

Model fit to observations was poor during southerly winds at night (Table 5, Fig. 25e), suggesting that other factors may have influenced the probability of flocks passing the eastern edge of the wind farm.

It can therefore be concluded that bird flocks avoided the wind farm consistently irrespective of the time of the day and during various crosswinds. In summary, less than 4-7% of the tracks passed the eastern edge during daytime in 2003, compared to 11-24% at night, dependent on the wind (Fig. 26).

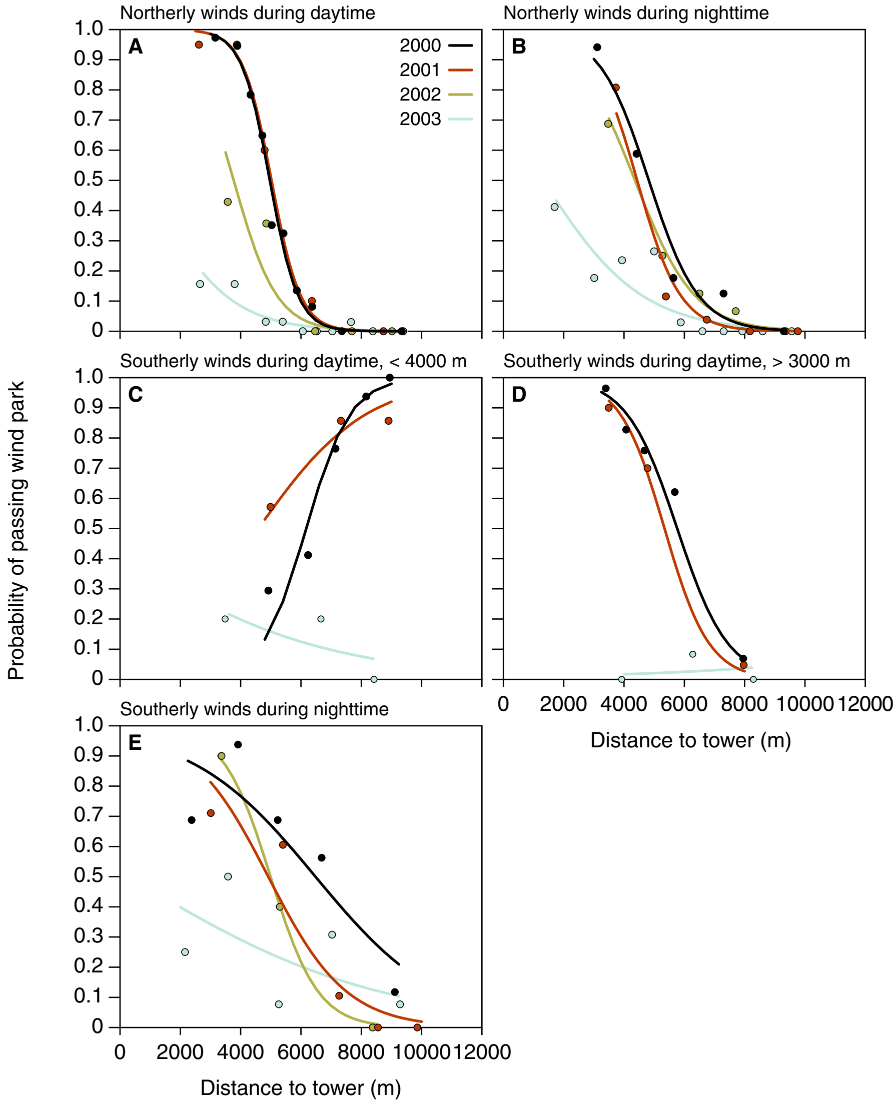


Figure 25. Probability that bird flocks flying in a westerly direction at Rødsand will pass the eastern edge of the wind farm area as a logistic function of their position on a transect south of the observation tower. Logistic functions are presented under five sets of conditions: A) northerly wind during the day (N = 862), B) northerly wind at night (N = 631), C) southerly wind during the day (< 4000 m from the tower; N = 140), D) southerly wind during the day (> 3000 m from the tower; N = 241) and E) southerly wind during the night (N = 365). Observation points appeared by dividing data sets in distance categories of equal size (3, 5 or 10 categories). An observed probability and a mean distance was calculated for each category.

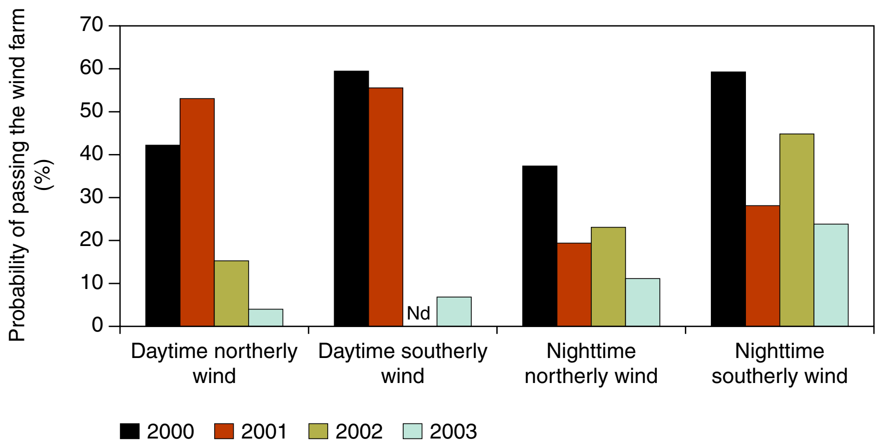


Figure 26. Probability of waterbirds passing through the Nysted wind farm in the autumns of 2000, 2001 and 2002 (base-line) and 2003 (operation) in relation to day/night and wind conditions (northerly or southerly). Nd: no available data.

Table 4. Significance of Maximum Likelihood Estimates of parameters in logistic regression models comparing the probability that bird flocks pass the wind farm area in autumn 2003 (operation) with 2000, 2001 and 2002 (base-line) as a function of the distance in metres to the observation tower at northerly wind directions and during daytime and nighttime. Goodness-of-Fit Tests were carried out according to Hosmer & Lemeshow (SAS 1999).

Wind direction	Distance interval (m)	Period	Factor	χ^2	P
North	0-11,000	Day	Intercept	0.64	0.42
			Year 2000	47.49	< 0.0001
			Year 2001	15.76	< 0.0001
			Year 2002	4.70	0.03
			Distance	14.77	0.0001
			Distance*Year 2000	19.91	< 0.0001
			Distance*Year 2001	6.50	0.01
			Distance*Year 2002	1.65	0.20
			Goodness-of-Fit	6.76	0.56
	0-11,000	Night	Intercept	3.74	0.05
			Year 2000	12.31	0.0005
			Year 2001	12.51	0.0004
			Year 2002	6.85	0.0089
			Distance	38.34	< 0.0001
			Distance*Year 2000	4.22	0.04
			Distance*Year 2001	6.29	0.01
			Distance*Year 2002	2.17	0.14
			Goodness-of-Fit	17.27	0.03

Table 5. Significance of Maximum Likelihood Estimates of parameters in logistic regression models comparing the probability that bird flocks pass the wind farm area in autumn 2003 (operation) with 2000, 2001 and 2002 (base-line) as a function of the distance in metres to the observation tower at southerly wind directions and during daytime and nighttime. Note that during daytime a segmented model provided the best fit of data due to an avoidance response both north and south of the wind farm. Note also that in 2002, the number of tracks registered during daytime and southerly winds was too small for any meaningful analysis. Goodness-of-Fit Tests were carried out according to Hosmer & Lemeshow (SAS 1999).

Wind direction	Distance interval (m)	Period	Factor	χ^2	P
South	0-4,000	Day	Intercept	0.02	0.89
			Year 2000	7.60	0.006
			Year 2001	0.71	0.40
			Distance	0.53	0.47
			Distance*Year 2000	11.35	0.0008
			Distance*Year 2001	3.43	0.06
			Goodness-of-Fit	6.13	0.63
	3,000-11,000	Day	Intercept	1.61	0.20
			Year 2000	8.71	0.003
			Year 2001	8.37	0.004
			Distance	0.14	0.71
			Distance*Year 2000	5.85	0.02
			Distance*Year 2001	6.08	0.01
			Goodness-of-Fit	3.25	0.92
	0-11,000	Night	Intercept	0.01	0.92
			Year 2000	8.87	0.003
			Year 2001	15.07	0.0001
			Year 2002	5.66	0.0174
			Distance	3.41	0.06
			Distance*Year 2000	1.83	0.18
			Distance*Year 2001	9.72	0.0018
			Distance*Year 2002	3.86	0.049
			Goodness-of-Fit	36.85	< 0.0001

Spring migration of waterbirds

During the construction phase in spring 2003, the overall percentage of waterbird tracks passing the eastern edge of the wind farm area was 11%, i.e. after flocks may have passed through the entire wind farm, due to the prevailing orientation during spring. This was a lower percentage compared to the base-line study (16% in 2001, and 25% in 2002). The percentage of bird flocks, which passed the eastern edge of the wind farm, may also be dependent on wind direction (northerly/southerly) and time of the day (day/night) (e.g. Desholm et al. 2003). An analysis including these factors showed that year, time of the day and wind direction all had a significant effect on the relative number of flocks that passed the eastern edge of the wind farm area (Table 6). In addition, the magnitude of the year-effect was dependent on time of the day and wind direction (combined effects in Table 6). For this reason comparisons across years were performed separately during specific wind directions and during day and night (Figs. 27A-D).

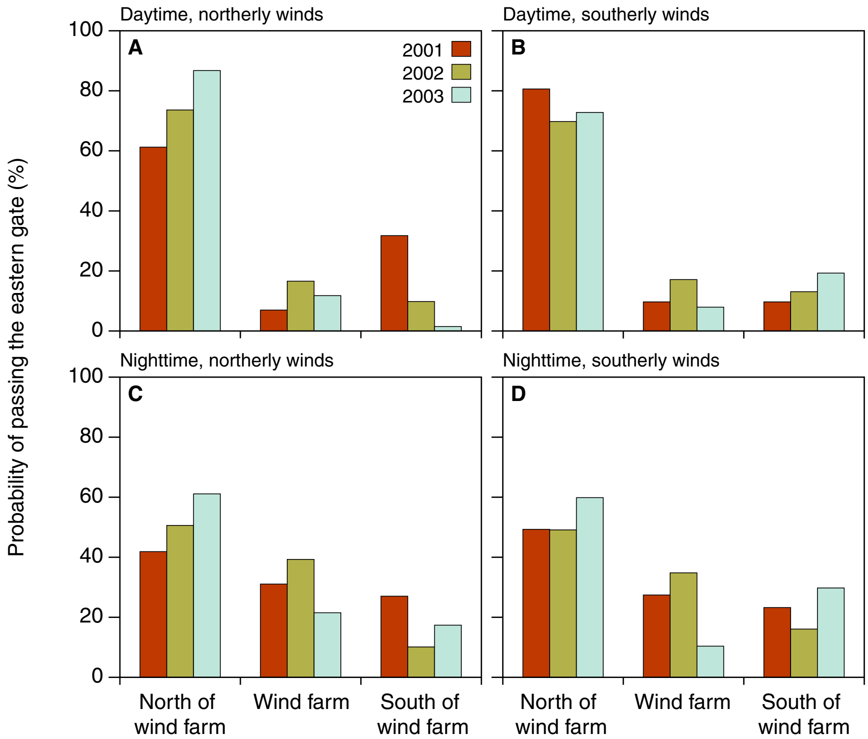


Figure 27. Probability of waterbirds passing the eastern wind farm gate in the springs of 2001 and 2002 (base-line) and 2003 (construction) at Rødsand. Data are presented for A) daytime, northerly winds, B) daytime, southerly winds, C) night, northerly winds and D) night, southerly winds.

During daytime, the majority (more than 60%) of the bird flocks passed on the transect north of the wind farm and less than 18% passed the transect at the eastern edge. During daytime, there was no support for the hypothesis that birds avoided the wind farm area in the construction phase (spring 2003). In northerly winds, the percentage passing the eastern edge was within the range measured during the base-line study (Fig. 27A). During southerly winds, the proportion passing the eastern edge was lowest in 2003 (7.9%) compared to 2001 (9.7%) and 2002 (17.1%). However, the difference to 2001 was minor and not significant ($\chi^2 = 0.75$, DF = 1, P = 0.39).

During night, the main migration route was also north of the wind farm area (see Figs. 27C and 27D), although this route was less frequently used compared to during daytime. More flocks passed the eastern edge of the wind farm during the night (10-39% compared to < 18% during the day). However, there were some indicatives that

Table 6. Maximum Likelihood Analysis of Variance of effects from wind direction (Wind), time of the day (Time), year (2001, 2002 and 2003) and the combined (*) effects of the three factors on the presence of tracks at the eastern gate of the wind farm area during spring 2001, 2002 (base-line) and 2003 (operation) (N = 2,744 tracks).

Factor	χ^2 (df = 1)	P
Wind	3.96	0.05
Time	77.34	< 0.0001
Year	53.77	< 0.0001
Year*Time	11.33	0.0035
Year*Wind	6.76	0.03
Wind*Time	2.00	0.15

birds avoided the wind farm area at night during the construction phase. The percentage passing the eastern edge was consistently smaller (9-24%) during spring 2003 compared to the base-line study. The reduction in relative number of flocks passing the eastern edge was highly significant (χ^2-tests, $P < 0.00001$), except in the comparison between 2001 and 2003 at northerly winds ($\chi^2 = 2.39$, DF = 1, $P = 0.12$). The lower proportion of tracks at the eastern border of the wind farm mainly resulted in a higher proportion of tracks north of the wind farm area. This area already constituted the main migration route prior to construction activities.

It may be hypothesised that the observed changes in migration routes during night may result from changes in species composition, i.e. different species may have different migration routes. Unfortunately, species determination was impossible during night. However, ground speed of migratory birds can be used to indicate whether a dramatic change in species composition had occurred during night-time migration in 2003. As a reference, the verified ground speeds of different species were used from observations made during daytime, when species could be determined. In addition, head- and tailwind was taken into consideration. For eiders average ground speed was 55 km/h (range: 50-78, N = 43) during headwind and 71 km/h (range: 54-122, N = 132) during tailwind. Average ground speed differed during head- and tailwind whereas the lower end of the ranges converged to a similar value.

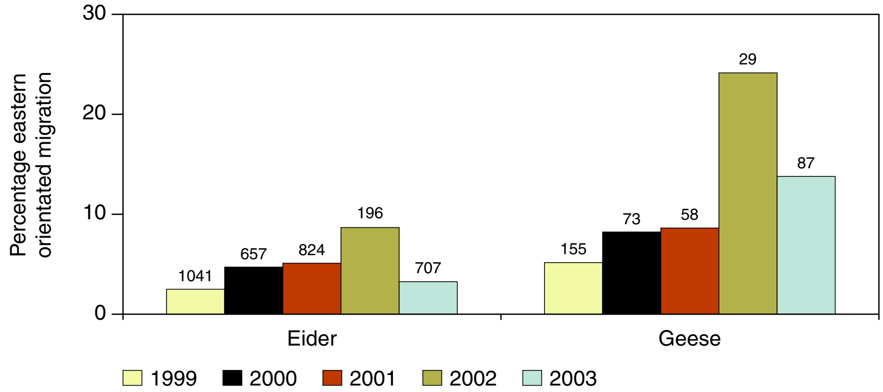
This information was used to give a crude estimate of the proportion of eider and similar species (waterbirds), which occurred at night in 2001, 2002 and 2003. On this basis, the data set was divided in flocks with ground speeds above and below 50 km/h. It was previously shown that birds likely to be terrestrial birds generally had ground speeds below 50 km/h (Desholm et al. 2003).

Analysis showed that the proportion of flocks with a ground speed greater than 50 km/h amounted to 88% during the construction phase in 2003 compared to 94% in 2001 and 73% in 2002. The difference across years did not differ significantly ($\chi^2 = 3.56$, DF = 2, $P = 0.17$). Although the analysis should be considered with caution, it may be taken to indicate that the composition of species groups occurring in the wind farm area did not change markedly in spring 2003.

3.1.3 Reverse migration

In autumn, eider and geese occurred in such large numbers that it was possible to study the extent of potential reverse migration (i.e. in an eastbound direction), if a severe barrier effect of the wind farm occurred. The test investigated whether a higher percentage of eastern orientated migration was observed at the Buoy-transect, (which runs north-south and lies 5.29 km east of the northeastern most turbine and 5.15 km east of the southereastern most turbine). Hence, only long distance reverse migration (i.e. not just those birds turning back from the immediate vicinity of the eastern gate) is dealt with in this analysis.

Figure 28. Percentage of eiders (left columns) and geese (right columns) showing "reversed" migration at Rødsand in autumn, expressed as the proportion of birds flying across the Buoy-transect in a easterly direction in 1999, 2000, 2001, 2002 (base-line) and in 2003 (operation).



The percentage of eastern orientated eider flocks that passed the Buoy-transect differed significantly between the years 1999-2003 (χ^2 = 21.43, DF = 4, P = 0.0003). However, the 3% eastern orientated flocks observed in 2003 was within the variation observed during the base-line study (Fig. 28). Geese also showed a significant difference in the percentage of eastern orientated flocks between years (χ^2 = 16.13, DF = 4, P = 0.0028), which primarily derived from a high percentage in 2002 (Fig. 28). When 2003 was tested specifically against the base-line years 2000 and 2001, no significant effect was found (χ^2 = 1.24, DF = 1, P = 0.27 and χ^2 = 0.90, DF = 1, P = 0.34).

Hence, the results from 2003 do not support the hypothesis that reverse migration occurred as a result of the wind farm.

3.1.4 Migration intensity in the wind farm area

As in previous reports, the data relating to migration intensity is presented in standard format, based on the mean numbers of flocks observed (per 15 minute period) passing the eastern and northern gates in spring and autumn. Attempts have been made to separate the effects of differences in the prevailing winds on migration intensity for each season and for eastern and northern gates.

In addition, track densities from autumn 2003 in the eastern part of the wind farm area (operational phase) were compared with results obtained during the base-line study (see Fig. 17). A reference area was also included in the analysis (see Fig. 10).

Autumn migration

Track densities differed significantly between years both in the eastern part of the wind farm area and in the reference area (wind farm: F = 143.67, DF = 3, P < 0.0001; reference: F = 111.97, DF = 3, P < 0.0001, ANOVA). In particular, track densities were markedly higher in 2000 (Fig. 29). Track densities in the reference area were also significantly higher compared to the eastern part of the wind farm area (F = 570.67, DF = 1, P < 0.0001, Repeated measures ANOVA). This derived most likely from the distance-dependent detectability of radar tracks. However, the difference between reference area and wind farm area also differed across years (F = 13.91, DF = 3, P < 0.0001, Repeated measures ANOVA). Further analysis showed that track densities were significantly lower in 2003 in the eastern part of the wind farm area compared to 2000, 2001 and 2002 (Table 7). In the reference area,

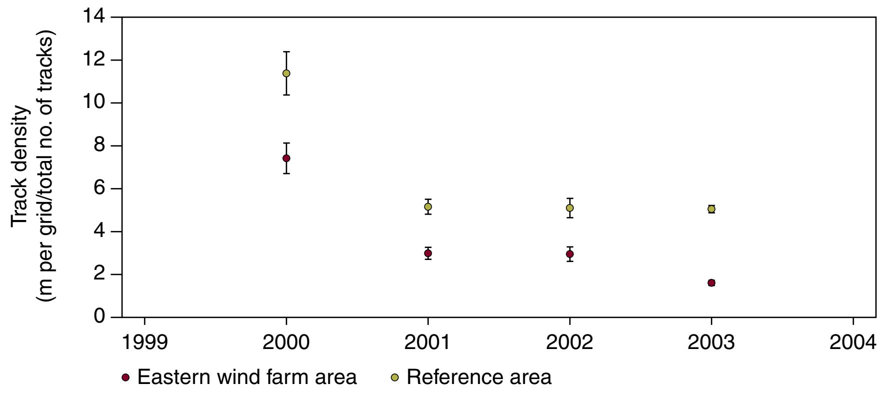


Figure 29. Mean track densities (±95% confidence intervals) from 108 grid squares in the eastern part of the wind farm area and an adjacent reference area in 2000, 2001, 2002 and 2003.

track densities only differed between 2003 and 2000. Interpretation of track densities should be drawn with caution because they may be affected by several factors such as overall migration volume, track detectability and flight altitude. Nevertheless, the results support the prediction that birds undertake avoidance responses as suggested from other data (see sections 3.1.1 and 3.1.2).

The intensity of migration at the eastern gate was similar to that witnessed in 2001 and 2002, showing highest intensities during the northeasterly winds which prevailed in 2000 (Fig. 30A). This effect was not apparent by night, although again, patterns in 2003 fell within the variation observed in the base-line years (Fig. 30B). Northeasterly and southeasterly winds apparently affected daytime migration in 1999-2001 (Fig. 30C), but less so by night (Fig 30D). The intensity of migration in 2003 fell within the range of variation of the overall base-line years.

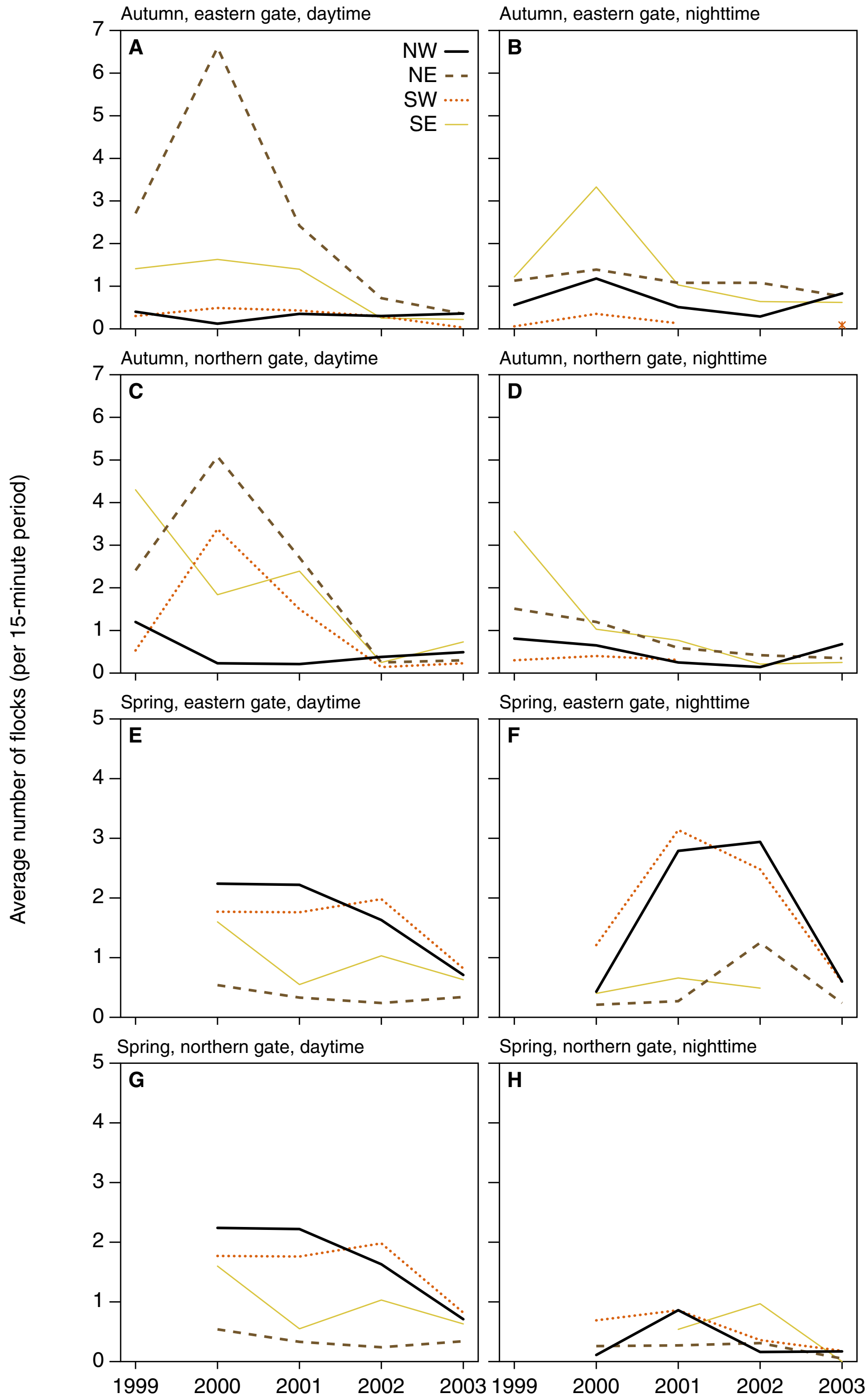
Spring migration

The intensity of migration by daytime in 2003 at the eastern and northern gates was generally less than that witnessed in 2000, 2001 and 2002 (Fig. 30E, 30F and 30G), There were no obvious difference in nighttime migration intensity between the base-line years and 2003, which was less affected by wind direction than during the day (Figs. 30G and 30H).

Table 7. Statistical comparisons of track densities in the eastern part of the wind farm area and an adjacent reference area (t-test with Satterthwaite's approximation due to unequal variances.)

Area	Comparison	t	DF	P
Wind farm	2003 v. 2000	16.04	113	< 0.0001
	2003 v. 2001	9.15	149	< 0.0001
	2003 v. 2000	7.39	135	< 0.0001
Reference	2003 v. 2000	12.23	113	< 0.0001
	2003 v. 2001	0.53	155	0.5969
	2003 v. 2000	0.19	136	0.8459

Figure 30. Average number of flocks per 15-minute period crossing the eastern (A, B, E, F) and northern (C, D, G, H) gate in situations with different wind directions at Rødsand. The graphs are depicted for autumn (A, B, C, D) and spring (E, F, G, H), and by day (A, C, E, G) and night (B, D, F, H).



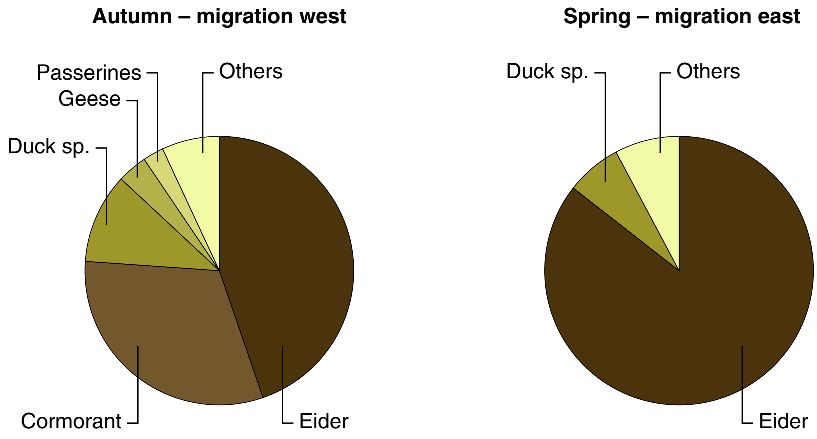
3.1.5 Species composition, numbers and flock size

Overall the west bound autumn migration observed during daytime was predominantly comprised of eiders (45%), but cormorants were also observed in substantial numbers (31%), as they undertook their daily foraging bouts (Fig. 31A). The eastbound spring migration was dominated by eider (86%) to an even greater extent than in autumn (Fig. 31B).

Cormorant *Phalacrocorax carbo*

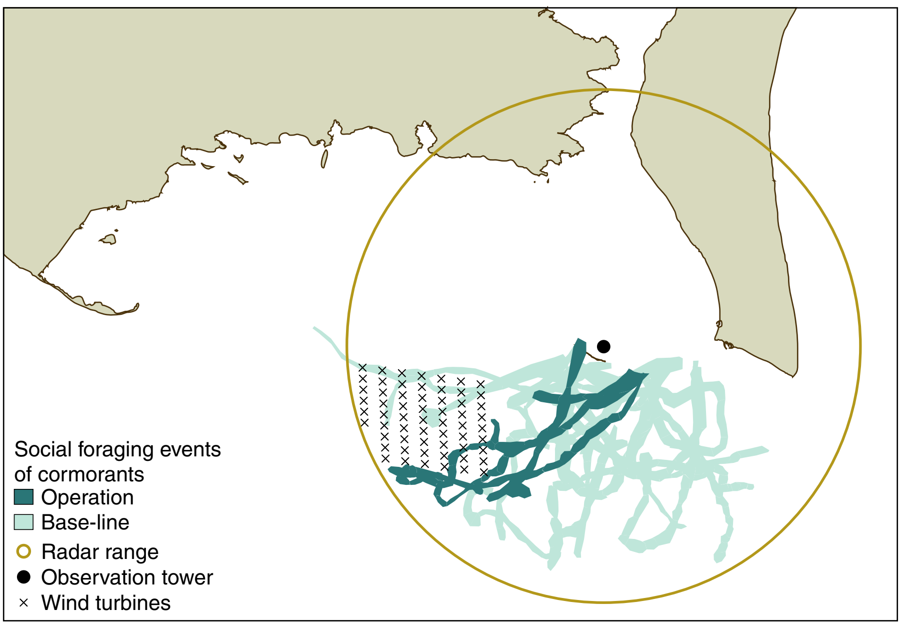
A total of 13,520 cormorants was registered during autumn 2003. Cormorants observed during the visual migration studies were local

Figure 31. Relative species composition of all visual observations of birds passing west in autumn 2003 and passing east in spring 2003 at Rødsand.



birds, roosting at Rødsand during non-foraging periods (Kahlert et al. 2000). Movements between the roost and the foraging areas in the Baltic Sea showed a relative consistent intensity in September and early October, with between 2.2 and 2.3 individuals per 15 minute period passing the Buoy-transect in a westerly direction. In late October, the mean passage fell to only 0.37 individuals, consistent with the departure of the majority of birds to wintering areas in the Mediterranean region. Previous results have shown that more than 90% of the flocks comprised less than 10 individuals each (Desholm et al. 2003), explaining the relatively small mean flock size of 1.71 individuals (Appendices I and II). Mean flock size never exceeded 2.1 individuals during the base-line study. On some occasions large flocks of more than 1,000 individuals were observed during the leaving and returning from the communal roost at Rødsand in 2003. The maximum number recorded was 4,390 individuals. Social foraging events were monitored by radar (Fig. 32). During autumn, there was no evidence that cormorants have changed their habit, using the communal roost at Rødsand. Anecdotal information from staff associated with construction and maintenance of the wind turbines confirmed that new permanent roosts have not been established in the

Figure 32. Social foraging events of cormorants registered by radar from the observation tower in 2000, 2001, 2002 (base-line) and 2003 (operation).



wind farm area, neither on the foundations nor on the transformer station (information Energi E2). On one occasion in 2003, social foraging of 3,700 individuals was observed by radar in the southeastern part of the wind farm (Fig. 32). On two other occasions in 2003 social foraging (2,150 and 1,500 individuals) occurred close to the wind farm area (within approx. 1 km). Foraging cormorants were also observed by staff working in the wind farm area.

A total of 123 cormorants and a mean migration intensity of 0.32 individuals per 15-minute period during spring 2003 confirmed results derived from previous years (Appendix III; Kahlert et al. 2000, Desholm et al. 2001, Kahlert at al. 2002). Migration intensity of cormorants was again higher in autumn than in spring. The mean overall flock size of 1.15 individuals in spring 2003 showed that the majority of the cormorants were observed as solitary migrants (Appendix IV). During spring, anecdotal information suggested that flocks of cormorants roosted on the foundations before turbines were erected (information Energi E2). The general impression from construction workers was that cormorants did not use foundations as turbines were erected, although there was one observation of a cormorant sitting on the fence of a foundation with an operating turbine.

Geese *Anserini*

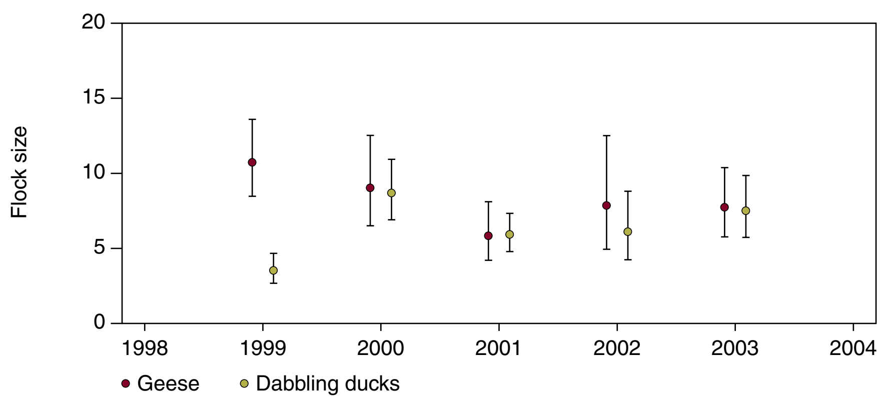
The total number of geese registered during autumn 2003 was 1,521 individuals (see Appendix I). The majority of geese could not be identified to species, however, four species were identified: greylag goose *Anser anser,* barnacle goose *Branta bernicla, w*hite-fronted goose *Anser albifrons* and brent goose. Goose migration peaked in early October, showing a mean migration intensity of 2.90 individuals per 15 minute period. In previous years goose migration either peaked late September or early October. The mean flock size was 7.74 (see Appendix II). Compared to other species, only eiders migrated in larger flocks than geese. During the entire study period 1999-2003, mean flock size of geese varied between 7 and 11 individuals (Fig. 33).

During the period 16 March - 15 April, migration was markedly lower than during autumn (15 flocks in 2003). The spring migration of dark-bellied brent goose in late May was not monitored in 2003.

Dabbling ducks *Anas sp.*

The total number of dabbling ducks registered during autumn 2003 was 878 (see Appendix I), close to the average of the base-line study (837 individuals). As in previous years, wigeon *Anas penelope* was the

Figure 33. Mean flock size (±95% confidence intervals) of all visual observations of geese (solid symbols) and dabbling ducks (open symbols) in the autumns of 1999-2002 (base-line) and autumn 2003 (operation) at Rødsand.



most numerously occurring dabbling duck species (61%). The mean flock size was 7.51 individuals in 2003. Except for 1999, mean flock size of dabbling ducks varied between 5 and 10 (Fig. 33). The migration peaked with a mean of 0.89 individuals per 15-minute period in early October which was later than during the base-line study (See Appendix I). Spring migration of dabbling ducks was negligible in 2003 (12 individuals), as was the case in previous years.

Eider *Somateria mollissima*
During autumn 2003, a total of 19,208 eiders was observed (see Appendix I). This was the lowest number recorded during the entire study except for 2002 when the observations were suspended during the main migration period of eider. In 2003, migration peaked in early October with a mean of 218 individuals per 15 minute period. This was the most intense migration activity recorded during the study. By contrast, during other periods in September and October migration intensity was markedly lower, i.e. less than 3 eiders per 15 minute period. In 3 out of 5 autumns eider migration peaked between 1 and 15 October. The eider had the largest flock size with a mean of 14.64 individuals in 2003 (see Appendix II). This was slightly lower than during the period 1999-2001 but about double the flock size of 2002 when the main migration period was not covered (Fig. 34).

During spring 2003, a total of 9,848 eiders was counted, the dominant species in spring (see Appendix III). The number of eiders during spring migration varied considerably throughout the study (range: 5,750-26,569). However, the mean number of spring migrating eiders per 15-minute period has been quite consistent in the springs of 2000, 2001, 2002 and 2003 (13.58, 13.40, 13.96 and 13.58 individuals, respectively). The mean flock size was 5.28 individuals (see Appendix IV). Flock size varied between approximately 4 and 8 during the study and was only about one third of the flock sizes observed during autumn (Fig. 34).

Other diving ducks
During autumn 2003, a total of 337 diving ducks of other species than the eider was registered (see Appendix I), of these 299 (88%) were red-breasted merganser *Mergus serrator*. It was previously assessed that many of the red-breasted mergansers observed at Rødsand are local birds staging in the area, because a large proportion were orientated against the prevailing direction of migration (Kahlert et al. 2000) and 2003 was no exception to this pattern.

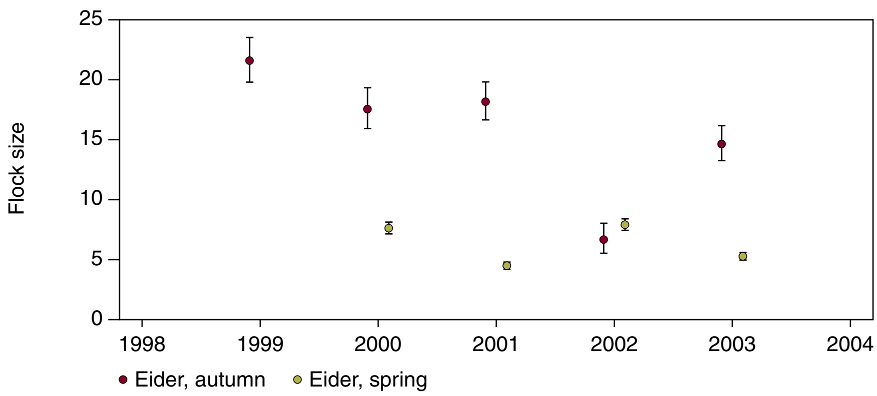


Figure 34. Mean flock size (±95% confidence intervals) of all visual observations of eider in springs (solid symbols) and autumns (open symbols) of 1999-2002 (base-line) and spring 2003 (construction) and autumn 2003 (operation) at Rødsand.

The mean flock size of other diving ducks was 2.12 (see Appendix II), which confirms previous results that other diving ducks migrate in considerably smaller flock sizes than the eider (Kahlert et al. 2000, Desholm et al. 2001, Kahlert et al. 2002). Migration intensity of other diving ducks peaked in early October with a mean of 0.67 individuals per 15-minute period as was the case with the other duck species (see Appendix I).

During spring 2003, a total of 223 diving ducks other than eider was observed. Red-breasted merganser constituted the vast majority (76%). Markedly fewer long-tailed ducks were observed during spring 2003 (44 individuals) compared to the base-line study when numbers varied between 185 and 644. A mean flock size of 1.61 and 1.67 individuals for red-breasted merganser and long-tailed duck complied with previous results (Appendix IV). The mean number of migrating individuals per 15-minute period was 0.46 and 0.10 for the two species (see Appendix III), and it was generally lower than in the previous years of the study.

Gulls *Laridae*

During autumn 2003, a total of 449 gulls was registered (see Appendix I), which was close to the number observed in 2000 and 2001, when 369 and 494 were observed. In 1999, 843 gulls were observed. However, the most intensive gull migration occurred in November (Kahlert et al. 2000), a period that was not covered in 2003. In total 7 species were identified: little gull *Larus minutus*, black-headed gull *Larus ridibundus*, lesser black-backed gull *Larus fuscus*, greater black-backed gull *Larus marinus*, common gull *Larus canus,* herring gull *Larus argentatus* and mediterranean gull *Larus melanocephalus.* Herring gull was the most abundant occurring species.

During autumn 2003, the mean flock size of gulls was 1.19 individuals (see Appendix II), which was comparable to those of the autumns of 1999 (1.27), 2000 (1.15), 2001 (1.16) and 2002 (1.10) and confirms that gulls in many cases occur as solitary individuals. Movements of gulls at the Buoy transect was most intense in early October with a mean of 1.63 individuals per 15 minute period. However, as during the base-line study, no clear trend in terms of phenology was detected, probably because most of the gulls were local birds staging in the area for longer periods (Desholm et al. 2002).

During spring 2003, a total of 249 gulls were counted (see Appendix III), of which 90% could not be identified to species. The mean number of migrating gulls per 15-minute period was 0.65 individuals, which was the lowest number during the entire study. The mean flock size of 1.02 individuals (see Appendix IV) indicated that the majority of the gulls were observed as solitary also during spring.

Sandwich tern *Sterna sandvicensis*

During autumn 2003, a total number of 663 sandwich terns was registered (see Appendix I). This was the highest number registered during an autumn observation bout and almost twice as many as in 2001, when the second highest number was recorded (356 individuals). The mean flock size of 1.35 individuals (see Appendix II) was comparable to the results in the previous years. Migration intensity peaked early September with a mean of 2.10 individuals per 15-minute period (see Appendix I), which makes sandwich tern the most commonly occurring species in early September. The vast majority of sandwich terns have left Danish waters by the end of September. In early October, a mean of 0.04 individuals occurred per 15 minute observation period and in late October sandwich tern was not observed in the study area.

During spring 2003, a total of 95 sandwich terns was observed (see Appendix III). This was the lowest number recorded during spring observations 2000 (304 individuals), 2001 (223) and 2002 (112). The mean migration intensity was 0.23 individuals per 15-minute period in 2003. The mean flock size of 1.20 (see Appendix IV) was within the 95% confidence limits of the mean flock size in 2001 and 2002 (Kahlert et al. 2002, Desholm et al. 2003). In 2000 mean flock size was slightly higher (1.30 individuals).

Passerines *Passeriformes*
During autumn 2003, the total number of passerines recorded was 1,177 individuals (see Appendix I). During the base-line study, numbers fluctuated between 180 and 7,164 individuals. The lowest number was observed in 2002 when the bird programme was temporary suspended (Desholm et al. 2003). The highest number was recorded in 2001 when an intense migration of swallows *Hirundinae* was observed in September. No particular species occurred in outstanding numbers in autumn 2003. Numbers peaked in late September with a mean of 2.85 individuals per 15 minute period (Appendix I). The mean flock size was 2.44 individuals (see Appendix II). Flock size of passerines migrating westwards varied between 1.84 and 3.02 during the base-line study, suggesting that the area around the tower on Rødsand is of minor importance compared to the Gedser Odde area, where for example several thousand finches *Fringillidae* are observed daily during peak migration (e.g. Nielsen 2000).

Other species
The category 'other species' covers wood pigeons *Columba palumbus* and species that were observed in numbers <100 individuals on the observation transect. Species such as grebes *Podicipediae* and divers *Gaviidae* (which were described in the EIA report by Kahlert et al. 2000) are not dealt with in this report. No species or groups of species, which have not been described above, occurred in numbers exceeding 100 individuals during spring or autumn 2003 and therefore will not be analysed further in this report.

3.2 Staging, moulting and wintering birds

This section describes the presence and distribution of the most numerously occurring species in the study area. The data originate from aerial surveys, primarily the four conducted during 2003, but combined with data from 21 previous surveys from the period August 1999 – August 2002. Details on each of the 25 surveys are given in Table 8.

Table 8. Summary details of the 25 aerial surveys carried out in the study area, August 1999-December 2003. Table shows the dates when the surveys were carried out, the transect widths used on different aerial survey dates, and the total distance of transect surveyed (including counts from both sides of the aircraft).

Survey Number	DATE	Band A	Band B	Band C	Km Transect Covered
1	19990829	44-250 m	>250 m		1005
2	19991115	44-163 m	163-432 m	432-1,000 m	1093
3	19991213	44-163 m	163-432 m	432-1,000 m	1027
4	20000114	44-163 m	163-432 m	432-1,000 m	1175
5	20000214	44-163 m	163-432 m	432-1,000 m	597
6	20000404	44-163 m	163-432 m	432-1,000 m	1165
7	20000426	44-163 m	163-432 m	432-1,000 m	1164
8	20000911	44-163 m	163-432 m	432-1,000 m	1102
9	20001007	44-163 m	163-432 m	432-1,000 m	1078
10	20001127	44-163 m	163-432 m	432-1,000 m	1081
11	20010110	44-163 m	163-432 m	432-1,000 m	1035
12	20010210	44-163 m	163-432 m	432-1,000 m	1169
13	20010316	44-163 m	163-432 m	432-1,000 m	1165
14	20010420	44-163 m	163-432 m	432-1,000 m	1138
15	20010815	44-163 m	163-432 m	432-1,000 m	1164
16	20010928	44-163 m	163-432 m	432-1,000 m	569
17	20011114	44-163 m	163-432 m	432-1,000 m	1168
18	20020103	44-163 m	163-432 m	432-1,000 m	1162
19	20020213	44-163 m	163-432 m	432-1,000 m	1163
20	20020326	44-163 m	163-432 m	432-1,000 m	1145
21	20020822	44-163 m	163-432 m	432-1,000 m	1163
22	20030110	44-163 m	163-432 m	432-1,000 m	919
23	20030304	44-163 m	163-432 m	432-1,000 m	1160
24	20030424	44-163 m	163-432 m	432-1,000 m	1164
25	20031209	44-163 m	163-432 m	432-1,000 m	1150

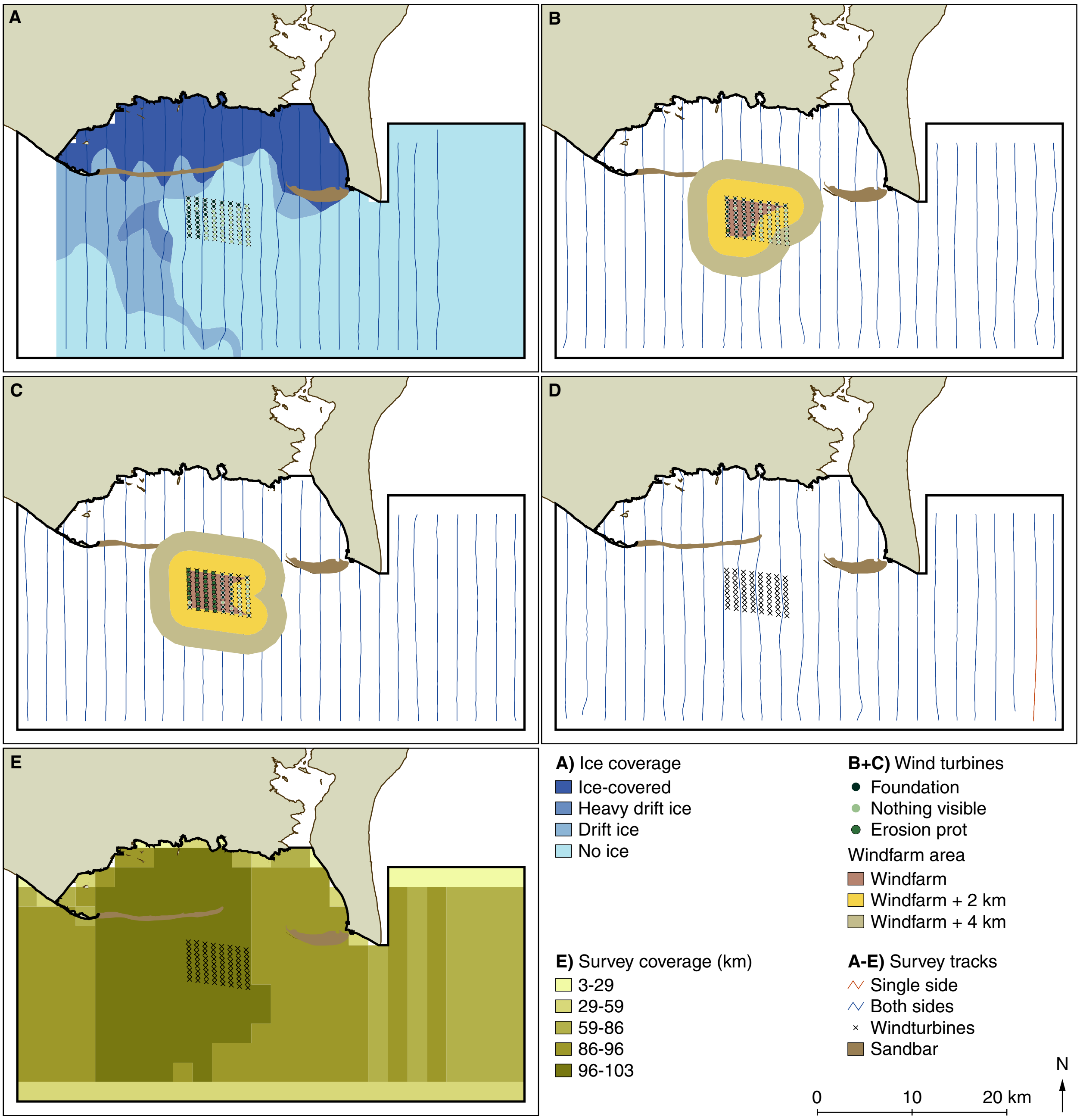


Figure 35. Survey track lines for the four surveys conducted in 2003 on 10 January with ice cover (A), 4 March (B), 24 April (C) and 9 December (D) and the overall survey coverage for all 25 surveys, expressed as kilometer of covered transect by 2 x 2 km grids (E). The extent of the corresponding 2 and 4 km zones around erected turbines is shown in B and C. Wind farm construction progress for each survey is illustrated by differentiated wind turbine icons (A, B, C, D and E).

3.2.1 Survey coverage

The spatial coverage of the four aerial surveys in 2003 was almost full for March, April and December surveys (Fig. 35 B, C, D), while the two westernmost and the four easternmost transects of the January 2003 survey were abandoned due to poor light conditions (Fig. 35 A). Ice cover extended unusually south of the Rødsand sandbars during the January 2003 survey, influencing the distribution and abundance of a number of bird species (Fig. 35 A). The overall survey coverage in the study area, based on all 25 surveys, was highest in the central parts, including the wind farm area (Fig. 35 E).

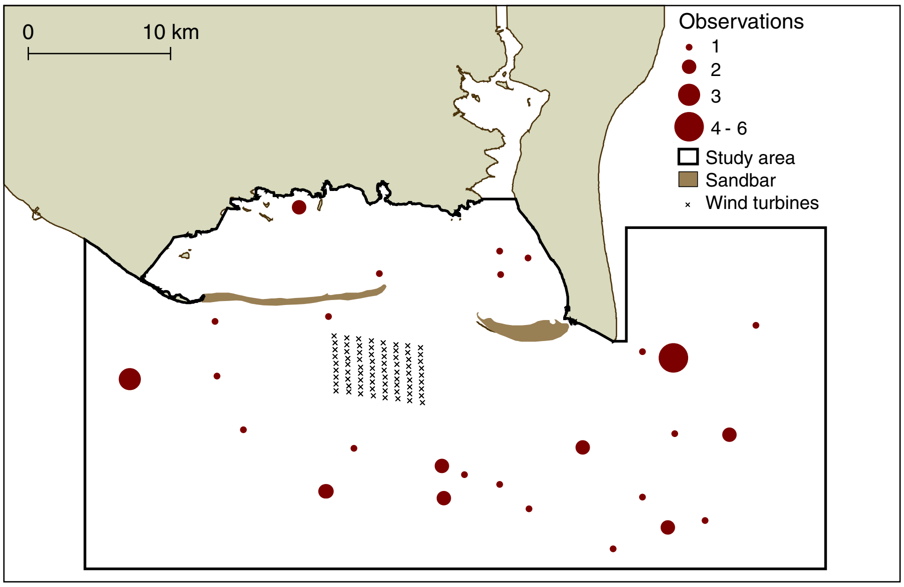


Figure 36. Distribution of diver sp. in the study area during four aerial surveys conducted in 2003.

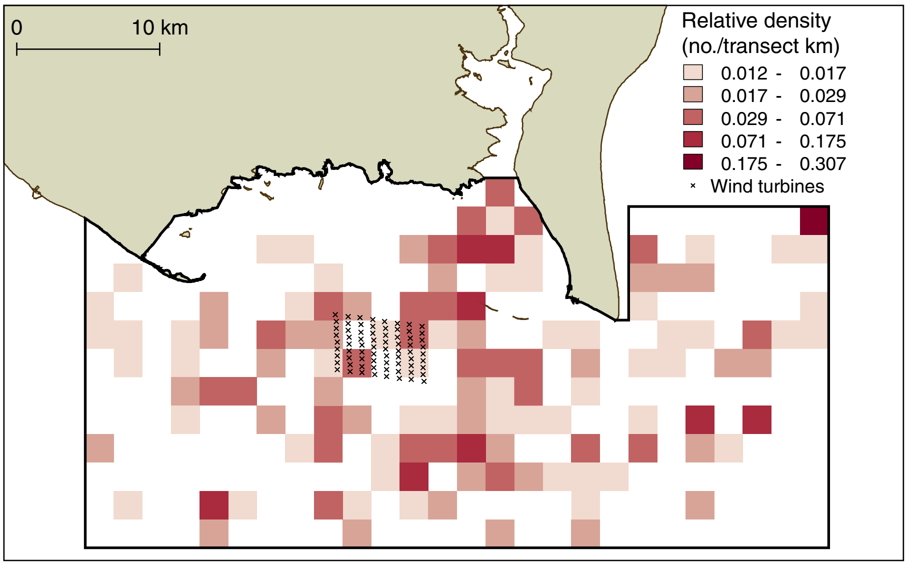


Figure 37. Cumulative distribution map of diver observations in the study area, based on 21 aerial surveys between August 1999 and August 2002. Data are expressed as relative densities measured as observations per kilometre of flown transect coverage for each survey in each 2 x 2 km grid square.

3.2.2 Species account

Red- and black-throated diver *Gavia stellata/arctica*

A total of 43 divers were recorded in 2003, most of which (20) were seen in December 2003 (Table 9). In 2003, the distribution gravity was south and east of the wind farm area, with few observations north and west of the site (Fig. 36). This distribution pattern differed from the general distribution pattern found when pooling data from surveys performed between August 1999 and August 2002, where the areas northeast and east of the wind farm had higher densities (Fig. 37). No divers were recorded closer than 1,400 m from a wind turbine in 2003.

In 2003, 33% of the observed divers were identified to species. Of the 43 birds recorded 28% were red-throated diver, while 5% were black-throated diver.

Table 9. Number of birds recorded at the four aerial surveys carried out in 2003.

Species	Total	10 Jan. 2003	4 March 2003	24 April 2003	9 Dec. 2003
Diver sp.	43	7	9	7	20
Red-necked grebe	24	0	6	2	16
Crested grebe	2	0	1	1	0
Grebe sp.	2	1	0	0	1
Cormorant	101	1	11	62	27
Mute swan	2882	842	911	455	674
Greylag goose	136	0	69	62	5
Brent goose	154	0	0	141	13
Canada goose	40	24	0	0	16
Shelduck	55	0	29	26	0
Mallard	2371	1019	97	32	1223
Teal	73	0	0	18	55
Wigeon	64	0	0	64	0
Shoveler	4	0	0	4	0
Pochard	120	0	120	0	0
Tufted duck	12205	12025	80	100	0
Scaup	10	0	0	0	10
Golden-eye	1285	198	94	5	988
Long-tailed duck	2797	798	1423	371	205
Eider	3142	191	447	2126	378
Common scoter	128	16	46	23	43
Velvet scoter	24	18	5	0	1
Red-breasted merganser	1061	105	278	142	536
White-tailed eagle	1	0	1	0	0
Coot	1290	1200	90	0	0
Herring gull	1737	589	564	260	324
Great black-backed gull	148	89	38	5	16
Little gull	41	9	0	32	0
Auk/guillemot	2	1	0	0	1

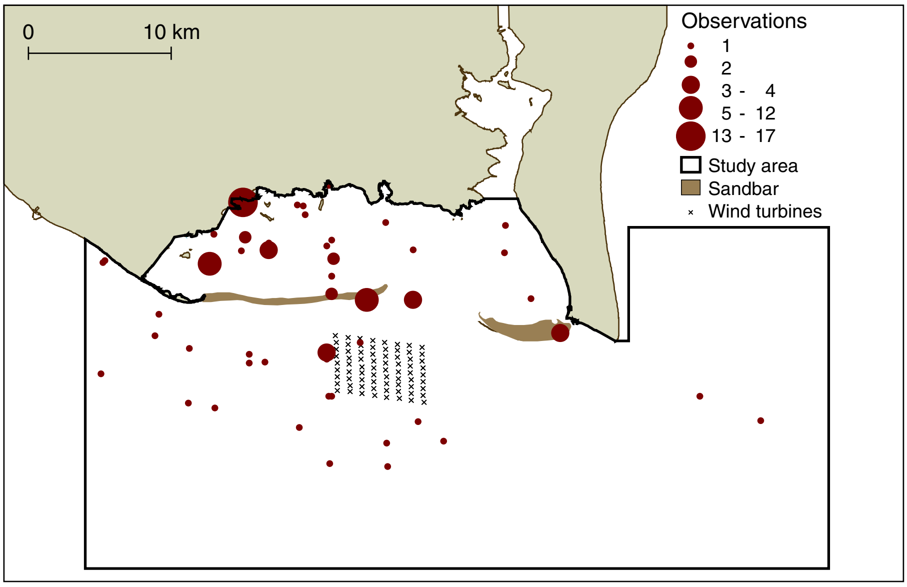


Figure 38. Distribution of cormorant in the study area during four aerial surveys conducted in 2003.

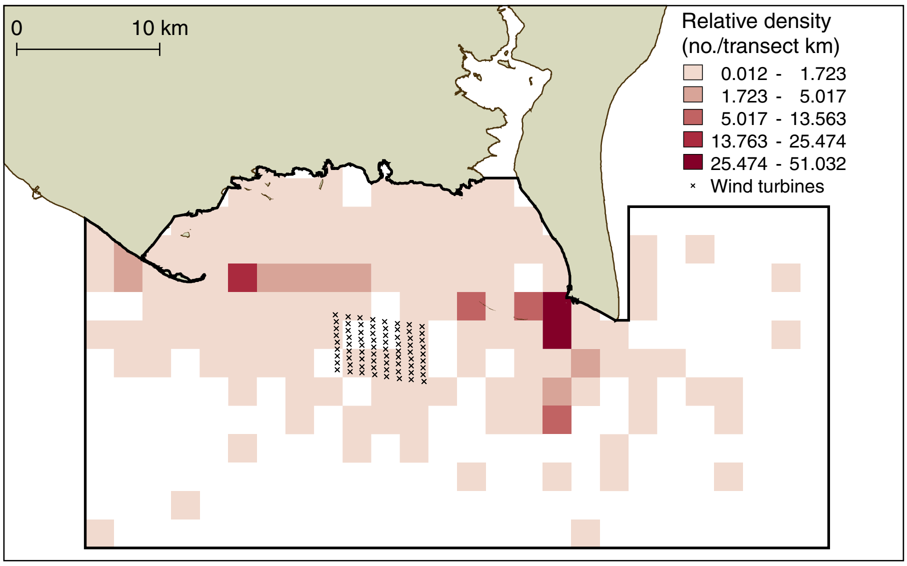


Figure 39. Cumulative distribution map of cormorant observations in the study area, based on 21 aerial surveys between August 1999 and August 2002. Data are expressed as relative densities measured as observations per kilometre of flown transect coverage for each survey in each 2 x 2 km grid square.

Cormorant *Phalacrocorax carbo*

A total of 101 cormorants was recorded during the four surveys in 2003, which was considerably less than in previous years (Table 9 and Appendix V). This was mainly due to the fact that no surveys were performed in autumn, when cormorant occurred in large numbers in the study area.

The majority of cormorants was observed close to the sandbars between Gedser and Hyllekrog, or in shallow waters north of this area. Birds were recorded in scattered flocks in open sea, south of the sandbars (Fig. 38). The general distribution pattern observed in 2003 was similar to that based on data from surveys performed between August 1999 and August 2002 (Fig. 39, Desholm et al. 2003).

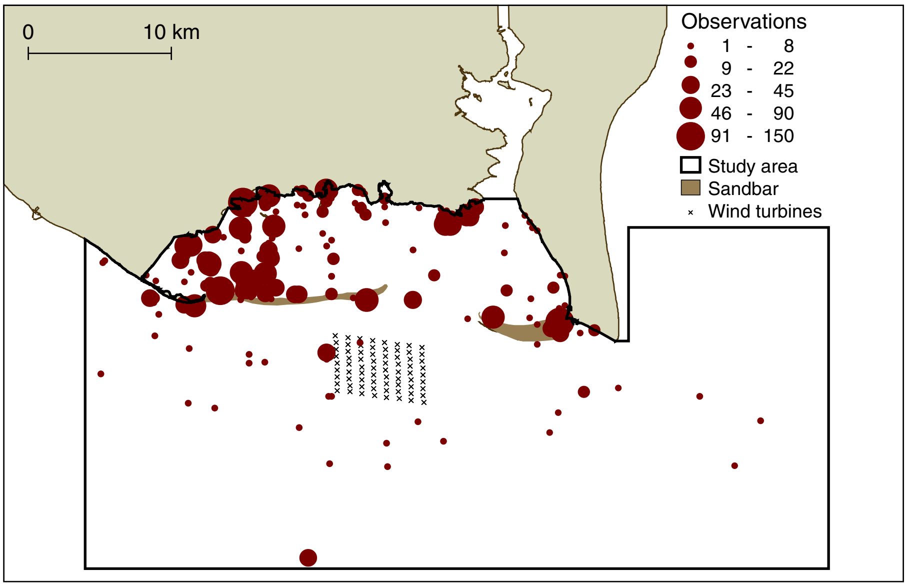


Figure 40. Distribution of mute swan in the study area during four aerial surveys conducted in 2003.

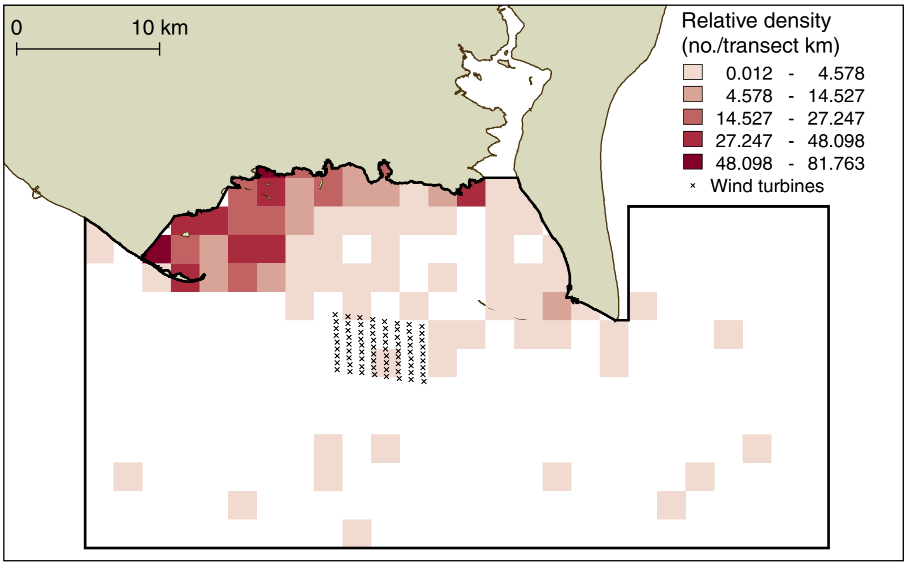


Figure 41. Cumulative distribution map of mute swan observations in the study area, based on 21 aerial surveys between August 1999 and August 2002. Data are expressed as relative densities measured as observations per kilometre of flown transect coverage for each survey in each 2 x 2 km grid square.

Mute Swan *Cygnus olor*

A total of 2,882 mute swans was recorded during the four surveys, which was considerably lower than during previous years (Table 9 and Appendix V). The main reason for this is the lack of autumn surveys in 2003, when mute swans were occurring numerously in the survey area. In addition, the January ice conditions in the area was believed to have influenced the number of birds recorded.

In 2003, the majority of mute swans were observed north of the sandbars between Gedser and Hyllekrog, but with more observations south of this line than during the surveys of the previous years (Fig. 40). Most of these southern occurring observations were made in January 2003, when the preferred habitat for mute swans was covered with ice. This led to higher numbers of mute swan around the Rødsand islet in that month than previously observed. Apart from this change the distribution of mute swan in 2003 resembled the distribution pattern based on surveys performed between August 1999 and August 2002 (Fig. 41, Desholm et al. 2003).

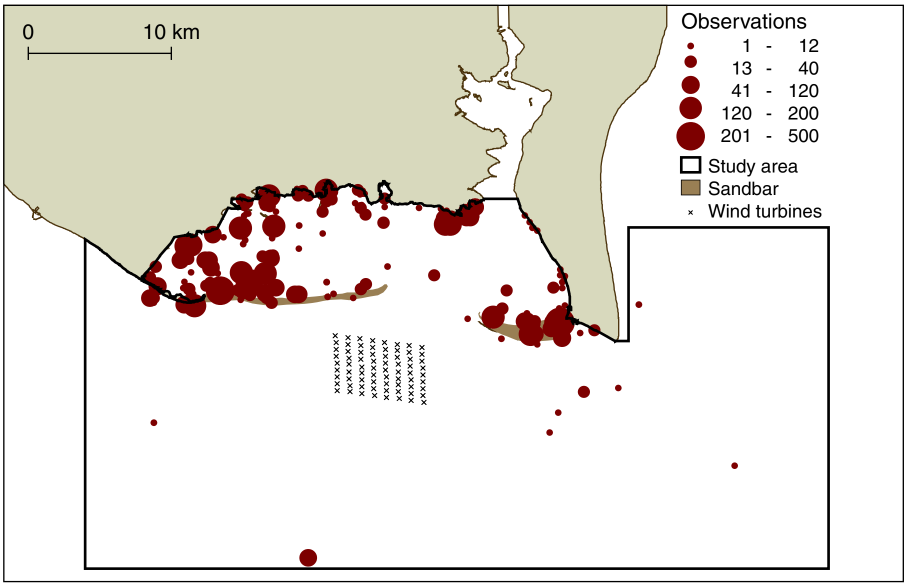


Figure 42. Distribution of mallard in the study area during four aerial surveys conducted in 2003.

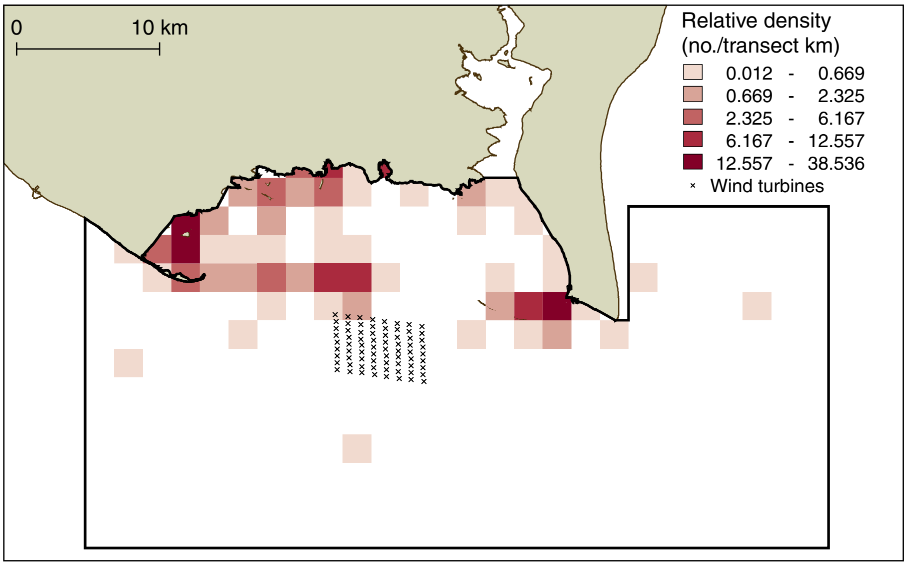


Figure 43. Cumulative distribution map of mallard observations in the study area, based on 21 aerial surveys between August 1999 and August 2002. Data are expressed as relative densities measured as observations per kilometre of flown transect coverage for each survey in each 2 x 2 km grid square.

Mallard *Anas platyrhynchos*
A total of 2,371 mallards was recorded during the four surveys in 2003 (Table 9 and Appendix V), which is similar to the numbers observed in the previous years, except for 2000, when more than 5,000 mallards were recorded (Desholm et al. 2001).

The distribution pattern of mallard for 2003 was similar to that observed in previous years. Most birds were recorded along the Rødsand sandbars in the western parts of the lagoon north of Rødsand (Figs. 42 and 43).

Figure 44. Distribution of goldeneye in the study area during four aerial surveys conducted in 2003.

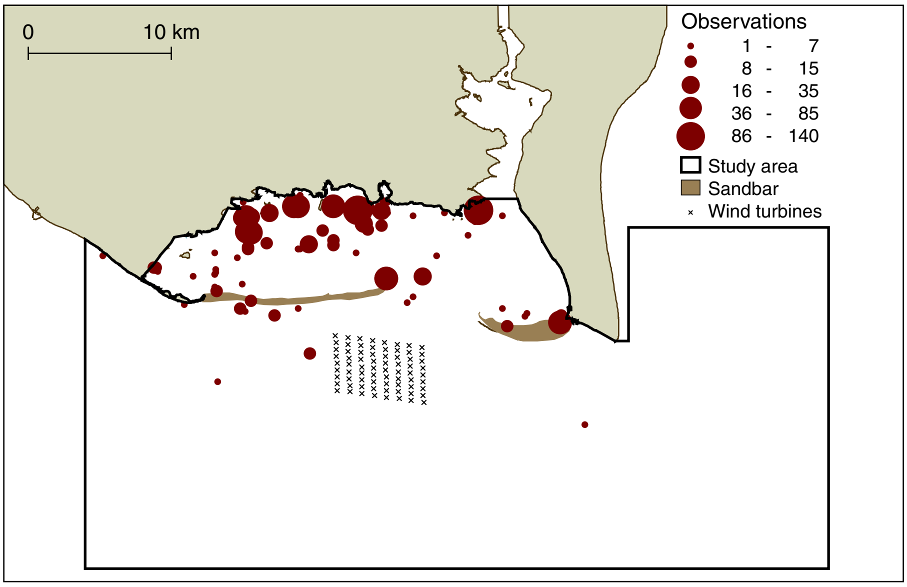
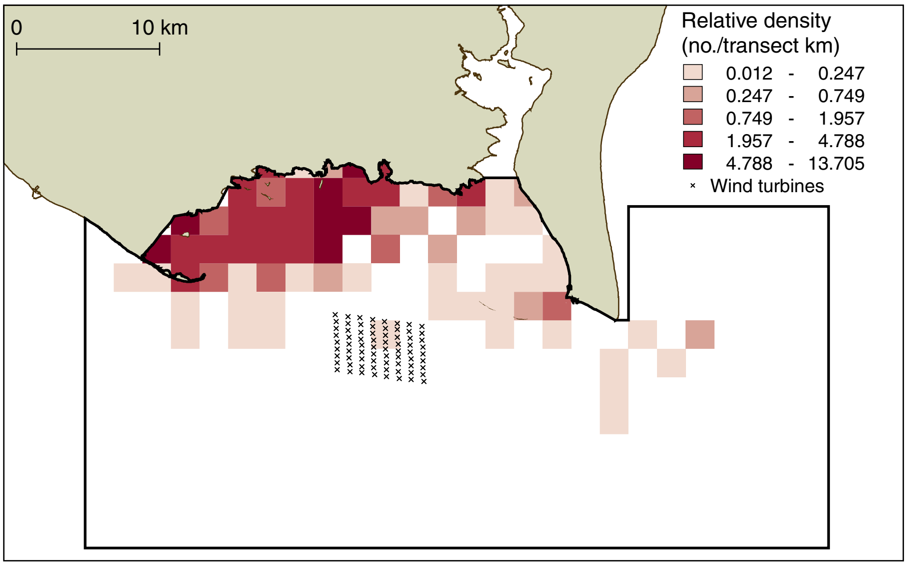


Figure 45. Cumulative distribution map of goldeneye observations in the study area, based on 21 aerial surveys between August 1999 and August 2002. Data are expressed as relative densities measured as observations per kilometre of flown transect coverage for each survey in each 2 x 2 km grid square.



Goldeneye *Bucephala clangula*
A total of 1,285 goldeneyes were recorded during the four surveys in 2003, and occurred most numerously in December, when 988 birds were encountered (Table 9). In previous years, January and February have had most goldeneyes. In 2003, comparatively few goldeneyes were recorded in January, probably caused by the ice conditions in the area.

The distribution in 2003 resembled the distribution of previous years (Fig. 44), though with some observations in the open sea south of the Rødsand sandbars. The general distribution pattern based on surveys made between August 1999 and August 2002 was similar to the results of the 2003 surveys, when most birds were present in the shallow parts of the lagoon north of the sandbars (Fig. 45).

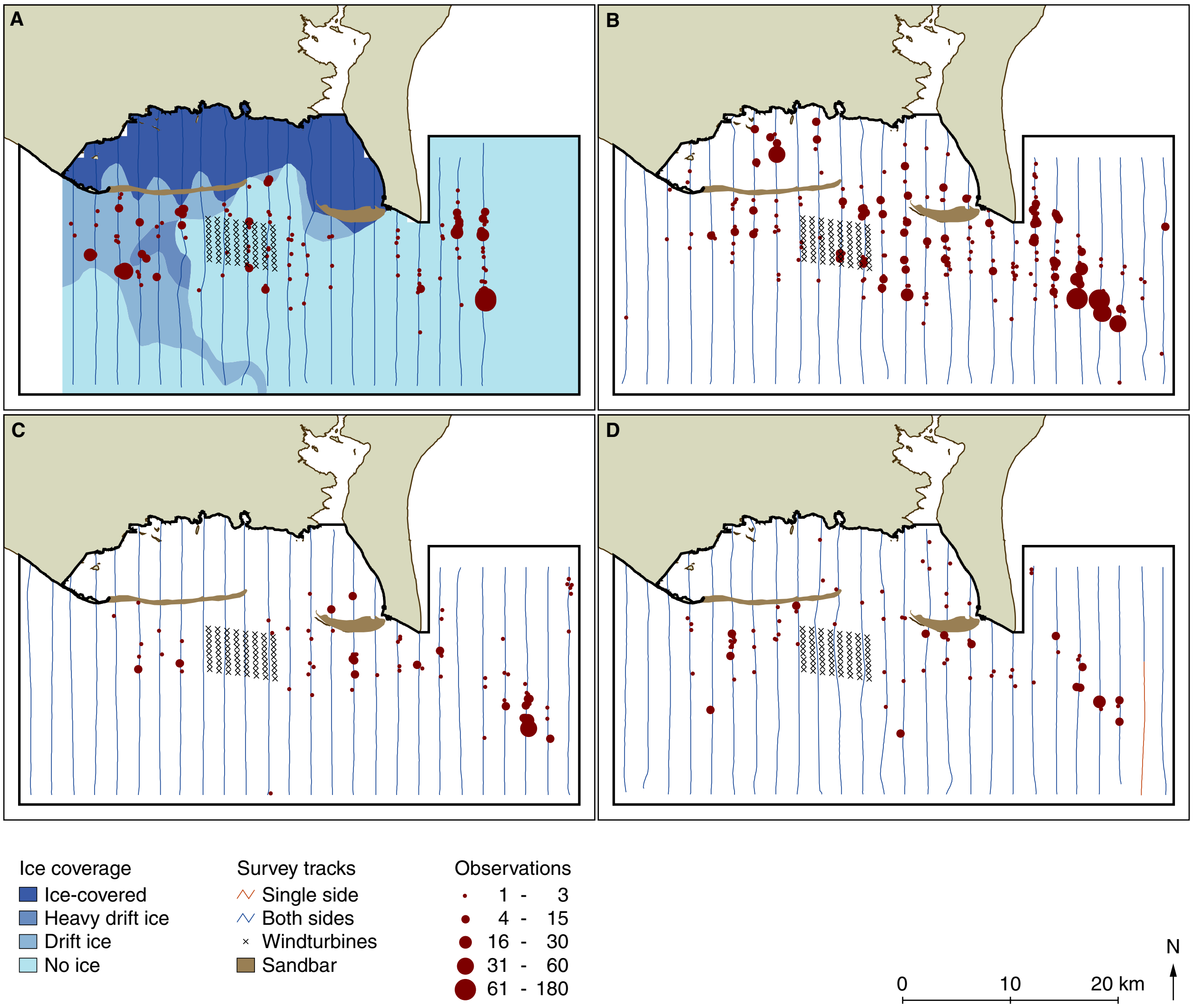


Figure 46. Distribution of Long-tailed Duck in the study area for each of four aerial surveys conducted in 2003, 10 January (A), 4 March (B), 24 April (C) and 9 December (D).

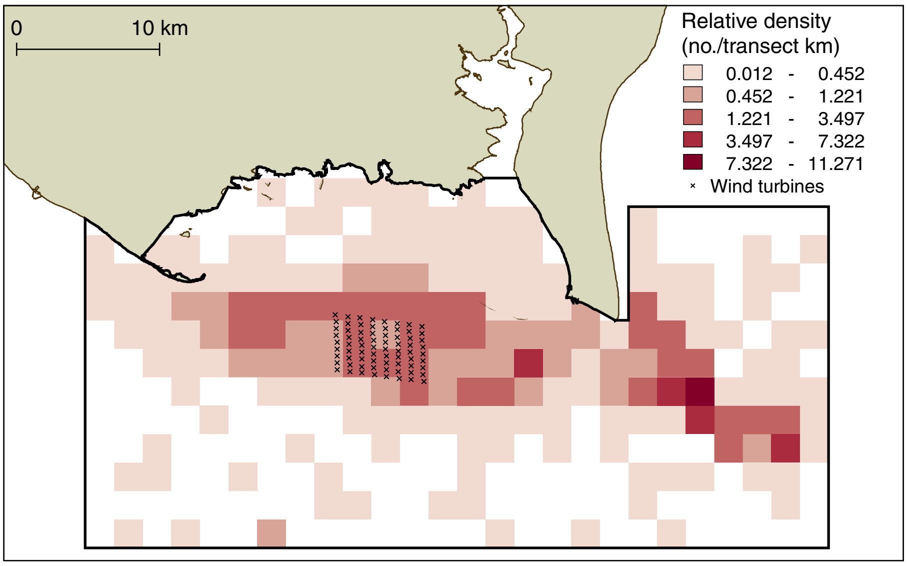


Figure 47. Cumulative distribution map of long-tailed duck observations in the study area, based on 21 aerial surveys between August 1999 and August 2002. Data are expressed as relative densities measured as observations per kilometre of flown transect coverage for each survey in each 2 x 2 km grid square.

Long-tailed duck *Clangula hyemalis*
A total of 2,797 long-tailed ducks were recorded during the four surveys conducted in 2003, most in January and March (Table 9). This complied with the observations in previous years, when the vast majority of long-tailed ducks was recorded during the period from January to April (Appendix V).

The distribution pattern in 2003 resembled the pattern observed in previous years, when the majority of birds were recorded at Gedser Rev during late winter and early spring (Fig. 46 A, B, C and D). Another concentration was found along the coast south of the Rødsand sandbars between Gedser and Hyllekrog, and extended through the wind farm area. Particularly in January and March, many birds were recorded in this part of the study area, while in April and December few long-tailed ducks were seen here. The January distribution was likely to have been influenced by the ice conditions. The general distribution pattern based on data from surveys performed between August 1999 and August 2002 showed highest concentrations were found at Gedser Rev and in a band, which extended west towards Hyllekrog, similar to the distribution found in 2003 (Fig. 47).

Figure 48. Distribution of eider in the study area during four aerial surveys conducted in 2003.

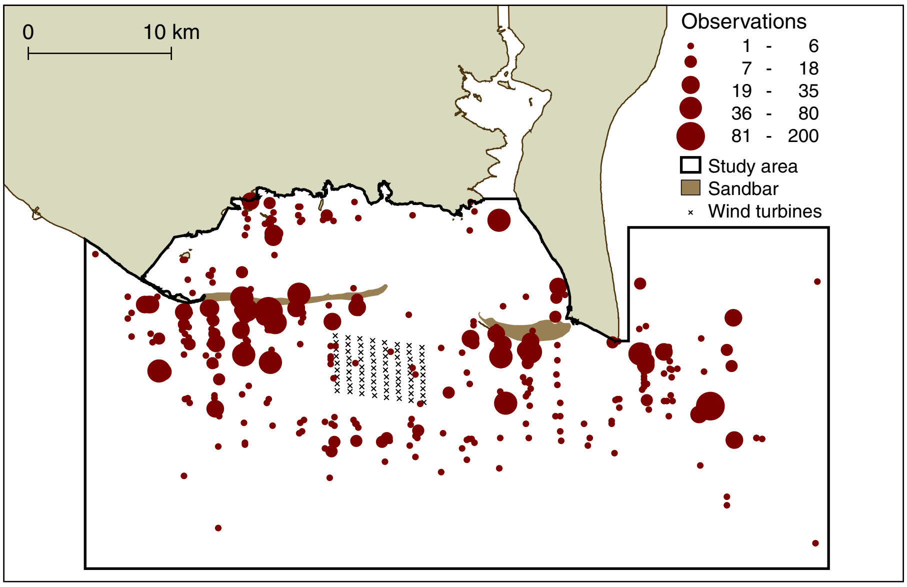
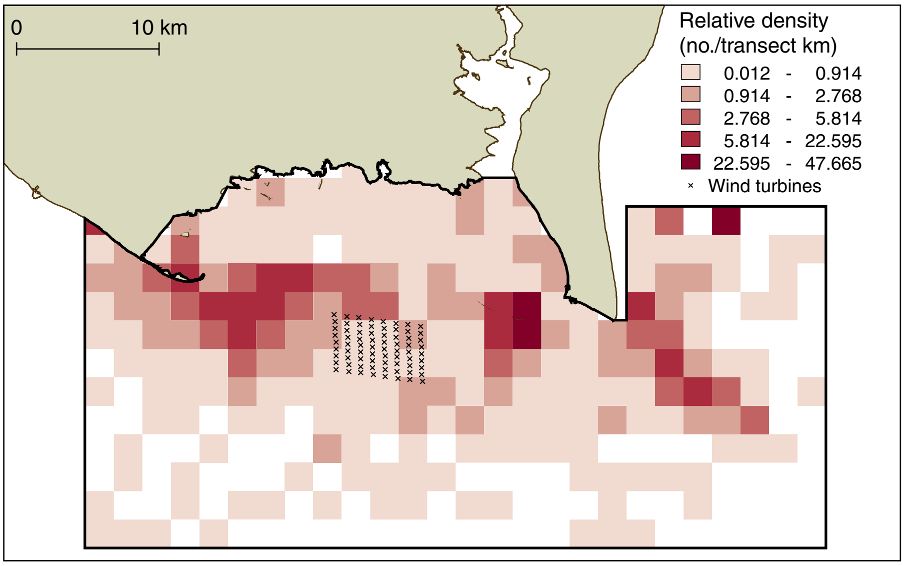


Figure 49. Cumulative distribution map of eider observations in the study area, based on 21 aerial surveys between August 1999 and August 2002. Data are expressed as relative densities measured as observations per kilometre of flown transect coverage for each survey in each 2 x 2 km grid square.



Eider *Somateria mollissima*
A total of 3,142 eiders were recorded during the four surveys in 2003, showing a maximum of 2,126 birds in April (Table 9). During previous years most eiders have been recorded from January to April. However, high numbers were also recorded in November 1999 (Appendix V).

In 2003, eiders were concentrated west and east of the wind farm area as well as at Gedser Rev (Fig. 48). Few eiders were recorded in the wind farm area. This followed the pattern observed in previous years of survey. Thus, the general distribution pattern based on data from surveys performed between August 1999 and August 2002 was similar to the distribution found in 2003 (Fig. 49).

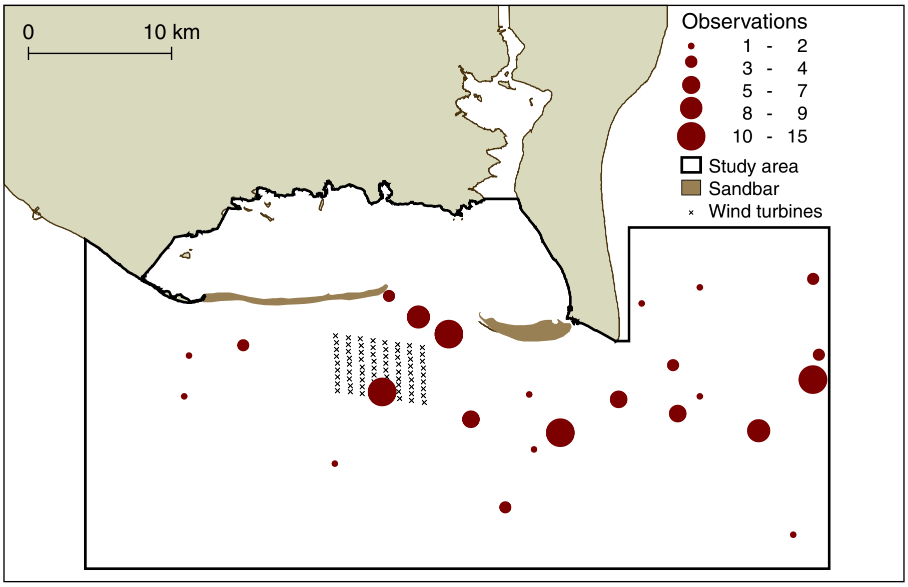


Figure 50. Distribution of common scoter in the study area during four aerial surveys conducted in 2003.

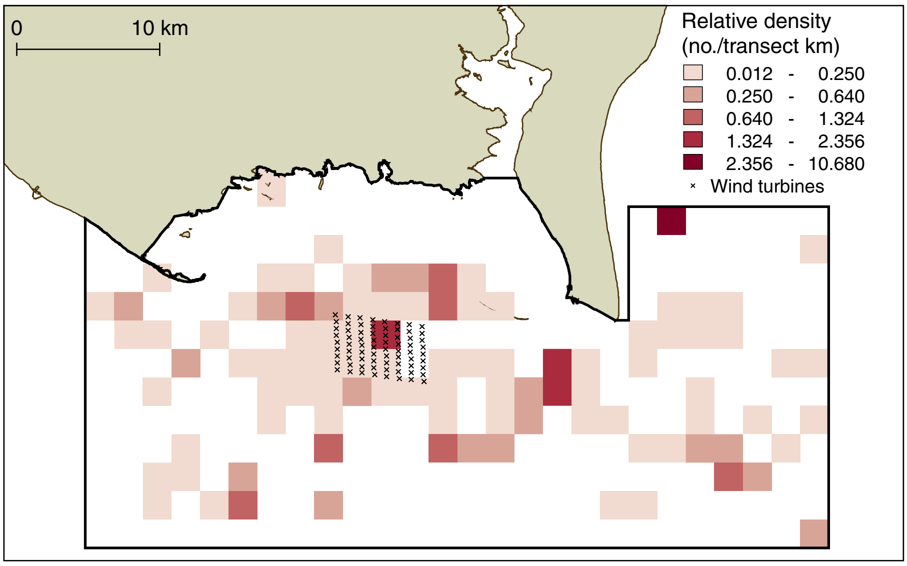


Figure 51. Cumulative distribution map of common scoter observations in the study area, based on 21 aerial surveys between August 1999 and August 2002. Data are expressed as relative densities measured as observations per kilometre of flown transect coverage for each survey in each 2 x 2 km grid square.

Common scoter *Melanitta nigra*
A total of 128 common scoters were recorded in the study area in 2003 (Table 9). This is the lowest number recorded in one survey year, apart from 1999, when 67 individuals were observed. In the previous years most common scoters were registered in late winter and spring (Appendix V).

In 2003 most common scoters were observed north and east of the wind farm and at Gedser Rev (Fig. 50). A flock of 12 birds were seen flying between the wind turbines during the December survey. The general distribution pattern based on surveys performed between August 1999 and August 2002 was similar to the distribution found in 2003 (Fig. 51, Desholm et al. 2003).

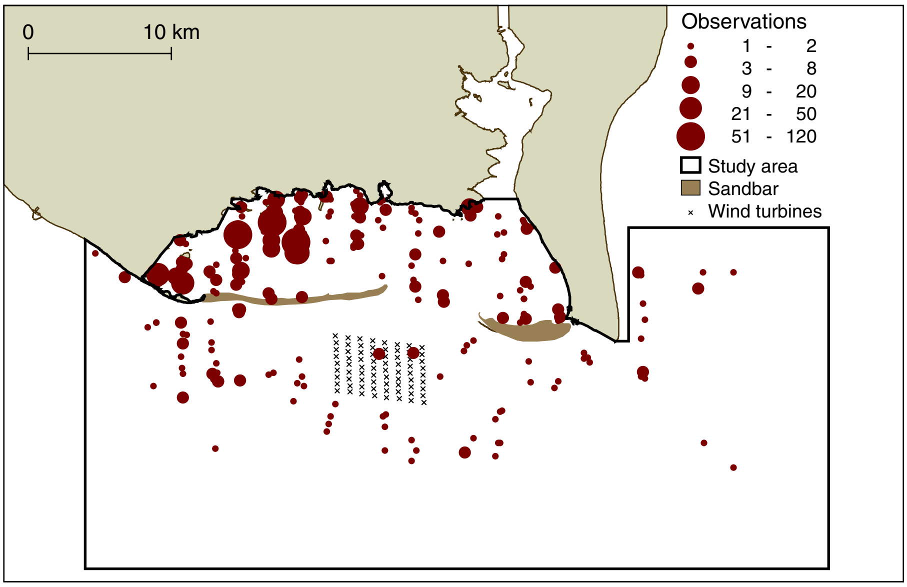


Figure 52. Distribution of red-breasted merganser in the study area during four aerial surveys conducted in 2003.

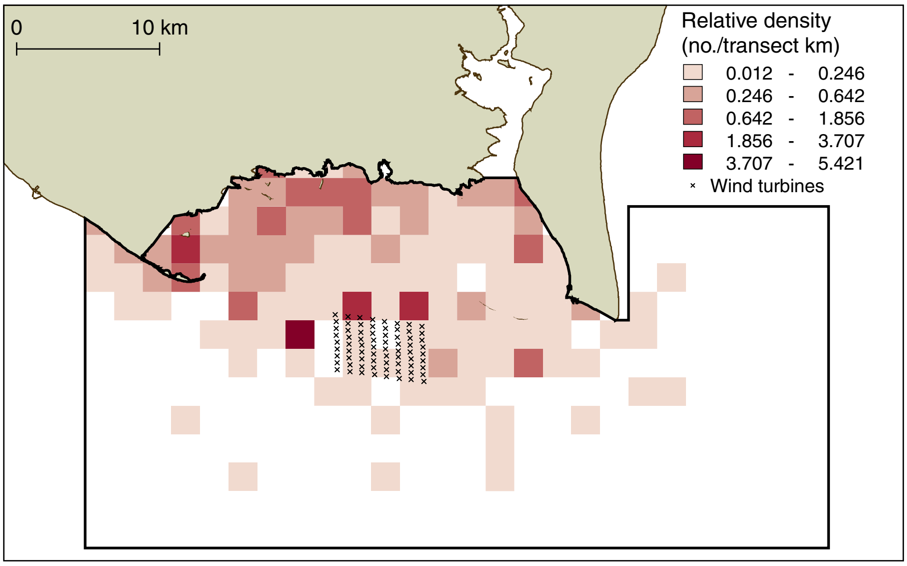


Figure 53. Cumulative distribution map of red-breasted merganser observations in the study area, based on 21 aerial surveys between August 1999 and August 2002. Data are expressed as relative densities measured as observations per kilometre of flown transect coverage for each survey in each 2 x 2 km grid square.

Red-breasted merganser *Mergus serrator*

A total of 1,061 red-breasted mergansers was recorded in 2003, of which most (536 individuals) were recorded in December (Table 9). The number of red-breasted mergansers recorded in the study area from 1999 up to the present time varied considerably (Appendix V). The highest number recorded was 1,685 in November 1999.

In 2003, most red-breasted mergansers were recorded in the shallow waters of the lagoon, with few birds recorded south of the Rødsand sandbars and particularly in the area south of the peninsula of Hyllekrog (Fig. 52). The general distribution pattern based on surveys performed between August 1999 and August 2002 was similar to the findings of 2003. However, more birds were recorded in the north-eastern areas of the lagoon, north of Hyllekrog (Fig. 53).

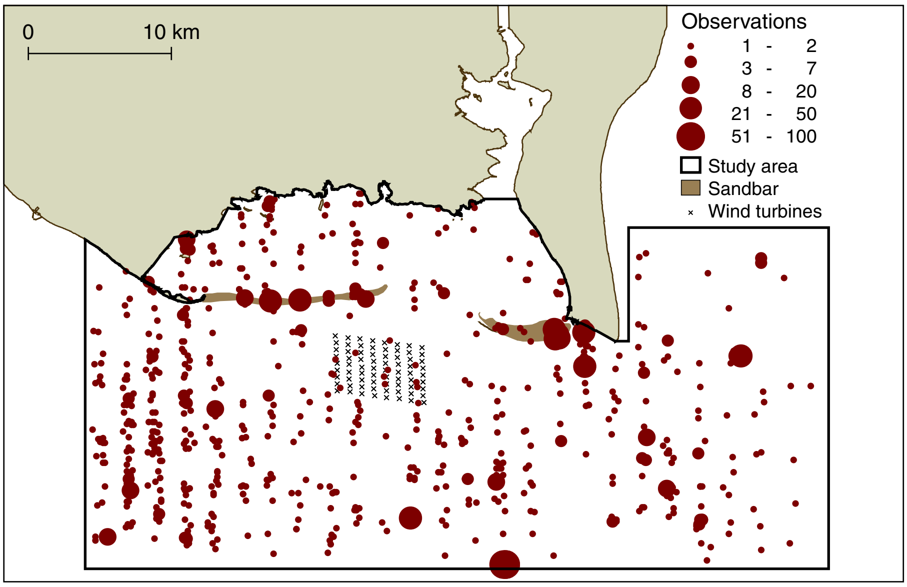


Figure 54. Distribution of herring gull in the study area during four aerial surveys conducted in 2003.

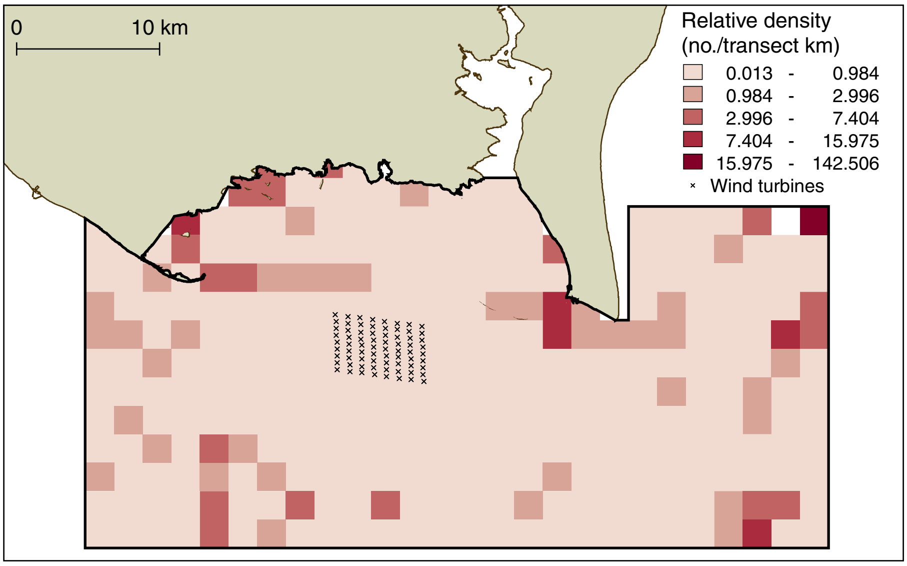


Figure 55. Cumulative distribution map of herring gull observations in the study area, based on 21 aerial surveys between August 1999 and August 2002. Data are expressed as relative densities measured as observations per kilometre of flown transect coverage for each survey in each 2 x 2 km grid square.

Herring gull *Larus argentatus*
A total of 1,737 herring gulls was recorded in 2003, most of which in January (589) and in March (564) (Table 9). This was considerably lower numbers than observed during the period 1999 to 2002, both as total numbers and when compared to numbers of the same months in previous years (Appendix V).

In 2003 herring gulls were distributed throughout the study area, but most birds were observed in the offshore southwestern part of the area as well as the waters south of Gedser. Groups of roosting herring gulls were seen on the Rødsand sandbars between Gedser and Hyllekrog (Fig. 54). Herring gulls gathered around active fishing vessels, leading to discrete observations of high numbers of birds in different parts of the study area. The general distribution pattern of herring gull based on data collected between August 1999 and August 2002 was similar to the distribution pattern found in 2003, although the relative density in the southwestern parts of the study area increased slightly in 2003 (Fig. 55).

Other species

A total of 28 grebes was recorded in 2003. Of these 24 were red-necked grebe *Podiceps griseigena*, two crested grebe *Podiceps cristatus* and two unidentified. Three goose species were recorded, 136 Grey-lag Geese, 154 Brent Geese and 40 Canada Geese *Branta canadensis*. A total of 12,205 Tufted Ducks *Aythya fuligula* was recorded. Of these 12,025 were observed in January 2003, when ice covered a great part of the study area and other preferred roosting areas of this species. This is believed to be the reason for the unusual high number of this species in the study area. Finally, 41 Little Gulls were recorded in 2003, 32 of these in March.

3.2.3 Bird distributions during base-line versus the construction phase

The wind farm base-line phase was covered by a total of 21 surveys of birds. Three surveys were performed during the construction phase (January, March and April 2003). Of these the January survey had unusual ice conditions, which are believed to have influenced the distribution of birds in the area considerably. Therefore data from this survey was not used in this analysis of possible impact on bird distributions from the wind farm construction work.

To ensure compatibility between base-line data and construction data only data from March and April of the base-line period were used (4 and 26 April 2000, 16 March and 20 April 2001 and 26 March 2002). Likewise, the wind farm area and the 2 and 4 km zones around it were defined according to the progress of the construction work (see Fig. 35).

An analysis of the selectivity index of all species confirmed that the majority of waterbirds avoided the wind farm area. Only three species occurred with any abundance at the construction site and which, analysed on the basis of the above mentioned survey data, indicated some spatial changes in the area (Tables 10-13). For long-tailed duck and eider, selectivity indices for the wind farm area, the wind farm + 2 and + 4 km zones decreased during the construction phase surveys, indicating a reduced preference for these areas. This was true when analysing on both the number of individuals (Tables 10 and 11) and on the number of observed flocks (Tables 12 and 13). Herring gull showed a slight increase in preference of the wind farm area and the zones around it.

Table 10. Percentage of bird numbers for three species encountered in the wind farm area (MA) based on five base-line aerial surveys compared to the entire survey area, and in the wind farm area and zones of 2 and 4 km radius from the wind farm site (MA+2 and MA+4). Also shown are the total numbers of birds for each species recorded throughout the surveys from the total study area from the base-line period (N). For each species and area, the Jacobs Index value (D) is given which varies between -1 (complete avoidance) and 1 (complete selection).

Species	MA	D for MA	MA+2	D for MA+2	MA+4	D for MA+4	N
Long-tailed duck	3.00	0.46	13.63	0.46	23.10	0.40	5966
Eider	0.12	-0.81	4.26	-0.13	12.27	0.04	21020
Herring gull	0.25	-0.64	1.23	-0.65	5.50	-0.38	4779
% of total survey coverage	1.14		5.51		11.47		

Table 11. Percentage of bird numbers for three species encountered in the wind farm area (MA) based on two construction phase aerial surveys compared to the entire survey area, and in the wind farm area and zones of 2 and 4 km radius from the wind farm site (MA+2 and MA+4). Also shown are the total numbers of birds for each species recorded throughout the surveys from the total study area from the construction phase (N). For each species and area, the Jacobs Index value (D) is given which varies between -1 (complete avoidance) and 1 (complete selection).

Species	MA	D for MA	MA+2	D for MA+2	MA+4	D for MA+4	N
Long-tailed duck	0.06	-0.91	4.46	-0.13	10.20	-0.10	1794
Eider	0.00	-1.00	1.59	-0.58	9.06	-0.16	2573
Herring gull	0.36	-0.52	1.21	-0.66	11.17	-0.05	824
% of total survey coverage	1.14		5.66		12.14		

Table 12. Percentage of birds flocks (clusters) for three species encountered in the wind farm area (MA) based on five base-line aerial surveys compared to the entire survey area, and in the wind farm area and zones of 2 and 4 km radius from the wind farm site (MA+2 and MA+4). Also shown are the total numbers of clusters for each species recorded throughout the surveys from the total study area from the base-line period (N). For each species and area, the Jacobs Index value (D) is given which varies between -1 (complete avoidance) and 1 (complete selection).

Species	MA	D for MA	MA+2	D for MA+2	MA+4	D for MA+4	N
Long-tailed duck	5.01	0.64	23.32	0.68	37.70	0.65	939
Eider	0.87	-0.14	7.02	0.13	17.50	0.24	1154
Herring gull	0.64	-0.29	3.18	-0.28	8.76	-0.15	1416
% of total survey coverage	1.14		5.51		11.47		

Table 13. Percentage of birds flocks (clusters) of three species encountered in the wind farm area (MA) based on two construction phase aerial surveys compared to the entire survey area, and in the wind farm area and zones of 2 and 4 km radius from the wind farm site (MA+2 and MA+4). Also shown are the total numbers of clusters for each species recorded throughout the surveys from the total study area from the construction phase (N). For each species and area, the Jacobs Index value (D) is given which varies between -1 (complete avoidance) and 1 (complete selection).

Species	MA	D for MA	MA+2	D for MA+2	MA+4	D for MA+4	N
Long-tailed duck	0.25	-0.64	7.27	0.13	18.55	0.24	399
Eider	0.00	-1.00	3.55	-0.24	10.64	-0.07	282
Herring gull	0.74	-0.21	2.48	-0.40	7.44	-0.26	403
% of total survey coverage	1.14		5.66		12.14		

D-values for long-tailed duck changed from 0.46 (MA), 0.46 (MA+2) and 0.40 (MA+4) during the base-line period to -0.91, -0.13 and -0.10 for the same three zones during the construction, when calculations were based on the number of individuals. When the number of flocks was used for the analysis, the same pattern was observed.

The eider had much lower preference of the wind farm area than long-tailed duck during the base-line phase. The reduced preference for the wind farm area and the two zones around it during the construction phase, was more moderate than for long-tailed duck.

The herring gull was recorded less than expected, assuming an even distribution of the observed birds prior to construction. This was also the case during construction of the wind farm, indicated by slight increases of D-values for all zones analysed.

A calculation of the cumulative percentage of the number of long-tailed ducks in distance intervals of 500 m from the wind farm were carried out for the March and April surveys in 2000, 2001, 2002 (base-line) and 2003 (construction). Preliminary analysis showed that at distances 16-24 km from the wind turbines, dramatic changes occurred in the cumulative percentages caused by the high number of birds recorded at Gedser Rev (Fig. 56). At distances 0-15 km from the turbines, 2001 and 2002 showed higher percentages of birds in the vicinity of the turbines, while the percentages were lower in 2000 and 2003 (Fig. 56).

When analysing the same data only within the wind farm area and the 2 and 4 km zones around the farm a slightly different pattern was found (Fig. 57). 2001 and 2002 had highest percentages of birds from the first distance band of 500 m, while 2000 and 2003 had lower percentages.

It must be born in mind that the construction phase was only covered by two surveys adequate for use in this context.

Figure 56. Cumulative percentage of numbers of long-tailed duck in distance intervals of 500 m from the wind turbines to the border of the study area, based on data from March and April from all survey years. Data from 2003 represent the wind farm construction phase.

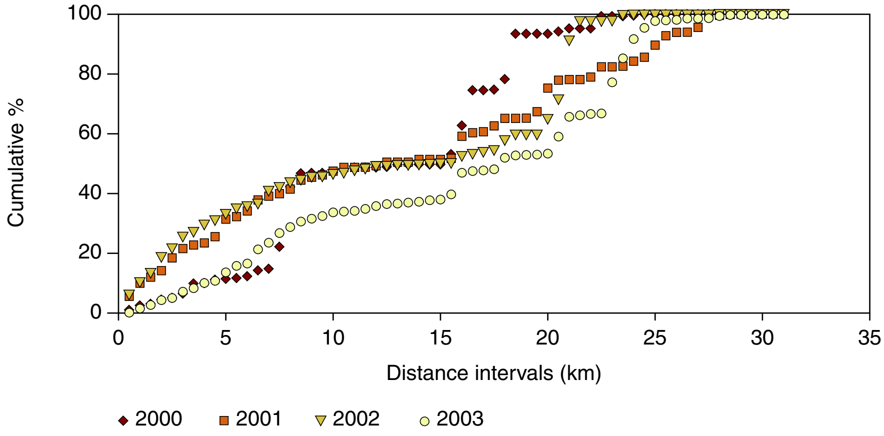
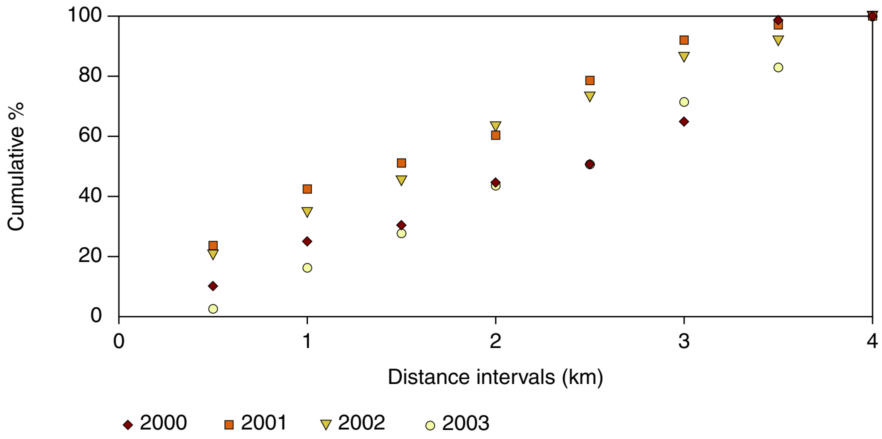


Figure 57. Cumulative percentage of numbers of long-tailed duck in distance intervals of 500 m from the wind turbines to 4 km from the wind farm, based on data from March and April from all survey years. Data from 2003 represent the wind farm construction phase.



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4 Discussion and conclusions

4.1 Patterns of migration

The data collected in 2003 reconfirmed the importance of the Rødsand area as a migration corridor for waterbirds in spring and autumn. The area remains the point of entry and departure for many waterbirds migrating from the Baltic to wintering areas further west. The intensity of spring and autumn passage did not differ markedly from the spread of migration intensity data gathered in the years 1999-2002 during the base-line investigations. The predominant waterbird species was still the eider, since the study area lies on the major spring and autumn migration route to and from its Baltic breeding areas. Eider numbers were generally less in 2003 than in previous years, linked in all probability to the general decline in this population, which is thought to be continuing (Desholm et al. 2002). In some aspects, data from 2002 tend to deviate from the data compiled during the other base-line years. In autumn 2002, data were only collected during the first three weeks of September due to a temporary suspension in the programme. During the first weeks of September eider migration is less intense than during October (see Appendix I). This may explain why flock size of eiders was markedly lower in autumn 2002 compared to the other base-line years, as flock size and migration intensity is likely to be correlated. In addition, the general consequence of a confined observation period in autumn 2002 is a reduced sample size for most of the variables used in the analyses. Evidently, this reduces the power of the statistical comparisons with 2002. Interpretation of comparisons with this particular year should therefore be drawn with caution and be supported by other aspects.

Following base-line observations in spring during 2001 and 2002, waterbird migration observations from 2003 generally confirmed the overall patterns from the base-line period. The main spring migration passage occurred to the north of the wind farm area in all years (see Fig. 19). As in previous years, tracks were divided into two groups by the island of Rødsand and the west coast of Falster also channelled movements. The density of tracks in the wind farm area tended to be lower than during the base-line study (Fig. 19). Although only some of the foundations were established at the time of the spring observations, there was an intense ship traffic associated with the wind farm area during this period, which could have contributed to displacement from the general area.

As the observations in 2001 and 2002 indicated a very low likelihood of dark-bellied brent geese passing through the proposed wind farm area, specific May observations of this species were not undertaken in 2003.

As in the base-line years, despite the major migration of passerines, pigeons and raptors through the Gedser Odde/Hyllekrog area northeast and northwest of the wind farm, it proved extremely difficult to study this movement in the vicinity of the wind farm. Because of the relative small body size of many passerines, they are difficult to detect by radar, and of the very few radar tracks that have been compiled, still less extended over a sufficient distance to enable meaningful interpretation of the data. Only in 2001, when 130 tracks were compiled, were data sufficient to offer some interpretation of the migration pattern.

For this reason, the present report has, by necessity concentrated upon the description of the substantial and highly significant waterbird migration that occurs in this region, not least because their large body size and aggregated flocking nature provide clear radar tracks over extended distances. The visual verification of species and numbers of individuals gives a reasonable assessment of the species specific migration patterns of the radar tracks during daylight hours. However, in the absence of visual verification of the species involved during the hours of darkness, our ability is limited with respect to do more than estimate the absolute volume by species based on the radar observations, measurement of flight speed and possibly using infra-red camera technology.

4.1.1 Assessing effects during the construction phase

Effects of the construction work on migration patterns of birds were studied during spring 2003. Due to the prevailing eastward direction of migratory birds during this period, the results from the eastern edge of the wind farm area were used to describe the relative occurrence of flocks after they had passed the wind farm area.

In spring 2003, construction activities had commenced on site, and continued day and night. During the construction phase at night, the relative number of flocks, which traversed the eastern edge of the wind farm area, was lower than during the base-line period, although not consistently significant. Such a trait was not found during daytime. Hence, construction activities during daytime, which included the presence of several ships and work associated with the developing foundations as well as occasional noisy activity, did not appear to affect the flight trajectories of birds. Thus, the flight patterns in spring 2003 suggested that construction work could have affected the flight corridors of the birds at night, when the most conspicuous difference to construction activities during the day was the strong lights used during the hours of darkness. Birds generally navigate in relation to natural sources of light such as the sun and the stars. However, they are also attracted towards light, e.g. to lighthouses, illuminated oil rigs and other man-made structures (see review in Wiese et al. 2001), in contrast to what the results from the Nysted windfarm suggest. However, general attraction effects seem to occur predominantly during periods of drizzle and fog (Weir 1976). It has been suggested that the illuminated area is increased during such conditions because of refraction of light on air droplets (Wiese et al. 2001). This may create an environment in which migratory birds loose their orientation, leading to circular flights around a well-lit man-made structure (Bourne 1979).

Our observations were carried out almost exclusively at good visibility (> 1 km) at nighttime. Therefore, we would not necessarily expect such an attraction effect. It may be hypothesised that sources of light mounted at the construction site could displace migratory waterbirds, which were likely to constitute the majority of spring migratory birds during the night. Hence, as waterbirds approached the construction site in good visibility they may have had several other points of reference by which to navigate, and at a distance they may have associated the lights at the construction site with a city or land. Many waterbirds, which undertake nocturnal migration, would usually avoid crossing land areas unless flying at high altitude (cf. spring migration of common scoter across Jutland, Pedersen 1988)

Even if the migration route through the wind farm was less used at night, (possibly as a result of the construction work) it must be concluded that the effects on the flight behaviour were minor, temporal and of relative short duration. Thus, the main construction period was terminated by summer 2003 and lasted only one spring migration season.

Indeed, the overall flight trajectories did not change dramatically in spring 2003, i.e. the main migration route was located north of the wind farm area just as was observed during the base-line study.

With regard to potential for collisions with structures associated with the construction work, the apparent avoidance response observed would actually reduce this potential risk, at least under conditions of good visibility. However, given that flying birds may be attracted to lights during foggy conditions we cannot exclude the possibilities of elevated collision risk during such periods.

The design of the effects during the construction phase is not as robust as the studies undertaken during the subsequent operational phase. Construction coincided only with spring observations, and for which only two years of base-line studies existed with respect to flight trajectories. In addition, the construction phase was of very short duration, confined to a single spring season. Hence, the results during construction cannot be replicated at the Nysted wind farm. Nevertheless, valuable information was compiled on aspects about which little are currently known, but which will contribute to knowledge compiled from other European countries in the future.

4.1.2 Assessing effects during the operational phase

Lateral change in migration routes

The evidence for effects of the operation of the wind farm presented here is based on the observations of migration tracks passing through the eastern gate of the wind farm of waterbirds derived from the radar observations. The populations of migration tracks from the three base-line years were compared with those from autumn 2003, after the wind turbines had been erected and commenced electricity generation. These results suggest that although the mean migration route of waterbirds at night showed no significant change, the standard deviation of the mean increased significantly from 1000 m from the eastern gate. In daylight, there was a lateral change in migration route towards the south in 2003, which was significant from 3000 m distance from the eastern gate, and the same was true for the increase in standard deviation over the same distance. Although these results need cautious interpretation, given that they are based on a single year, they offer some support for the hypothesis that waterbirds adjusted their migratory routes to the south and north as a result of the visual presence of the turbines over an approach distance of 3000 m under conditions of good visibility by day. The lack of clear directional response by night, but the associated increase in the variability of track orientation within 1000 m of the eastern gate suggests a reduced response and shorter response distance at night. This again provides support for one of the main predictions under the main hypothesis, namely that under dark conditions at night, reaction distances, in terms of lateral deflection, will occur at shorter distances to the wind farm. However, these tentative preliminary conclusions need confirmation by testing in future years allowing for difference in migration volume and wind conditions.

For the reasons outlined in the results chapter, emphasis has been placed upon waterbirds in this analysis because of the difficulties of obtaining sufficient data of sufficient quality to make any meaningful before and after construction comparisons of migration patterns of passerines and other landbirds.

Probability of passing the windfarm area

The overall percentage of waterbirds migration that passed through the eastern gate of the wind farm area in autumn 2003 (8.9%) was lower than that in the three base-line years (48.1%, 35.2% and 23.9% in 2000-2002 respectively). This result was consistent even when controlling for the effects of wind, time of day (i.e. day versus night) and for their latitudinal position as they approached the wind farm. By day, 4-7% of tracks passed the eastern gate compared to 11-24% by night. These results from logistic regression analyses suggest an active avoidance of entering the eastern gate compared to the base-line results that is not explained by prevailing wind conditions. These preliminary results also suggest that because of this avoidance, the potential collision risk is reduced at the site by waterbirds reacting at some distance from the wind farm to adjust their migration trajectories. However, it is important to stress again that these data originate from only one single season in operation, and firmer conclusions must await replication of these results in future years. Furthermore, there was no full commercial operation of the wind farm throughout the autumn 2003. As stressed in previous reports, even those birds entering the wind farm are not necessarily at risk from collision, since the tracks clearly show that many waterbirds are moving along the open corridors between the rows of turbines.

In addition, part of the flocks observed by lateral radar may actually fly below or above the sweeping area, and hence, the proportion of flocks which are potentially at risk of colliding with the wings of the turbines is likely to be lower than indicated by the present estimated proportions. In the initial environmental impact assessment, the results showed that the proportion of eiders, which flew within the risk altitude (30-110 m, varied considerably (10-53%) dependent on wind conditions and season (Kahlert et al. 2000). However, it may be criticised that these measurements were carried out under conditions, which did not comply with the environment at Nysted wind farm. For example, the measurements from Gedser Odde could be affected by the presence of land, which is known to increase the flight altitude of waterbirds.

However, to gain further insight in the nature of flight altitudes and to estimate the proportion of flocks actually undertaking vertical avoidance, it was suggested that measurements of flight altitudes are carried out in 2004. Given that the lateral distribution of flight trajectories has now been described during operation of the wind farm, valuable information has been compiled to help designing an *in situ* measurement of flight altitude at various distances to the wind farm.

Migration intensity in the wind farm area

Waterbird migration intensities vary considerably with weather conditions both locally and on a flyway scale, making predictions at a local scale difficult to model and comparisons difficult to make with statistical certainty. Nevertheless, even a superficial examination of the density of tracks in the eastern part of the wind farm area compared to the reference area east of the eastern gate and in the grid squares demonstrate a response (Fig. 17). These responses are undoubtedly overestimated in Fig. 17 because of the "shadow effects" caused by individual turbines, which cause the loss of clear radar signatures directly behind their positions on the screen. Nevertheless, this is considered not to be a major problem in interpretation of the data, because many of these tracks appear on the other side of the turbine shadow.

Furthermore, it is clear from the tracks identified to species, that many of the flocks or individuals do indeed take avoidance action and fly around the park, or adjust their flight trajectories to fly down the visually "clear" corridors that will be evident to them between the rows of turbines. Both these features clearly contribute to the overall reductions in relative densities of tracks from the area immediately outside of the wind farm compared to within it.

4.2 Staging, moulting and wintering birds

Following the decision in 2002 to reduce the aerial survey to monthly coverage between December and April, surveys were undertaken in January, March, April and December 2003. Although aerial surveys during the moult period had been undertaken during the base-line period, these were also discontinued, since no waterbird species occurred in sufficient numbers to warrant extended monitoring. This enabled concentration of coverage during the construction and operational phases to be confined to the most important periods for the key species of the area, namely long-tailed duck, eider, common scoter and red-breasted merganser (Desholm et al. 2003).

Peak numbers of cormorant derived from aerial surveys were less than in previous years because coverage was restricted to the winter months when most cormorants have moved to wintering areas outside Danish waters. Similarly, maximum numbers of mute swan were less in 2003 than in previous years, because no survey was carried out in August or September when peak numbers have tended to occur in the past (Desholm et al. 2003). As in previous years, the majority of the swans remained north of the Rødsand sandbars in shallow inshore waters, so there were no indicatives of a change in distribution related to the construction of the wind farm. There was no evidence of any subsequent persistent effects on swan distributions following the cable-laying operations (completed in October/November of 2002, but not monitored that winter because of suspension of the bird surveys).

Peak winter numbers of red-breasted mergansers counted in 2003 (536 individuals) exceeded those of the base-line, (131, 258 and 269 individuals in 2000-2002) in all years except 1999 (when 1,600 individuals were encountered, Kahlert et al. 2000, 2002, Desholm et al. 2001, 2003). The 2003 count failed to attain the level recognised for international importance (>1,200 individuals), but suggested construction activities had no obvious effect on local abundance which is likely to vary in response to local feeding opportunities. Previous surveys demonstrated that most of the mergansers did not occur in the wind farm area even prior to construction, and surveys in 2003 showed that most birds again were distributed in small groups north of the sandbars of the area.

Eiders also showed significant avoidance of the vicinity of the wind farm prior to construction. Peak numbers in 2003 (2,126 individuals) were less than in the base-line years (3,097 individuals in 1999, 8,706 in 2000, 2,214 in 2001 and 5,362 in 2002).

By contrast, previous surveys showed that common scoter and long-tailed duck occurred in the proposed wind farm area more than on average throughout the survey area. Common scoter numbers varied considerably within and between years, but the maximum of 46 individuals during the first operation period was less than in all base-line years (358 individuals in 2000, 182 in 2001 and 412 in 2002). Peak number of long-tailed ducks in 2003 (1,423 individuals) was less than in the last year of the base-line (3,053 individuals in 2002), but slightly higher than in the two previous years (1,308 individuals in 2001, 1,324 in 2000).

A comparison of the distributions of long-tailed duck, eider and herring gull during the base-line period and construction phase showed changes, though data set did not allow for firm conclusions on the impact of the wind farm construction. Taken into consideration the low number of surveys for comparison the indications were that long-tailed duck and eider had decreased preference of the wind farm area during construction, while the relative number of herring gull increased slightly.

It is thus difficult at this stage to conclude about the effects of the construction phase on the distribution and abundance of wintering waterbirds in the vicinity of the Nysted wind farm because of the short duration of the construction activities involved. Although construction activities started in June 2002 (excavations for foundations) and continued until after the survey April 2003, much of the period of peak construction activity during spring 2003 was not covered by aerial surveys. Similarly, given that there was only one winter survey during operation in 2003 (December) it is at present impossible to draw firm conclusions relating to the effects of the construction of the Nysted wind farm on wintering waterbird distribution and abundance in the vicinity.

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Appendixes

Appendix 1

Mean number (M) of birds per 15-minute period with 95% lower (L) and upper (U) confidence limits, and the total number of individuals (N) for ten species or groups of species observed during autumn 2003 passing the Buoy-transect from east to west early September (1-15), late September (16-30), early October (1-15) and late October (16-31). Only species or groups of species of which > 100 individuals were recorded are included. The data set was log-transformed before the means and confidence limits were calculated.

	Early Sept.			Late Sept.			Early Oct.			Late Oct.			
Species	L	M	U	L	M	U	L	M	U	L	M	U	N
Cormorant	1.58	2.32	3.28	1.31	2.23	3.52	1.01	2.21	4.12	0.19	0.37	0.58	13,520
Geese	.	0	.	0.09	0.31	0.58	1.27	2.90	5.70	0.22	0.52	0.89	1,521
Dabbling ducks	0.28	0.55	0.88	0.31	0.69	1.17	0.32	0.89	1.71	-0.01	0.08	0.16	878
Eider	0.96	1.58	2.40	1.60	2.54	3.83	150.26	218.42	317.31	1.59	2.88	4.82	19,208
Other diving ducks	0.11	0.23	0.38	0.17	0.33	0.53	0.31	0.67	1.13	0.33	0.58	0.88	337
Duck sp	0.41	0.75	1.17	0.77	1.27	1.90	11.45	18.97	31.04	2.27	3.66	5.65	4,609
Waders	0.05	0.14	0.23	-0.04	0.04	0.13	0.09	0.47	0.98	-0.02	0.12	0.29	392
Gulls	0.51	0.70	0.92	0.39	0.60	0.84	1.04	1.63	2.40	0.47	0.71	0.97	449
Sandwich tern	1.52	2.10	2.82	0.05	0.13	0.23	-0.04	0.04	0.13	.	0	.	663
Passerines	0.03	0.09	0.15	1.76	2.85	4.38	.	0	.	0.03	0.19	0.38	1,177
Total migration	14.80	19.11	24.60	15.90	22.23	30.95	266.75	340.53	434.63	9.83	15.00	22.64	

Appendix II

Mean flock size (M) with 95% lower (L) and upper (U) confidence limits, and total number of flocks (N) observed during autumn 2003. Data were log-transformed before the means and confidence limits were calculated.

Species/species group	L	M	U	N
Cormorant	1.56	1.71	1.87	554
Geese	5.77	7.74	10.38	75
Dabbling ducks	5.73	7.51	9.86	67
Eider	13.25	14.64	16.17	684
Other diving ducks	1.82	2.12	2.46	112
Duck sp	5.31	5.96	6.70	402
Gulls	1.14	1.19	1.25	334
Sandwich tern	1.26	1.35	1.45	320
Passerines	2.20	2.44	2.71	272

Appendix III

Mean number (M) of birds per 15-minute period with 95% lower (L) and upper (U) confidence limits, and the total number of individuals (N) of nine species or groups of species observed during spring 2003 passing the Buoy-transect from west to east during 16 March - 15 April. Only species or groups of species of which > 40 individuals were recorded in spring 2003 are included. The data set was log-transformed before the means and confidence limits were calculated.

Species/species group	L	M	U	N
Cormorant	0.23	0.32	0.42	123
Eider	10.46	13.59	17.58	9,848
Long-tailed duck	0.05	0.10	0.16	44
Red-breasted merganser	0.34	0.46	0.60	170
Duck sp.	1.29	1.67	2.10	775
Gulls	0.49	0.65	0.83	249
Sandwich tern	0.15	0.23	0.32	95
Total migration	19.20	23.62	29.00	

Appendix IV

Mean flock size (M) with 95% lower (L) and upper (U) confidence limits, and the total number of flocks (N) of eight species or groups of species observed during spring 2002. Data were log-transformed before the means and confidence limits were calculated.

Species/species group	L	M	U	N
Cormorant	1.02	1.15	1.29	75
Geese	2.34	3.89	6.44	15
Eider	4.97	5.28	5.61	1,074
Long-tailed duck	1.25	1.67	2.23	21
Red-breasted Merganser	1.43	1.61	1.82	88
Duck sp.	2.08	2.30	2.53	241
Gulls	1.01	1.02	1.04	240
Sandwich tern	1.10	1.20	1.32	72

Appendix V: Bird numbers for all species counted during 26 aerial surveys, August 1999 – December 2003.

Species	Total	1999	1999	1999	2000	2000	2000	2000	2000	2000	2000	2001	2001	2001	2001	2001	2001	2001	2001	2002	2002	2002	2002	2003	2003	2003	2003
		29.08	15.11	13.12	14.01	14.02	04.04	26.04	11.09	07.10	27.11	10.01	10.02	16.03	20.04	15.08	16.08	28.09	14.11	03.01	13.02	26.03	22.08	10.01	04.03	24.04	09.12
Diver sp.	299		7	12	6	3	9	2			2	45	42	15	4			2	11	52	27	31		7	3	3	16
Red-throated Diver	19		3		3														1						4	4	4
Black-throated Diver	2																								2		
Red-necked Grebe	204	14	65	19	4	3			1	2		19						8	8	14	7	13	3		6	2	16
Crested Grebe	43	1	13							3		15						1	8						1	1	
Grebe sp.	36								1				17	4				8	4					1			1
Gannet	1								1																		
Cormorant	15717	1063	72	5	38	27	63	389	5224	2519	404	160	245	97	292	1463	91	198	365	21	19	49	2812	1	11	62	27
Grey Heron	26	5	4		1				2	2	3	1		1		2		2				1	1	1			
Anseridae	20								1			1		16													2
Mute Swan	49901	7157	1154	351	1148	467	262	1146	5097	3259	955	1052	1273	870	671	9529	162	1523	339	1192	402	623	8387	842	911	455	674
Whooper Swan	26												3	1						22							
Yellow-billed Swan sp.	42																							42			
Greylag Goose	3635	161	2	2		276	6	131	360	294		345	300	3	24	685		185		6	361	84	274		69	62	5
Brent Goose	1913	270	2	2		63	63	301	6	121	2	23	386	58	283			25	33		13	108				141	13
Canada Goose	504		18			90		1		2	15	91	10	6	11					159	46	15		24			16
Shelduck	629		8	8	72	47	53	103			11	9	23	122	40	10	2				13	47	6		29	26	
Mallard	15064	561	1320	336	755	426	30	40	636	2207	1269	822	309	123	120	81	11	42	1333	1118	912	61	181	1019	97	32	1223
Garganey	2															2											
Teal	646	70					2		10	257	4				2	4			7			202	15			18	55
Wigeon	1735	11	453		218	48	62		25	205	88	154	20	22	2			127	13	8	21	159	35			64	
Shoveler	13							2								5						2				4	
Pochard	185																			65					120		
Tufted Duck	14081		6										20		75					1775				12025	80	100	
Scaup	10																										10
Golden-eye	9966		255	71	952	122	173	7		25	37	1898	2291	328	55				386	1529	360	192		198	94	5	988
Long-tailed Duck	12466		166	68	582	77	1324	157			76	554	1308	1055	377				82	393	397	3053		798	1423	371	205
Eider	35353	595	3097	92	410	169	3340	8706	950	2173	96	399	1301	2214	1398	156	27	747	180	221	457	5362	121	191	447	2126	378
Scoter	2219		38	29	358	83	310		92	122	136	45	182	4	106	1	25		44	14	81	412	9	16	46	23	43
Velvet Scoter	85		4		2			18				2		5	6				5	2		17		18	5		1
Diving Duck sp.	2002												1						1					2000			
Goosander	244			3	5		1	2			1	26	113	9	9					60	4			2	9		
Red-breasted Merganser	4386	45	1685	15	102	131	60	24	26	18	12	258	140	102	44	1		21	38	253	80	269	1	105	278	142	536

Appendix V continued

Species	Total	1999	1999	1999	2000	2000	2000	2000	2000	2000	2000	2001	2001	2001	2001	2001	2001	2001	2001	2002	2002	2002	2002	2003	2003	2003	2003
		29.08	15.11	13.12	14.01	14.02	04.04	26.04	11.09	07.10	27.11	10.01	10.02	16.03	20.04	15.08	16.08	28.09	14.11	03.01	13.02	26.03	22.08	10.01	04.03	24.04	09.12
Marsh Harrier	1	1																									
Osprey	1						1																				
White-tailed Eagle	2			1																					1		
Coot	6163		30	70	430	320	13	198	225		1	230	1000					200	251	1705	200			1200	90		
Oystercatcher	44						4	4						3	5	1	1				6	14			4	2	
Lapwing	34													1									33				
Grey Plover	3		2														1										
Golden Plover	20								10														10				
Ringed Plover	2														2												
Whimbrel	16																16										
Curlew	17	6			3															1					1	2	4
Bar-tailed Godwit	100									75		25															
Redshank	49						4	2	42							1											
Greenshank	4															3							1				
Knot	38	13							15								10										
Dunlin	731	5	25			30		7							300		1		25			300	38				
Ruff	15	15																									
Avocet	31						6															25					
Small Wader sp.	85					40			1					27			2	15									
Common Gull	744		21	13	34		10	1	251	67	13	3		3	59	6	2	1	228	11	2	4		5	1		9
Herring Gull	20355	482	1028	688	1141	235	1048	633	380	763	235	1520	3217	965	1261	127	246	130	144	1248	1776	872	479	589	564	260	324
Lesser black-backed Gull	17	15							2																		
Black-backed Gull	1080	68	34	41	178	5	13	9	52	31	31	78	238	9	7	10	2	7	29	40	34	9	7	89	38	5	16
Black-headed Gull	3221	221	135	52	47	9	120	38	223	213	487	171	17	25	32	269	69	334	170	20	10	97	342	5	3	34	78
Little Gull	484		1	1	2		1	51		84		11	3		3			259		24		3		9		32	
Kittiwake	5				5																						
Gull sp.	485						1		105	306				11				4		50						8	
Common Tern	6									6																	
Arctic Tern	58	1					1		1						42											13	
Arctic/Common Tern	22	1						1		1						2	13	1					3				
Little Tern	1																1										
Sandwich Tern	20						7	3	1								3						5			1	
Tern sp.	4														1											3	
Auk	2																		2								
Auk/Guillemot	103		22	10	3	1			1	1		11		1			1		8	26	4	12		1			1
Guillemot	2			1					1																		
Black Guillemot	1											1															

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Investigations of birds during construction and operation of
Nysted offshore wind farm at Rødsand

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