National Environmental Research Institute
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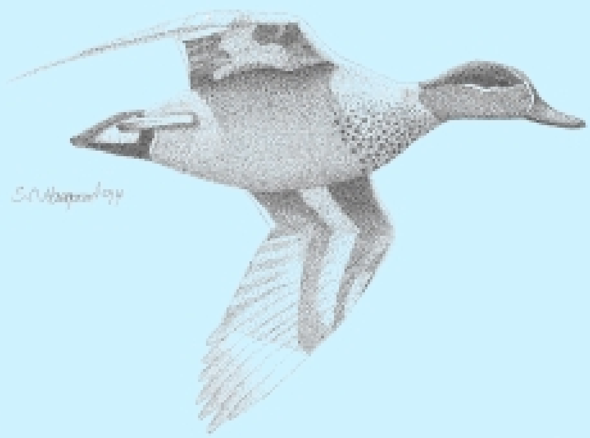
Base-line investigations of birds in relation to an off-shore wind farm at Rødsand

Results and conclusions, 2002

NERI Report
Commisioned by Energi E2



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Mark Desholm
Ib Krag Petersen
Johnny Kahlert
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Data sheet

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Author(s):	Mark Desholm Ib Krag Petersen Johhny Kahlert Ib Clausager
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Synopsis

This report presents data from the base-line investigations of birds, which were carried out during 2002 in relation to the Nysted/Rødsand offshore wind farm. Mapping of migration routes was carried out by use of radar day and night. The mapping of migration routes was combined with species identification during daytime by use of telescope. Waterfowl, which included staging migrants, wintering or wing moulting birds in the study area at the wind farm area, were monitored by aerial surveys.

The wind farm area is situated on a waterfowl migration route. Observations at Gedser Odde suggest that numbers of passing waterfowl may add up to 300,000 individuals during autumn. The baseline study has shown that between 26% (2002) and 49% (2000) of the waterfowl tracks registered by radar pass the eastern border of the wind farm area.

During spring, the percentage of waterfowl (mainly eiders), which passed the eastern edge of the wind farm area, was for the first time since the start of the base-line study in the same order of magnitude (25%) as in autumn (26%). Like in spring 2001, the 2002 main spring migration route of waterfowl was situated north of the wind farm area. In late May 2002, ca 9,000 dark-bellied brent geese followed the northern migration route.

Due to a temporary suspension of the study in autumn 2002, data on migrating landbirds from this period are absent in the present report. Spring migration of raptors, passerines and pigeons was almost absent both during 2000, 2001 and 2002.

All migration tracks were entered into a GIS – (Geographical Information System) database, subsets of data were selected for description of migration routes before the wind turbines are erected. These base-line data will be used for comparisons with similar data obtained during a monitoring programme carried out in a period after the wind farm has started to operate. Three key-variables are presented in this report:

1) the orientation of autumn migration routes for waterfowl and terrestrial bird species; the variable is to be used to measure potential avoidance response to individual wind turbines;
2) the probability that waterfowl will pass through the wind farm area during autumn and spring; the variable is to be used to measure the waterfowl response to the entire wind farm;
3) the migration intensity measured as the number of bird flocks that pass the eastern and northern edge of the wind farm area; the variable is to be used to measure the effect of the avoidance responses to the volume of migration in the wind farm area.

Comparisons of key variables between individual base-line years were undertaken while controlling for various factors such as weather conditions, season and time of day, mainly by use of multi-factorial

ANOVA or regression analyses. Measures of migration intensity tended to have least statistical power in between-year comparisons amongst the three key variables.

Count surveys of staging, wintering and moulting waterfowl have documented that cormorants (up to 5,200 individuals) and moulting mute swans (up to 9,700 individuals) occur in international important numbers (> 1% of total population in the entire study area) on an annual basis. Red-breasted merganser has not occurred in international important numbers since November 1999, when 1,600 individuals were counted.

On the basis of aerial count surveys waterfowl preferences of predefined areas were calculated by use of Jacobs's selectivity index. Cormorant, mute swan, mallard, goldeneye, herring gull and little gull all showed significant avoidance of the wind farm area and the three distance bands around it. Long-tailed duck and common scoter showed significant preference for the wind farm and the adjacent distance bands, making these species susceptible to disturbance effects from the future wind farm. Red-breasted merganser showed avoidance of the wind farm site, but preference for the three distance bands, whereas eider showed index values very close to 0, which indicated neither preference nor avoidance.

Radar studies revealed that cormorants may undertake social foraging events during early mornings and late afternoons. Social foraging flocks may hold 5,000 individuals and may occur inside the wind farm area. This behaviour makes cormorant a potentially high-risk species with respect to collisions with the wind turbines, also because the species may be attracted by the turbine foundations for roosting.

1 Introduction

1.1 Background

In June 2001, the Danish Ministry of Energy licensed Energi E2 to construct an offshore demonstration wind farm situated in the Baltic Sea, south of Lolland and Rødsand during 2003 (Fig. 1). This demonstration project will enable an assessment of 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).

The area around Rødsand is known to hold relatively large numbers of staging waterfowl 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 waterfowl and terrestrial bird species concentrate as they pass through the area. The significance of the area for staging and migrating waterfowl has been confirmed through extensive studies, carried out since 1999 by the National Environmental Research Institute (NERI) (Kahlert, Desholm, Clausager & Petersen 2000, Desholm, Kahlert, Petersen & Clausager 2001, Kahlert, Desholm, Petersen & Clausager 2002), and commissioned by SEAS Wind Energy Centre (SEAS) on behalf of Energi E2.

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

Of the total waterfowl migration at Gedser Odde, 19-49% passed through the planned wind farm area in 1999-2001, varying between season and whether migration occurred during day or night.

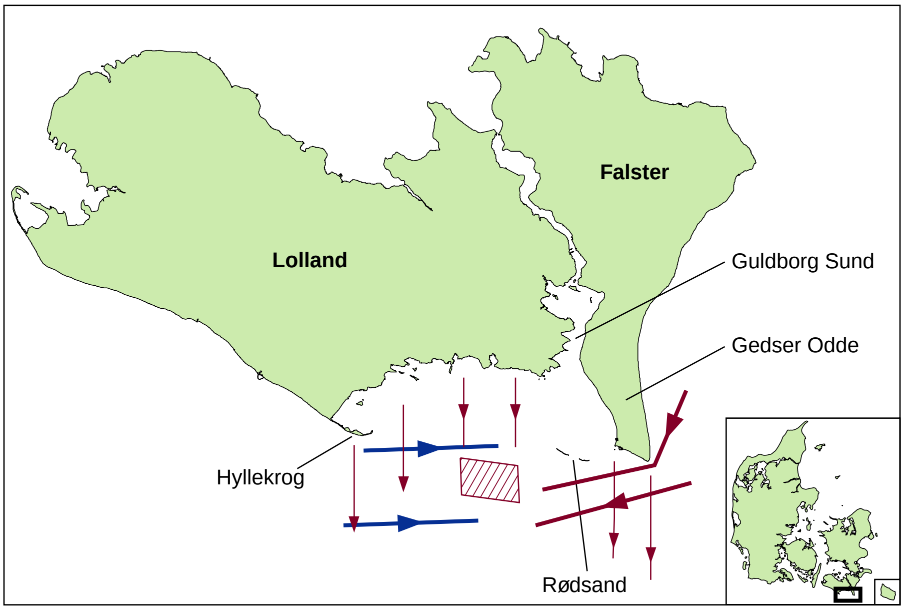


Figure 1. The wind farm and study area south of Lolland and Falster in southeastern Denmark. Names of locations referred to in the text are indicated. The hatched area represents the wind farm area, thin and thick arrows indicate the schematic direction of terrestrial and waterfowl migration, respectively.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

An area is classified 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). Based on this 1%-criterion the 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 analyses of the distribution during autumn 2000 and 2001 of the above-mentioned three species it was shown that red-breasted merganser was registered 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.

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

1) Disturbance effects (displacement, habitat loss);
2) Physical changes due to construction (bottom fauna changes and new resting facilities);
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, Schekkerman, Larsen, van der Winden, van der Haterd, van Horssen, Dirksen & Spaans 1999, Larsen & Madsen 2000). In relation to staging waterfowl, 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 are existing.
2) Physical changes of the habitat were judged to be of minimal and temporal importance, and it was estimated that resettling of the bottom fauna on the foundations of the turbines will exceed the loss of bottom fauna caused by the establishment of turbines (DHI 2000). Furthermore, the static turbine superstructure may be used by cormorants or gulls for resting.
3) Studies of the collision risk are not possible before the turbines have been erected. Nevertheless, the subject is 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 erection of the wind farm. This includes the avoidance response by flying birds, which may either deflect laterally when a wind farm is approached or may climb to attain height to avoid it altitudinally. Such avoidance responses are likely to be species specific for example caused by a different ability amongst the species to manoeuvre their sensitivity to the presence of huge constructions and interaction 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 waterfowl, are likely to be more sensitive to small changes in mortality compared to passerines that suffer a higher annual mortality (in some species more than 50%) and have a correspondingly higher reproductive output (Noer, Fox, Clausen, Petersen, Kahlert & Christensen 1996, Morrison, Pollock, Oberg & Sinclair 1998.

A separate project, which deals with the development of reliable methods to estimate collision frequency at the Nysted / Rødsand wind farm is currently 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 2003b).

1.2 Base-line investigations

This report presents the results of the base-line investigations carried out in 2002 following the procedures used in the base-line investigations from 2000 and 2001 (Desholm et al. 2001, Kahlert et al. 2002). However, due to a temporary suspension of the study in September / October, only four out of eight aerial surveys on staging waterfowl and three out of eight planned observations trips were conducted during autumn 2002.

The report includes a description of flight trajectories of migratory waterfowl and passerines during spring and autumn. From this description three variables were derived to provide a reference to detect future 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. The results of the four aerial counts of staging waterfowl are presented.

The cable between the offshore transformer station and Vantore beach was laid out during 2 September - 2 October 2002. Data for base-line investigations have therefore been collected for a number of years to reflect the 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 baseline data in order to determine possible effects of the construction activities and of the wind farm itself on birds.

Methods used are described in detail in earlier reports (Noer, Christensen, Clausager & Petersen 2000, Kahlert et al. 2000, NERI 2000, Desholm et al. 2001, Kahlert et al. 2002).

2 Methods

2.1 Study area

The wind farm is being placed south of Rødsand, ca 10.5 km west-southwest of Gedser Odde and ca 11.5 km south of Lolland at a water depth of 6-9.5 m (Fig. 2). For a detailed description of the planned wind farm and the model scenario with 72 turbines, see Kahlert et al. (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).

The study area for mapping of staging waterfowl by use of aerial surveys covered 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 are to be erected subsequently will be called the wind farm area. The island of Rødsand covers 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.

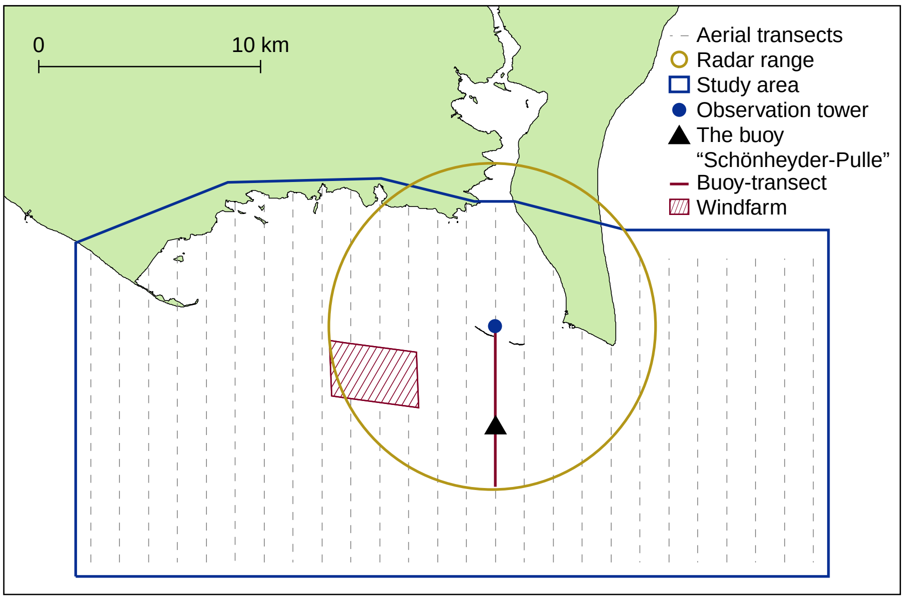


Figure 2. Location of the study area covered by aerial surveys, the observation tower on which the radar was mounted, radar range, wind farm area and the Buoy-transect.

2.2 Base-line investigations of migratory birds 2002

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), late May (one week) and 1-19 September (three weeks). These periods coincide with the main migration period of a substantial number of the species of waterfowl and raptors. But since no observations were conducted in October, the volume of data on passerines was relatively low in the 2002 autumn season compared to that of autumn 2001. Observations in late May were carried out to compile data on the spring migration of dark-bellied brent geese *Branta bernicla*, exclusively. 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 2002, visual data were collected during daytime 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 for each 15-minute period.

To compile 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. 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 waterfowl 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 waterfowl 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 directions 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 (NERI 2000), and therefore, these factors are dealt with in more details in the base-line study.

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, Camphuysen, Jonkers, Leopold, Schekkerman & Dirksen 1999), a phenomenon that only relates to nocturnal migrants. It is also possible that gulls and cormorants will use the static turbine superstructure for resting during both day and night, resulting in relatively high numbers of radar tracks moving 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;
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 east-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 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 waterfowl. Of 1,221 migration tracks recorded during autumn 2002 (Fig. 3), 36 were extracted for the analysis of lateral change in migration routes by excluding those that did not pass the 15 transects placed in parallel with and east of the most easterly row of turbines (Fig. 4), and those that crossed the north and south lines depicted in figure 4.

Figure 3. Radar registrations of 1,221 waterfowl flocks migrating at Rødsand during autumn 2002. Flocks that were not determined visually to species were classified as waterfowl on the basis of their radar signal and / or migration speeds exceeding 50 km / hour. All flocks presented were migrating in a westerly direction.

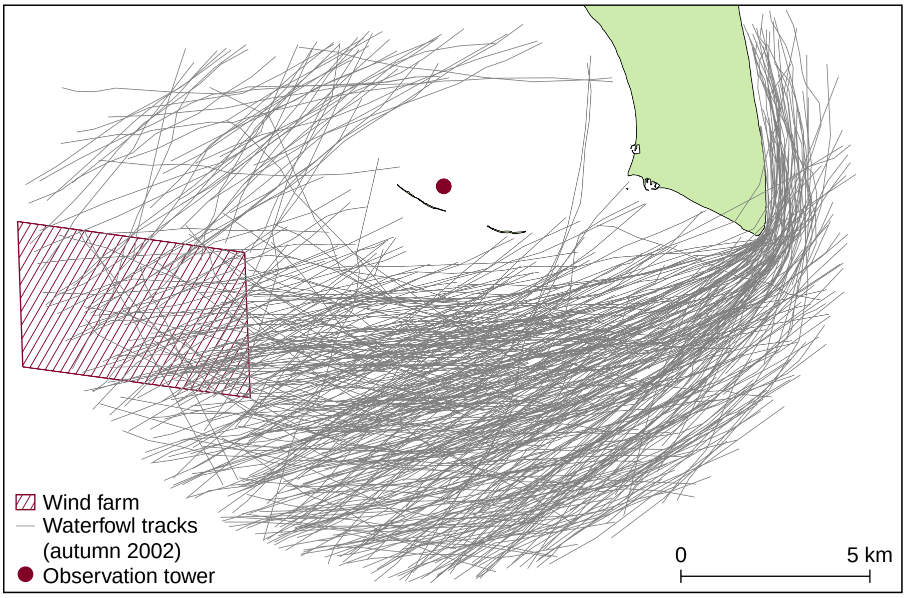


Figure 4. The 36 tracks of autumn migrating waterfowl flocks which were used in the analyses of the orientation of migration routes at the observation tower and the wind farm area. The letters A - N indicate the 14 sectors between the transects.

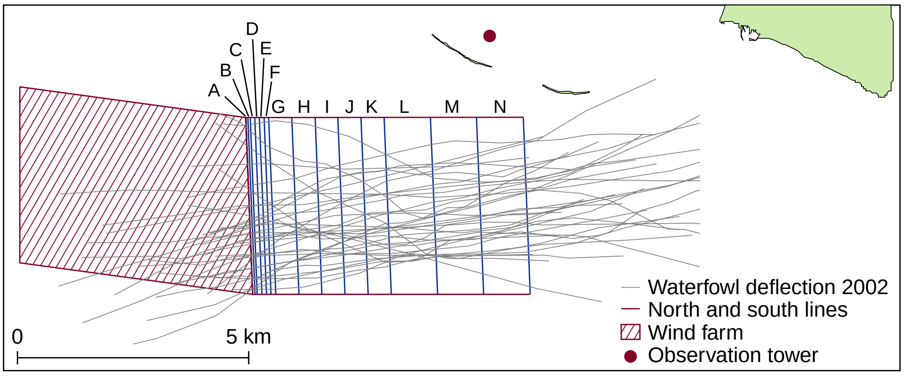
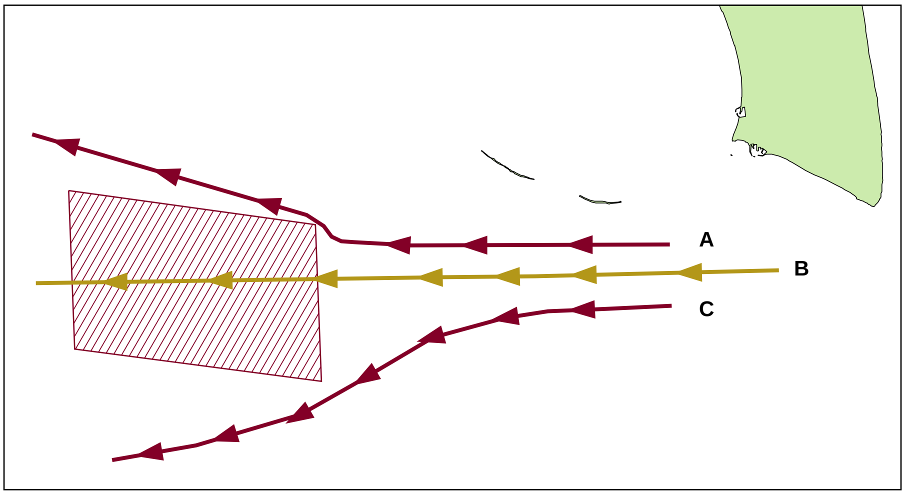


Figure 5. Schematic presentation of possible lateral avoidance responses by flocks of autumn migrating waterfowl: A) deflection with a short avoidance distance, B) no deflection and C) deflection with a long avoidance distance.



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 36 tracks was calculated.

The unequal intervals between the transects should be considered 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. 5).

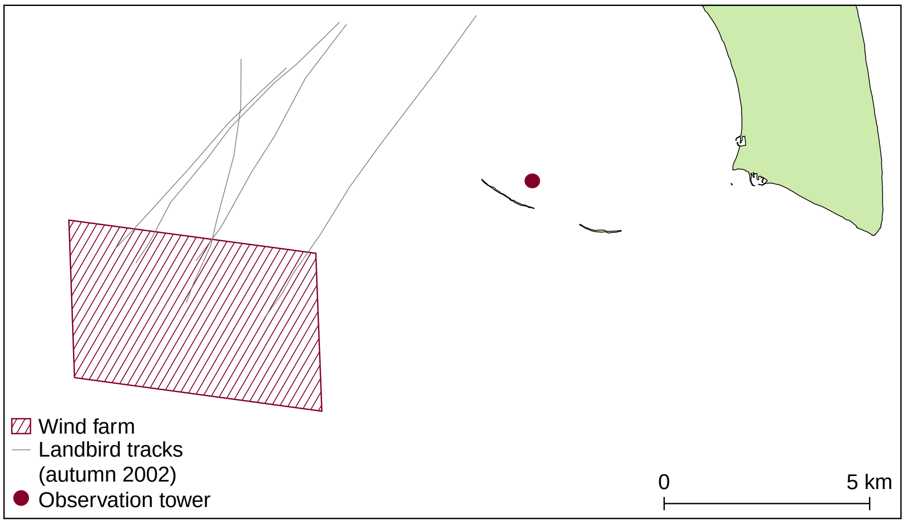
The mapping of migration routes gives the opportunity to test potential changes in the mean orientation at different distances from the wind farm area, and to test whether a systematic change in migration route has occurred. If data from all sectors are normally distributed and show equal variance, the 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 will result in a bimodal distribution close to the wind farm, but an unimodal distribution further away where the deflection has not yet begun. Hence, the final approach may involve the use of non-parametric tests to detect possible differences in the orientation of the migratory tracks.

Northern and southern winds can move west-flying flocks to the south and north, respectively. Visibility (continuous scale) and time of day (day and night) may affect the orientation 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 were tested using ANOVA. Separate analyses of the effect of visibility on orientation of migration at different distances to the wind farm area were carried out using a Pearson's Correlation Test.

Analyses were also carried out for the south-orientated migration tracks, which approached the wind farm area at the northerly row of turbines, to conclude on the orientation of terrestrial bird species. Tracks of locally migrating waterfowl and terrestrial bird species could not be discriminated strictly. Hence, to minimise a bias from local waterfowl, south-orientated tracks were only included in the analysis during periods when heavy migration occurred from the coasts of Lolland and Falster. Flight speed measurements were also carried out to support the selection of periods when terrestrial bird species were assessed to dominate the south-orientated migration during autumn (see Desholm et al. 2001).

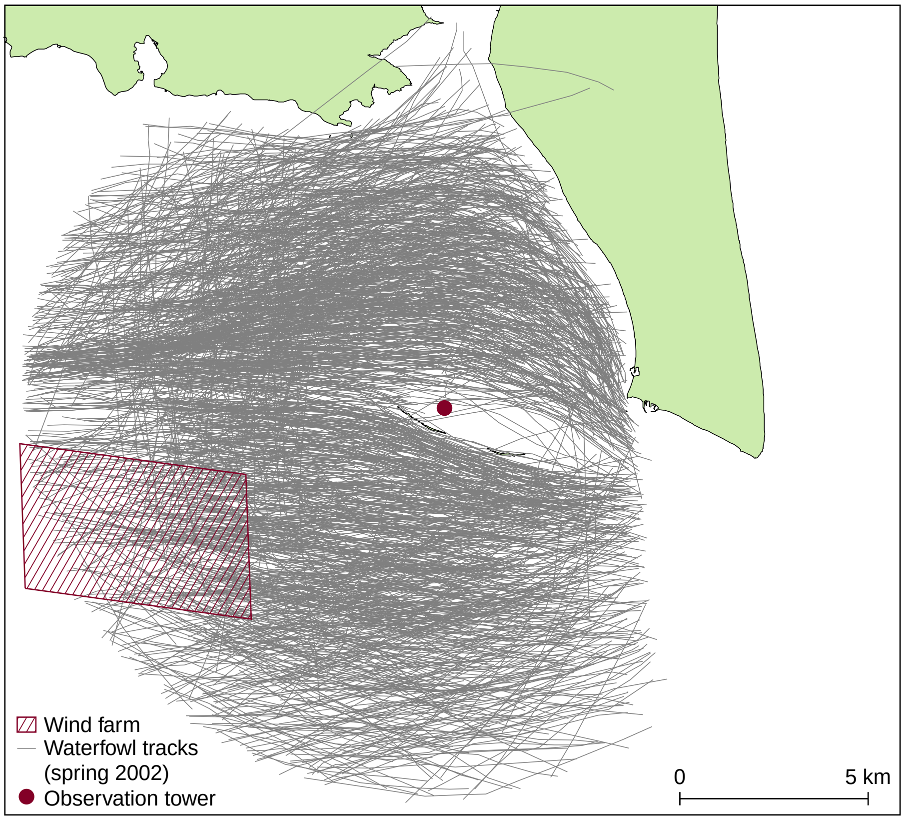
Unfortunately, migration of terrestrial bird species could not be followed by radar with the same consistency as waterfowl due to the smaller sizes of passerines, which dominate the autumn migration from land areas (Christensen & Grell 1989). For this reason, markedly shorter tracks were included in the data set at the northern edge of the wind farm area than the length of the tracks included in data set of the westerly-orientated waterfowl migration. In contrast to the base-line year 2001, very few autumn migration tracks of terrestrial birds were recorded (Fig. 6).

Figure 6. The five tracks of autumn migrating land-bird flocks recorded in 2002.



Reversed migration, which may be a relevant factor in 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 routes of waterfowl. 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.

Figure 7. Radar registrations of 1,533 waterfowl flocks migrating at Rødsand during spring 2002. Flocks that were not determined visually to species were classified as waterfowl on the basis of their radar signal and / or migration speeds exceeding 50 km / hour. All flocks presented were migrating in an easterly direction.



“Orientation of migration” and “proportion of reverse migration” is only relevant for bird flocks approaching the area designated for the wind farm. 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 erection of turbines will decrease. In accordance with the base-line study in 2001, data were collected in 2002 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.

Methods used for autumn analysis: Of the 1,221 migration tracks recorded during autumn 2002, 184 were extracted for analysis by excluding those that did not pass the line due south of the observation tower (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 wind farm area or not, and the proportion of flocks that actually did so was calculated.

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 five factors:

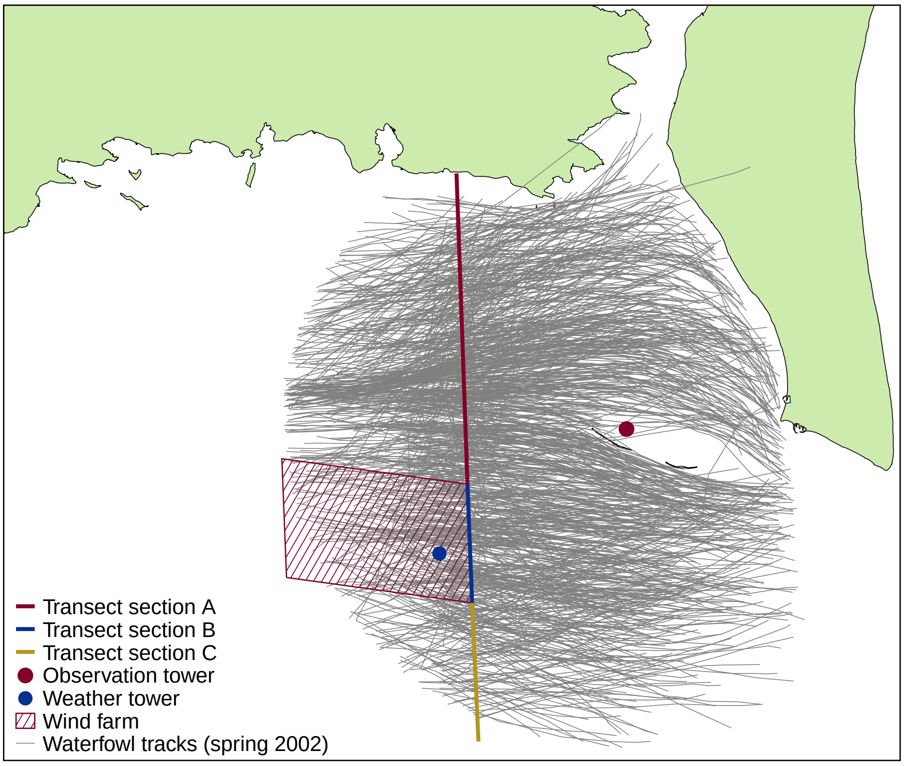
1) north-south placement of the track, measured as the distance from the observation tower to the intersection between the migration track and the Buoy-transect,
2) visibility,
3) time of day (day and night),
4) wind (northerly and southerly winds) and
5) year (2000, 2001 and 2002).

Methods used for spring analysis:

Of the 1,533 migration tracks recorded during spring 2002 (see Fig. 7), 957 were extracted for analysis by excluding the observations from May and the observations that did not pass the transect due south of Lolland or crossed the north-east and south-east corner of the wind farm area (Fig. 8). The May data were excluded from the general analysis, as they represent a rather limited time period and focus on dark-bellied brent goose.

The proportion of migration tracks that passed the eastern edge of the wind farm area was calculated to be compared with the situation after erection of the wind turbines. The effects of side wind (northerly and southerly wind directions) and time of the day (day and night) were analysed using a logit model.

Figure 8. The 957 tracks of spring migrating waterfowl flocks, which were used in the analysis of the probability of passing the wind farm area in 2002. The three transect sections A-C, as described in the text, are shown.



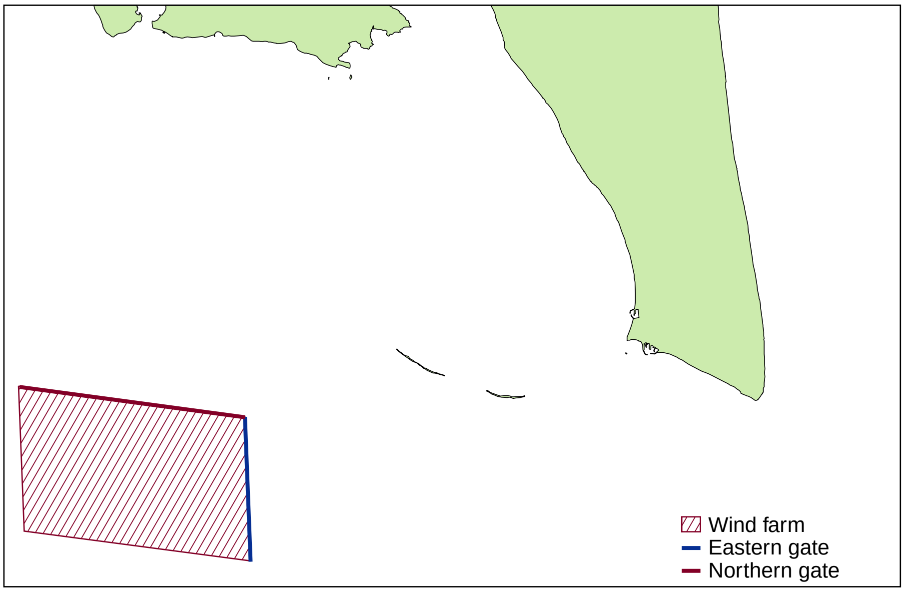
2.2.3 Migration intensity in the wind farm area

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. If it is assumed that it will be more difficult for migrating birds to detect the wind farm during nighttime than during daytime (this depends on the attraction effect of the future illumination of the turbines), thus, it is predicted that the decrease in migration intensity in the wind farm will be most pronounced during daytime.

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 2002, bird flocks that entered the wind farm area from the north or east were counted at 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 that tracks passing the eastern gate from the east could mainly be ascribed to migratory waterfowl (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 2002, the number of individuals passing per 15-minute period was counted on the same transects as during autumn. Due to the main heading of migration during spring (towards east and north), only bird flocks which 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 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. Firstly, the migration intensity data were divided into two periods: September (1-30 September) and spring (16 March - 15 April). For each period, cumulative frequency distributions of the number of flocks per 15-minute period were generated for each of the following wind conditions: 1) northeasterly winds (1°-90°), 2) southeasterly winds (91°-180°), 3) southwesterly winds (181°-270°) and 4) northwesterly winds (271°-360°). Separate distributions were generated for daytime and nighttime observations (see Appendix I). In the present report, new graphs are presented showing the between-year variation of the average number of flocks per 15-minute period for each season, time of day and wind direction. These graphs are based on the above described distributions which are depicted in Appendix 1.

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

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 three periods are presented for early September (1-15 September), late September (16-30 September) 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.

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, and a useful variable in the estimation of migration heights and as an element in models to estimate collision risk.

2.3 Base-line investigations of staging, moulting and wintering birds 2002

The presence (number and species composition) and distribution of staging, moulting and wintering birds in the study area (see Fig. 2) were recorded by four aerial surveys during January - August 2002. The data were collected to obtain a standard reference for subsequent investigations to detect possible impacts of the wind farm on birds. 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 study area was covered by 26 north-south orientated, parallel transects separated by a distance of 2 km and a total length of 579 km (Fig. 10). The 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).

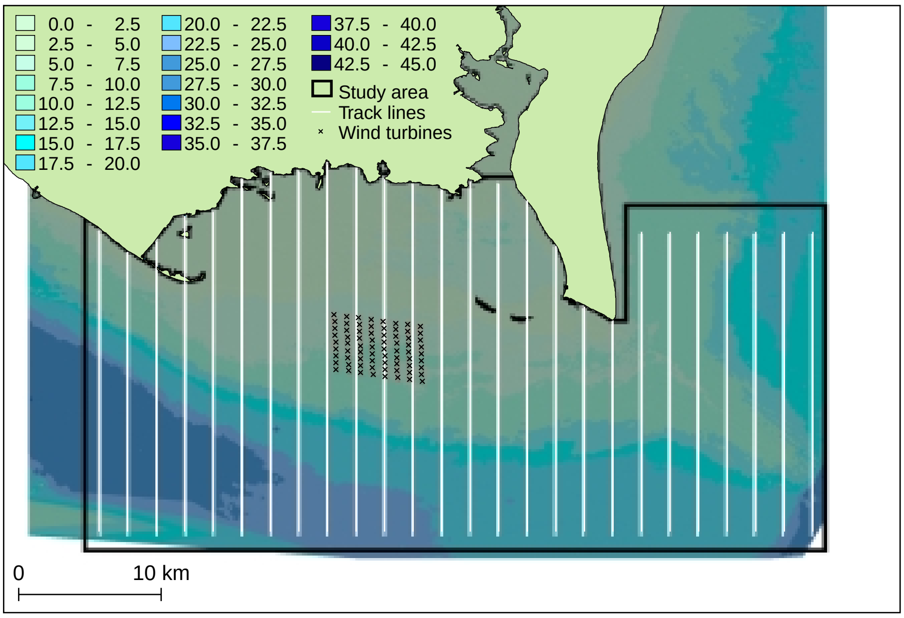


Figure 10. The Rødsand study area with positions of the wind turbines, and with the ideal survey transect lines and bathymetric profile shown.

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 geographical 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. Numerous species in the study area or in the near vicinity of the wind farm were selected, but also species of special conservation interest were chosen for a more thorough description.

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. In order to evaluate the method, the updated and pooled data will be presented by the end of each study year adding new registrations to the data set successively. The pooled data set now comprises 21 aerial surveys.

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, Petersen & Hedley 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 2002 will be presented in the same general format as the previous reports. In order to correct for the coverage of the study area, the pooled data for 1999 – 2002 are presented as the number of individuals observed, by species, relative to the covered transect length in a grid net of 2x2 km cells.

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 was computed: 1) the wind farm area, 2) the wind farm area + a 275 m zone around it, 3) the wind farm area + a 2 km zone around it, and 4) the wind farm area + a 4 km zone around it.

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 r and p 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).

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

High-resolution bathymetric data from the study area were obtained from the Danish Coast Guard (Farvandsvæsenet) (see Fig. 10). These data were established on the GIS platform, enabling calculation of depth to observations made during the bird surveys. Based on this information a depth frequency distribution was made for selected species.

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. SEAS 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. The Danish Meteorological Institute compiled visibility data at Gedser Odde every three hours.

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:

1) Internal scientific review by a senior researcher
2) Internal editorial and linguistic revision
3) Internal proof-reading
4) Layout followed by proof-reading
5) Approval by project managers.

3 Results

3.1 Migratory birds

Migration tracks of waterfowl are presented as original tracks (see Figs. 3 and 7) and in a grid-based manner showing the relative densities expressed as the sum of metres of tracks within each grid cell (Figs. 11 and 12). The high concentration of westbound tracks rounding Gedser Odde during autumn was confirmed in 2002 to almost exclusively being representing waterfowl flocks that have followed the east coast of Falster (detour effect).

General summary maps and analyses of the autumn migration of terrestrial birds could not be accomplished in 2002, due to a suspension of the study during part of the autumn 2002.

The eastbound spring migration (mainly of waterfowl) in the study area (Kahlert et al. 2000) tended to show two migration routes in 2002 as was the case in 2001 (see Fig. 12). The main route occurred north of the wind farm area, but in general massive eastward migration took place within all the radar range (see Fig. 12). The migrating common eiders were observed both south and north of Rødsand (Fig. 13). The majority of the spring migrating dark-bellied brent geese were observed north of both the wind farm and Rødsand (Fig. 14), but in contrast to the former years a few flocks were observed south of Rødsand in late May.

3.1.1 Lateral change in migration routes

Autumn migration of waterfowl

The selected tracks of migrating waterfowl moving in a westerly direction towards the eastern gate of the wind farm area showed during autumn 2002 the same consistency as in 2000 and 2001. The mean orientation of the migratory flocks varied within 262.5º - 266.6º in 2002 (Fig. 15) which is a more southerly direction (270° is due west) compared to 265.7° - 272.1° in 2000 (Desholm et al. 2001) and 267.5°-270.7° in 2001 (Kahlert et al. 2002).

Similar to the analysis for 2000 and 2001, the effects of three variables on the orientation of the waterfowl migration was also explored in 2002. The three variables were 1) distance to wind farm area, 2) wind direction (northerly and southerly), and 3) time of the day (day or night). A multi-factorial analysis (3-way ANOVA) showed that time of the day was the only factor, which significantly affected the orientation of waterfowl migration ($F = 9.04$, $df = 1$, $P = 0.0028$). The analysis showed that migration was orientated more to the south during daytime than during nighttime, differing by 5.0°. This was in accordance with the result from 2001 (Kahlert et al. 2002), but contrasting those of 2000 in which year distance to wind farm area and wind direction also showed significant effects on the orientation of the waterfowl migration (Desholm et al. 2001).

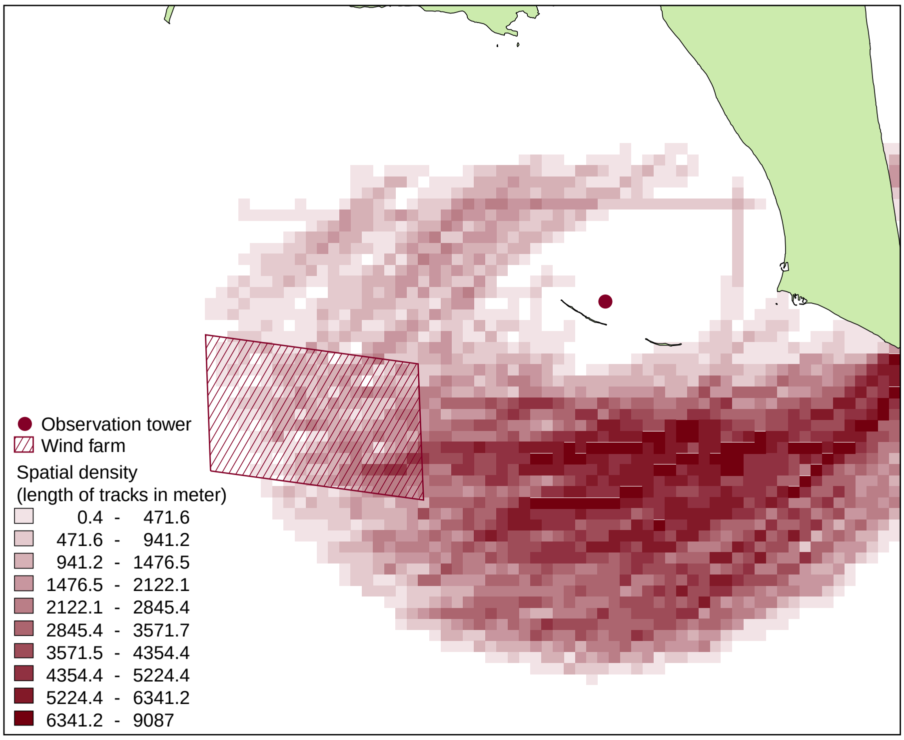


Figure 11. Spatial migration density of 1,221 waterfowl flocks migrating at Rødsand during autumn 2002. The density is indicated by the total length of tracks in metres within each grid cell.

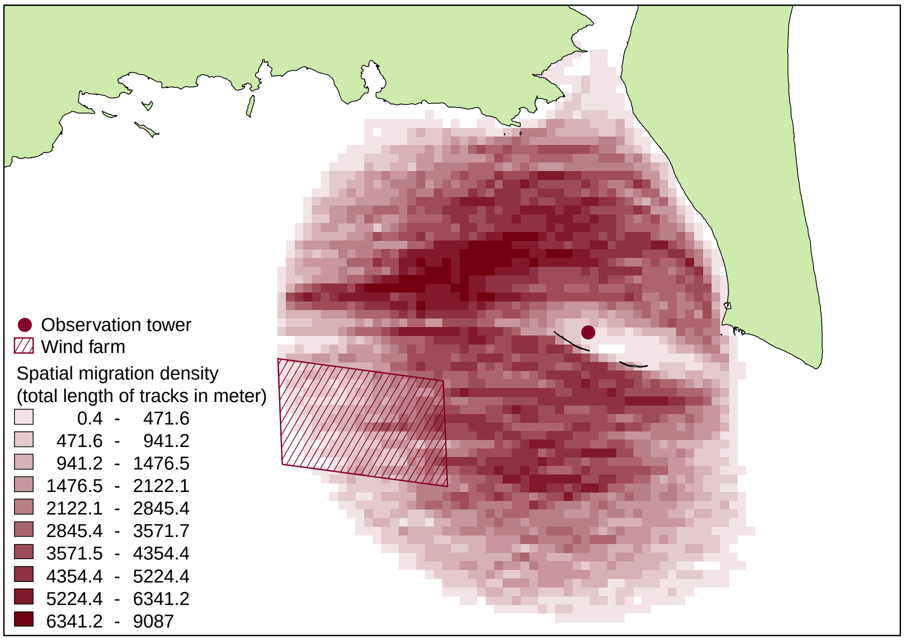


Figure 12. Spatial migration density of 1,533 waterfowl flocks migrating at Rødsand during spring 2002. The density is indicated by the total length of tracks in metres within each grid cell.

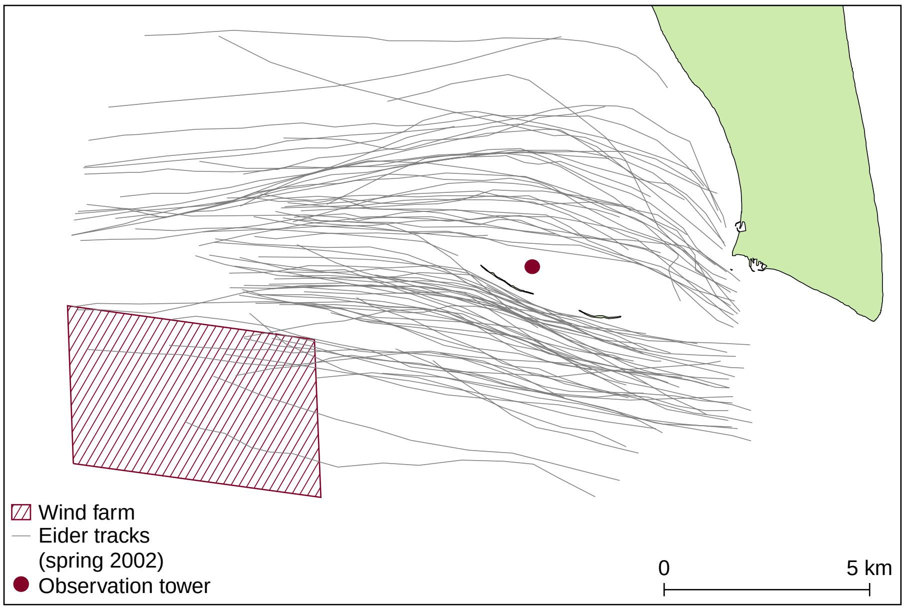


Figure 13. Radar registrations of 89 flocks of 4,650 migrating eiders determined visually at Rødsand during spring 2002.

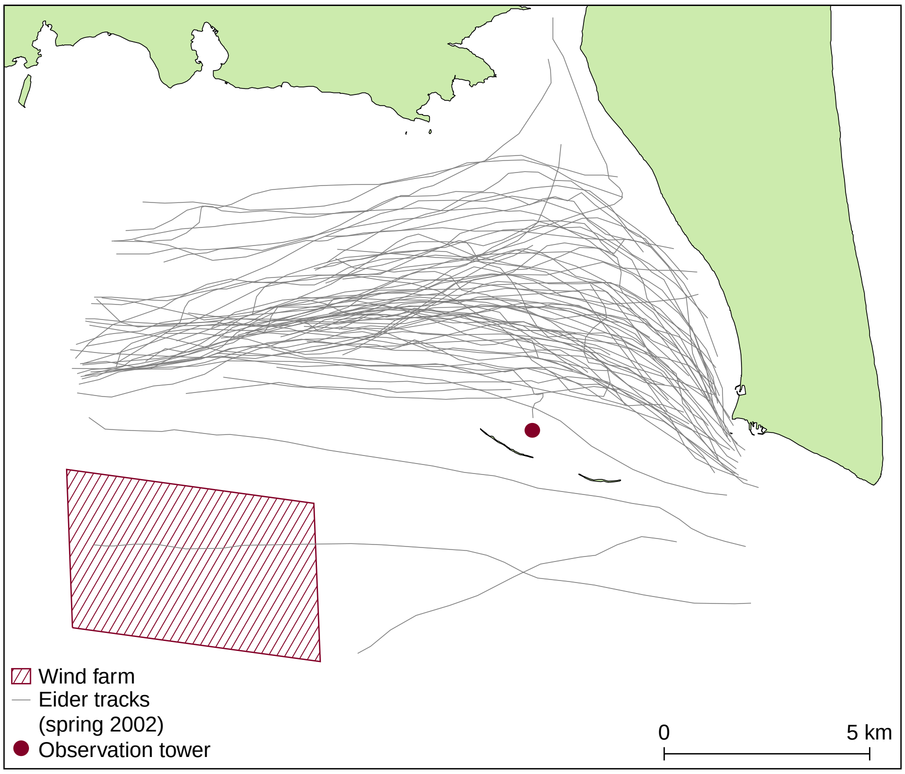
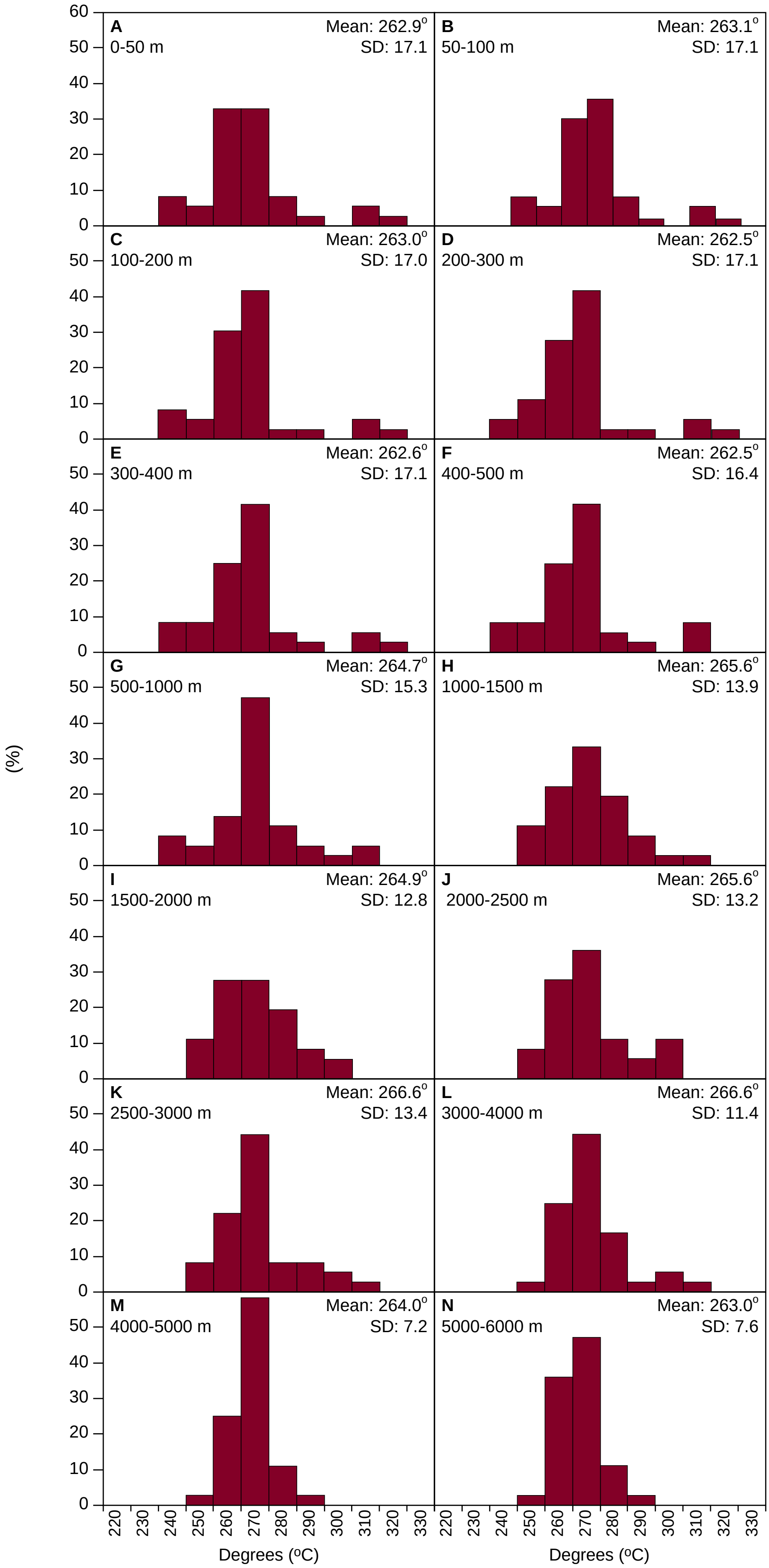


Figure 14. Radar registrations of 72 tracks, which were determined to be brent geese and included 6,928 birds migrating at Rødsand during spring 2002.

Figure 15. Frequency distributions of the orientation of the autumn migrating waterfowl flocks for each of the 14 sectors A-N (see Fig. 4). Mean course and standard deviation for each sector (A-N) are given in the graphs.



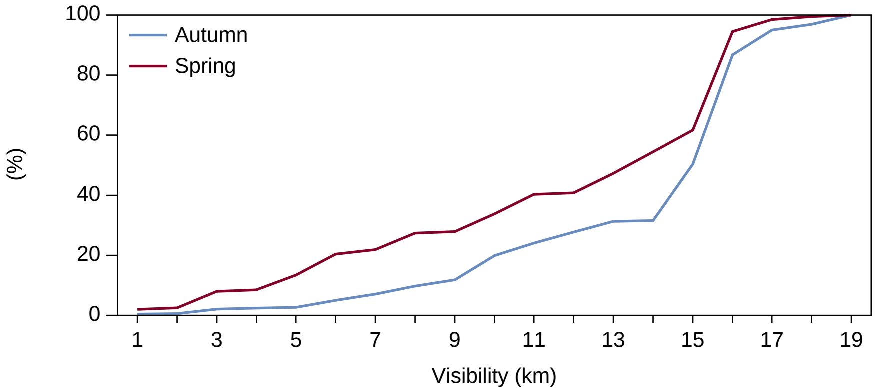


Figure 16. Cumulative percentage of observations in relation to visibility (km) measured at the Danish Meteorological Institute's meteorological station at Gedser. Observations were made every three hours during the spring period 15 March - 10 April and the autumn period 1 September - 31 October 2002.

An overall comparison of the orientation of waterfowl migration between 2000, 2001 and 2002, which controlled for distance to wind farm area, wind direction and time of the day (4-way ANOVA), showed that there was a significant difference between the three base-line years ($F = 62.52$, $df = 2$, $P < 0.0001$). Comparisons using t-tests showed that both 2000 ($T = 9.33$, $df = 600$, $P < 0.0001$) and 2001 ($T = 8.42$, $df = 661$, $P < 0.0001$) differed significantly from 2002, whereas the two first years did not differ (Kahlert et al. 2002).

In accordance with the previous base-line report analysing 2000 and 2001 (Kahlert et al. 2002), interactive effects on the migratory orientation were present between year and wind direction ($F = 3.83$, $df = 2$, $P = 0.02$) and between year and time of the day ($F = 12.20$, $df = 2$, $P < 0.0001$).

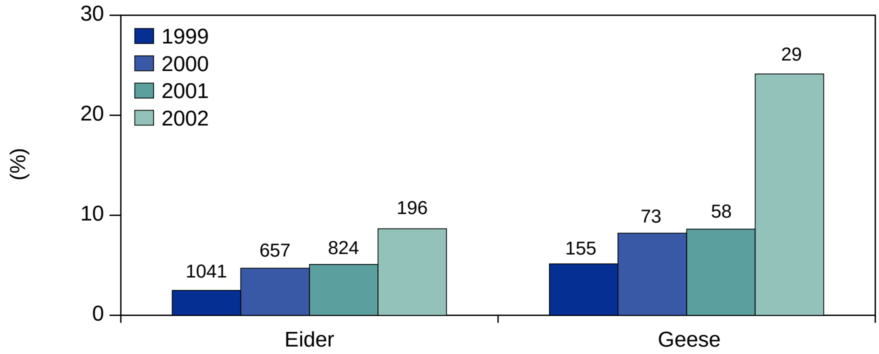
Visibility was recorded as a continuous variable and was analysed in relation to migratory orientation for all combinations of the three variables with ordinal scales: distance to wind farm area, wind direction and time of the day. Only the comparison: during nighttime and northerly winds directions, 3 km east of the wind farm showed significant positive correlation between visibility and orientation ($R = 0.59$, $P = 0.04$).

The fact that only one out of 35 correlations was significant in 2002 and a similar low number of significant correlation in 2000 and 2001 support that visibility was not a factor that had a major influence on the orientation of waterfowl migration. In fact, one significant result ($P \leq 0.05$) out of 35 comparisons is close to what should be expected by chance ($0.05 \times 35 = 1.75$ significant results).

During the autumn study period in 2002, the visibility was shorter than 2 km for ca 2% of all registrations (Fig. 16).

At present, only eiders and geese are assessed to have characteristics which make them adequate for studying reversed migration during autumn, to establish the impact of the wind farm when it is in operation. Thus, eider and geese occurred in considerable numbers and were mainly migrants. During the base-line years 1999, 2000, 2001 and 2002 significant differences in the proportion of eastern-orientated migration amongst flocks of eiders were found (Fig. 17; $\chi^2 = 19.00$, $df = 3$, $P < 0.0001$); for geese the proportion during 2002 differed significantly from the previous years (1999-2001; see Fig. 17; $\chi^2 = 14.62$, $df = 1$, $P = 0.001$).

Figure 17. Proportion of eastern-orientated migration (in %) for eider and geese in the four base-line years 1999-2002.



Autumn migration of terrestrial birds

As a consequence of the temporary suspension of the study during the late part of the autumn season of 2002, only five tracks categorised as landbirds (passerines/raptors) were collected, which all agreed with the tracks obtained in 2000 and 2001 in the same period. The main migration period of e.g. thrushes is late October - early November, and this group of birds is thought to constitute the major part of the landbird data of 2000 and 2001. Due to the very low number of records of 2002 no analyses of the effects on orientation were conducted.

3.1.2 Probability of passing the wind farm area

Autumn migration of waterfowl

During the autumn of 2002, the overall probability of crossing the planned wind farm area was 26.1% for flocks of waterfowl migrating at Rødsand and passing the Buoy-transect (see Fig. 2). This was significantly different from the probabilities calculated in autumn 2000 (49.1%; $\chi^2 = 5.2$, df = 1, $P < 0.05$) and 2001 (37.0%; $\chi^2 = 5.2$, df = 1, $P < 0.05$). In order to describe the probability of bird flocks passing the wind farm area in further detail, logistic regression models for different wind situations (northerly and southerly) and for day and night were computed incorporating visibility and distance to the observation tower when passing the Buoy-transect. The latter measure corresponded to the spatial distribution of the westerly-orientated migration route for waterfowl along a north-south axis as they approached the designated wind farm area.

Table 1. Significance of Maximum Likelihood Estimates of parameters in logistic regression models predicting the probability that bird flocks pass the designated wind farm area during autumn 2002 as a function of the distance in metres to the observation tower and visibility in km at northerly and southerly wind directions. Model Goodness-of-Fit Tests were carried out according to Hosmer & Lemeshow (in SAS 1999).

			Significance of parameter estimate				Goodness-of-Fit Test		
			Distance		Visibility				
Wind direction	Distance interval (m)	Period	χ^2 (df=1)	P	χ^2 (df=1)	P	χ^2 (df=1)	P	N
North	2000-11000	Day	9.92	0.0016	4.80	0.03	0.68	0.9996	73
		Night	17.31	0.0001	0.10	0.75	3.67	0.89	79
South	2000-11000	Day	–	-	–	-	–	-	-
		Night	4.70	0.03	3.49	0.06	6.19	0.63	31

Table 2. Maximum Likelihood Estimates of parameters in logistic regression models predicting the probability that bird flocks pass the designated wind farm area during autumn 2002 as a function of the distance in metres to the observation tower (DIST). Significance of distance in explaining changes in (S): *: P<0.01 and ***: P<0.001. Model Goodness-of-Fit Tests were carried out according to Hosmer & Lemeshow (in SAS 1999). Parameter estimates were inserted in the logistic regression model ($S_i = \frac{e^{\alpha+(\beta 1 \cdot DIST)_i}}{1 - e^{\alpha+(\beta 1 \cdot DIST)_i}}$) to establish the probability curves in Figure 18A-18C.

			Parameter estimate		Goodness-of-Fit Test		
Wind direction	Distance interval (m)	Period	Intercept (α)	Distance (β1)	χ^2 (df=8)	P	N
North	2000-11000	Day	5.4943	-0.00142***	13.73	0.09	73
		Night	5.1881	-0.00114***	4.12	0.85	79
South	2000-11000	Day	–	-	–	-	-
		Night	6.5087	0.00131*	7.22	0.51	31

The number of tracks registered during daytime and southerly winds was too small for any meaningful analysis. The logistic regression models showed that the distance to the tower could significantly explain the variation in the probability that bird flocks would pass through the wind farm area for the remaining three situations (Table 1). In contrast to the other base-line years, visibility was found to affect the probability of passing the wind farm area in one instance: during daytime and northerly winds (see Table 1). However, as distance to the observation tower was the only significant factor during autumn 2002 which was consistent between the three situations, logistic regression models were applied with distance as the only independent variable (Table 2 and Fig. 18A-18C). In contrast to the previous two years of base-line studies, in which the probability of passing the wind farm area was low close to the tower, but converged to unity at the same latitude as the wind farm area, no such pattern could be detected in 2002. However, at all wind directions and both in 2000, 2001 and 2002, birds which migrated at a lower latitude (approximately > 5.6 km) than the wind farm area had probabilities of passing the wind farm area significantly lower than unity (see Table 2 and Fig. 18A-18C, Desholm et al. 2001). Thus, the probabilities for birds, which migrated at the same latitude as the wind farm area, tended to converge to unity. Therefore, the predicted probabilities for the three situations during autumn 2002 were all based on one model each (see Fig. 18A-18C).

The regression lines predicting the probability that birds will pass through the wind farm area now represent the first three base-line years of reference to compare with regression lines to be established from data sets compiled after the erection of the wind farm.

The autumn migration pattern of waterfowl showed little annual variation from 2000 to 2002. For example, at northerly and southerly winds at nighttime during 2002 the probability that bird flocks would pass through the wind farm area converged to similar values as in 2000 and 2001 (see Figure 18B-18C; Table 3). Only at northerly winds during daytime, significantly lower probabilities of birds passing the wind farm area were detected in 2002 than in both 2000 (χ^2 = 15.09; P = 0.0001) and 2001 (χ^2 = 11.90; P = 0.0006; see Fig. 18A).

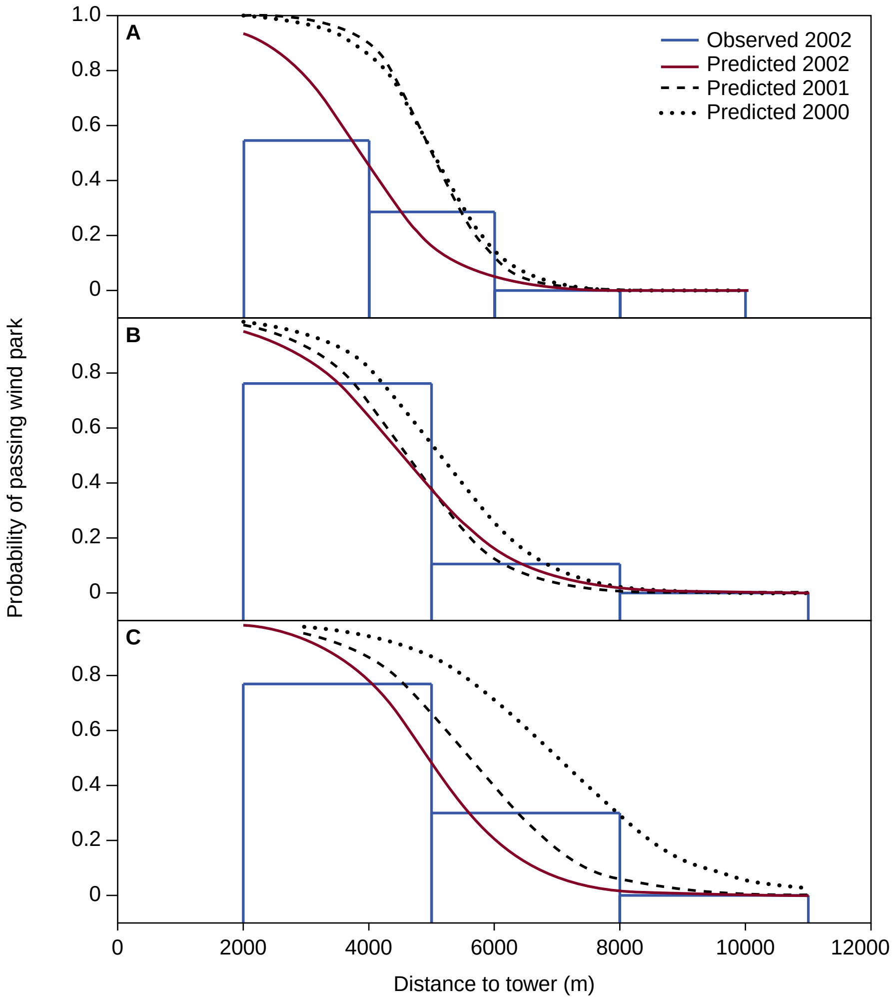


Figure 18. Observed and predicted probability that bird flocks flying in a westerly direction at Rødsand will pass the wind farm area as a logistic function of their position on a transect south of the observation tower. Logistic functions were developed under four conditions: A) northerly wind and daytime, B) northerly wind and nighttime and C) southerly wind and nighttime.

Table 3. Significance of Maximum Likelihood Estimates of parameters in logistic regression models comparing the probability that bird flocks pass the designated wind farm area during autumn 2000, 2001 and 2002 as a function of the distance in metres to the observation tower at northerly and southerly wind directions. Model Goodness-of-Fit Tests were carried out according to Hosmer & Lemeshow (in SAS 1999).

			Significance of parameter estimate				Goodness-of-Fit Test		
			Year		Distance				
Wind direction	Distance interval (m)	Period	χ^2 (df=2)	P	χ^2 (df=1)	P	χ^2 (df=8)	P	N
North	2000-11000	Day	3.36	0.19	10.83	0.001	11.24	0.19	549
		Night	0.62	0.73	17.52	0.0001	13.44	0.10	298
South	2000-11000	Day	–	-	–	-	–	-	-
		Night	0.0014	0.9993	6.72	0.0096	7.05	0.53	278

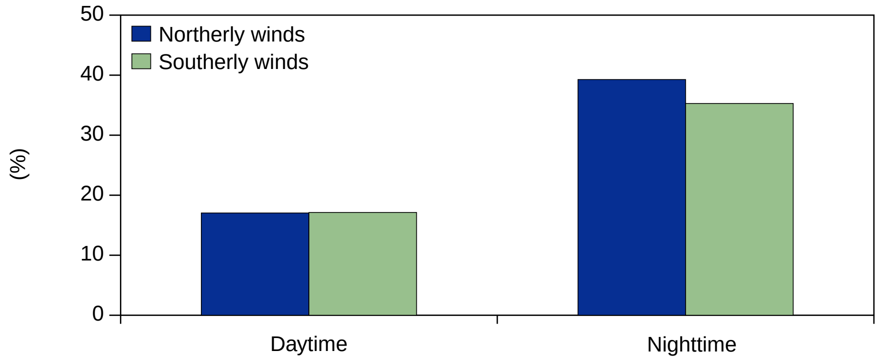


Figure 19. Probability of waterfowl passing the eastern wind farm gate in spring 2002 in relation to time of the day and whether the wind directions were northerly or southerly.

Spring migration of waterfowl

During spring 2002, the overall percentage of waterfowl tracks passing the eastern edge of the wind farm area was 25.0%. Time of the day had a significant effect on the relative number of waterfowl that passed through the wind farm area during spring 2001 and 2002 (Table 4). During nighttime the percentage was approximately twice as high as during daytime in 2001 and 2002 (Fig. 19). There was a combined effect of year and time of the day (see Table 4). Side wind from a northerly or southerly direction did not affect the migration route during spring (see Table 4).

3.1.3 Migration intensity in the wind farm area

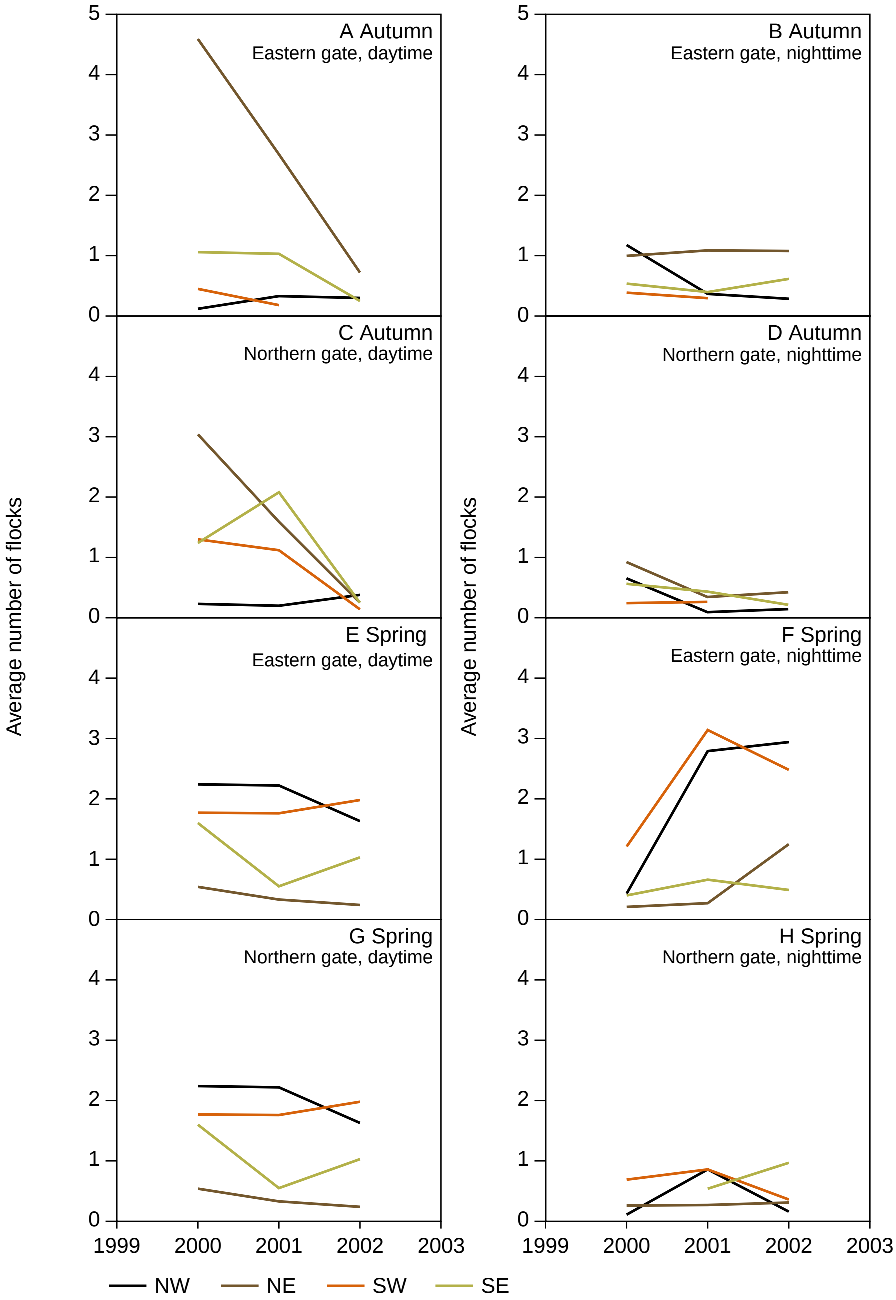
In the following section the change in migration intensity between 2000, 2001 and 2002 is depicted separately for the two seasonal periods and four wind directions during day- and nighttime at the eastern and northern gate.

At the eastern gate, autumn migration showed a higher intensity during northeasterly winds, a tendency which was most pronounced during daytime (Fig. 20A and 20B). By contrast, both northeasterly and southeasterly winds seem to increase the autumn migration intensity at the northern gate (Fig. 20C and 20D), and again this tendency was most pronounced during daytime.

Table 4. Maximum Likelihood Analysis of Variance of effects from wind direction (Wind), time of the day (Time), year (2001/2002) 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 and 2002.

Factor	χ^2 (df=1)	P
Wind	0.00	0.96
Time	111.85	<0.0001
Year	1.59	0.21
Year-Time*	5.77	0.02
Year-Wind*	0.49	0.49
Wind-Time*	0.27	0.60

Figure 20. 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. The graphs are depicted for autumn (A, B, C, D) and spring (E, F, G, H), and for daytime (A, C, E, G) and nighttime (B, D, F, H).



At the eastern gate, spring migration showed higher intensity during westerly winds both during daytime and nighttime (Fig. 20E and 20F). At the northern gate the same pattern was seen during daytime but not during nighttime (Fig. 20G-20H).

In general, the largest changes between years in migration intensity were registered in tail wind situations, i.e. westerly winds during spring and easterly wind during autumn (see Fig. 20A-20H).

3.1.4 Species composition, numbers and flock size

Due to the temporary suspension of the study in October 2002, the described peak migration periods in the following sections will not reflect the overall autumn migration pattern.

Table 5. 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 nine species or groups of species observed during autumn 2002 passing the visual transect from east to west early September (1-15) and late September (16-30). Only species or groups of species of which >50 individuals were recorded are included. The data set was log-transformed before the means and confidence limits were calculated.

	Early September			Late September			
Species	L	M	U	L	M	U	N
Cormorant	1.80	2.53	3.45	1.71	2.89	4.56	2009
Geese	0.001	0.10	0.21	0.29	0.72	1.29	278
Dabbling ducks	0.39	0.77	1.26	0.15	0.42	0.73	618
Eider	2.60	4.14	6.35	1.33	2.32	3.72	2391
Other diving ducks	0.06	0.17	0.29	0.08	0.18	0.29	58
Duck sp.	1.05	1.75	2.70	0.73	1.33	2.14	1378
Gulls	0.33	0.50	0.68	0.42	0.64	0.89	140
Sandwich tern	0.28	0.42	0.58	0.15	0.29	0.45	95
Passerines	0.01	0.07	0.13	0.32	0.70	1.21	180
Total migration	15.66	20.92	27.83	14.94	20.75	28.68	

Cormorant *Phalacrocorax carbo*

The total number of cormorants registered during autumn 2002 was 9,009 individuals, which made it the most numerously occurring species in the data set (Table 5). As described by Kahlert et al. (2000), cormorants observed during the visual migration studies were local birds, roosting at Rødsand during non-foraging periods. The majority of all observations (93%) consisted of small groups (<10 individuals) leaving or returning to Rødsand before or after foraging events. The mean flock size of cormorants during autumn 2002 was 1.83 individuals (Table 6). The number of cormorants peaked with a mean of 2.89 individuals per 15-minute period in late September (see Table 5). Communal roosting and foraging of several thousands of cormorants was registered in autumn 2002 as was observed during the other base-line years (see Chapter 3.2).

A total of 161 cormorants and a mean migration intensity of 0.58 individuals per 15-minute period during spring 2002, is in agreement with the previous results (Table 7; Kahlert et al. 2000, Desholm et al. 2001, Kahlert at al. 2002), showing a higher migration intensity of cormorants in autumn than in spring. A mean flock size of 1.17 individuals in spring 2002 shows that the majority of the cormorants was observed as solitary migrants (Table 8).

Table 6. Mean flock size (M) with 95% lower (L) and upper (U) confidence limits, and total number of flocks (N) observed during autumn 2002. Data were log-transformed.

Group/species group	L	M	U	N
Cormorant	1.70	1.83	1.96	611
Geese	4.94	7.86	12.51	22
Dabbling ducks	4.24	6.11	8.81	48
Eider	5.54	6.67	8.04	179
Other diving ducks	1.23	1.57	2.00	28
Duck sp.	3.68	4.58	5.71	137
Gulls	1.04	1.10	1.16	118
Sandwich tern	1.08	1.16	1.25	77
Passerines	1.52	1.84	2.23	67

Table 7. 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 2002 passing the visual transect from west to east during16 March - 15 April. Only species or groups of species of which >50 individuals were recorded in spring 2002 are included. The data set was log-transformed before the means and confidence limits were calculated.

Group/species group	L	M	U	N
Cormorant	0.45	0.58	0.72	161
Eider	13.96	13.96	19.57	26.569
Common scooter	0.15	0.28	0.42	213
Long-tailed duck	0.26	0.39	0.55	185
Red-breasted merganser	0.51	0.67	0.85	214
Duck sp.	2.28	2.89	3.60	1178
Gulls	1.61	1.97	2.37	608
Sandwich tern	0.22	0.33	0.43	112
Total migration	35.80	45.53	57.83	

Geese *Anserini*

The total number of geese registered during autumn 2002 was 278 individuals (see Table 5) and it was the lowest number observed since the study was initiated in 1999 (Desholm et al. 2001). Two species were identified: greylag goose *Anser anser* and brent goose. The goose species are not strictly confined to specific migration routes along the coastlines but may also choose routes crossing land areas (Desholm et al. 2001). A less conservative migration pattern amongst birds will inevitably lead to larger fluctuations in the number of migrating birds at a specific observation point compared to species following more conservative migration routes. The goose migration peaked in late September, where the mean passage amounted to 0.72 per 15-minute period (see Table 5); the mean flock size was 7.86 (see Table 6).

During 16 March - 15 April 2002, less than 50 geese were registered, and hence, no further analysis was performed.

In 2001, it was confirmed that dark-bellied brent geese passed the study area on their spring migration to the breeding areas in the Arctic (see Fig. 14). In total 9,056 individuals were counted in late May. Mean flock size was calculated to 107 individuals after a log-transformation. Seven flocks were not counted with respect to number of individuals. As was seen in the previous years of the study, the majority of the flocks passed the observation tower to the south of Rødsand with one flock flying through the wind farm area.

Table 8. Mean flock size (M; ±95% lower (L) and upper (U) confidence limits) and total number of flocks (N) observed during spring 2002. Data were log-transformed.

Species/species group	L	M	U	N
Cormorant	1.10	1.17	1.25	125
Geese	0.75	3.29	14.54	5
Eider	7.45	7.91	8.40	1590
Long-tailed duck	1.60	1.81	2.04	86
Red-breasted Merganser	1.33	1.47	1.62	121
Duck sp.	1.96	2.14	2.34	357
Gulls	1.08	1.11	1.14	499
Sandwich tern	1.10	1.19	1.28	87

Dabbling ducks *Anas sp.*

The total number of dabbling ducks registered during autumn 2002 was 618 (see Table 5), and it was about half the numbers observed in autumn 2001. Wigeon *Anas penelope* was the most numerously occurring dabbling duck species (88%). The mean flock size was 6.11 individuals (see Table 6), and was higher than in 2001 (Kahlert et al. 2002). The migration peaked in early September with a mean of 0.77 individuals per 15-minute period (see Table 5), and this was consistent with the results found in autumn 2000 and 2001 (Desholm et al. 2001, Kahlert et al. 2002).

Eider *Somateria mollissima*

During autumn 2002, a total of 2,391 eiders was observed (see Table 5). Due to the temporary suspension of the study in autumn 2002, this figure was lower than the number recorded in the previous years of the study (Kahlert et al. 2000, Desholm et al. 2001, Kahlert at al. 2002). Peak numbers in autumn 2002 were observed in early September with a mean number of 4.14 eiders per 15-minute period, which is substantially lower than in the other years. The mean flock size of eiders was 6.67 individuals (see Table 6).

During spring 2002, a total of 26,569 eiders was counted (see Table 7). This was ca five times the number registered during spring 2001 (Kahlert et al. 2002). The mean number of spring migrating eiders per 15-minute period was about the same in the springs of 2000, 2001 and 2002 (13.58, 13.40 and 13.96 individuals, respectively). The mean flock size of 7.91 individuals (see Table 8), and it was about twice the number observed in 2001 (Kahlert et al. 2002).

Other diving ducks

During autumn 2002, a total of 58 diving ducks of other species than the eider was registered (see Table 5), of these 36 (62%) were red-breasted merganser *Mergus serrator*. A mean flock size of 1.57 (see Table 6) was smaller than registered in previous autumns (Kahlert et al. 2000, Desholm et al. 2001, Kahlert et al. 2002). A mean of 0.17 and 0.18 individuals per 15-minute period was counted in September 2002 (see Table 5), and this mean was much lower than the previous years, which also included October.

During spring 2002, a total of 185 migrating long-tailed ducks *Clangula hyemalis* was registered (see Table 7), and the mean flock size was 1.81 individuals (see Table 8). This flock size was of similar size as the mean flock size recorded in 2001 (Kahlert et al. 2002). The mean number of migrating individuals per 15-minute period was 0.39 (see Table 7), and it was much lower than in the previous years of the study.

Gulls *Laridae*

During autumn 2002, a total of 140 gulls was registered (see Table 5), and this was less than in previous years (Kahlert et al. 2000, Desholm et al. 2001, Kahlert et al. 2002). However, the most intensive gull migration occurred in November 1999 (Kahlert et al. 2000), and in October 2000 and 2001, periods that were not covered in 2002. During autumn 2002, the mean flock size was 1.10 individuals (see Table 6), which was comparable to those of the autumns of 1999 (1.27), 2000 (1.15) and 2001 (1.16). No clear trend in terms of phenology was detected, probably because most of the gulls that passed the visual transect at Rødsand were local birds staging in the area for longer periods. In September 2002 the mean number of individuals per 15-minute period ranged between 0.50 and 0.64 (see Table 5).

During spring 2002, a total of 608 gulls was counted (see Table 7), and this was twice the number observed in 2001. The mean number of migrating gulls per 15-minute period was 1.97 individuals (see Table 7), and the mean flock size of 1.11 individuals (see Table 8) indicated that the majority of the gulls was observed as solitary.

Sandwich tern *Sterna sandvicensis*

During autumn 2002, a total number of 95 sandwich terns was registered (see Table 5). This number was four times the number observed during autumn 2001 and twice the number observed in 2000 (Desholm et al. 2001, Kahlert et al. 2002). The mean flock size of 1.16 individuals (see Table 6) was within the 95% confidence limit of flock sizes in autumn 1999, 2000 and 2001 (Kahlert et al. 2000, Desholm et al. 2001, Kahlert et al. 2002). The mean migration intensity was 0.42 individuals per 15-minute period (see Table 5).

During spring 2002, a total of 112 sandwich terns was observed (Table 7), and the mean migration intensity was 0.33 individuals per 15-minute period. Both of these values were half the values obtained in 2001 (Kahlert et al. 2002). The mean flock size of 1.19 (see Table 8) was within the 95% confidence limits of the mean flock size in 2001 (Kahlert et al. 2002).

Passerines *Passeriformes*

During autumn 2002, the total number of passerines registered was 180 individuals (see Table 5). This number was much smaller than the number observed during autumn 2001 (Kahlert et al. 2002). The mean flock size of 1.84 individuals (see Table 6) was outside the range of the 95% confidence limits of flock size during autumn 2001. The peak autumn migration period for Passerines lies outside the study period of 2002.

Other species

The category "other species" covers wood pigeons and species that were observed in numbers <100 individuals on the observation transect. Species like grebes and divers which were described in the EIA report (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 2002 and therefore will not be analysed further in this report.

Table 9. Mean ground speed (km / h), standard deviation (SD), range (km / h) and sample size (N = number of flocks) of migrating bird species and groups of species recorded by radar during 1999-2002. Unidentified species were categorised due to their migratory pattern which followed the pattern of either eider (category E – see Fig. 10 in Desholm et al. 2001) or terrestrial birds (category T – see Fig. 11 in Desholm et al. 2001).

Species/-groups	Mean (km/h)	SD	Range (km/h)	N
Geese *Anserini*	78.6	17.9	45.6 - 107.8	64
Eider *Somateria mollissima*	71.8	13.9	41.1 - 122.1	236
Wood pigeon *Columba palumbus*	54.6	9.0	34.5 - 68.3	39
Unidentified species, category E	79.8	16.4	44.1 - 114.3	151
Unidentified species, category T	33.2	6.5	14.5 - 53.2	117

3.1.5 Migration speed

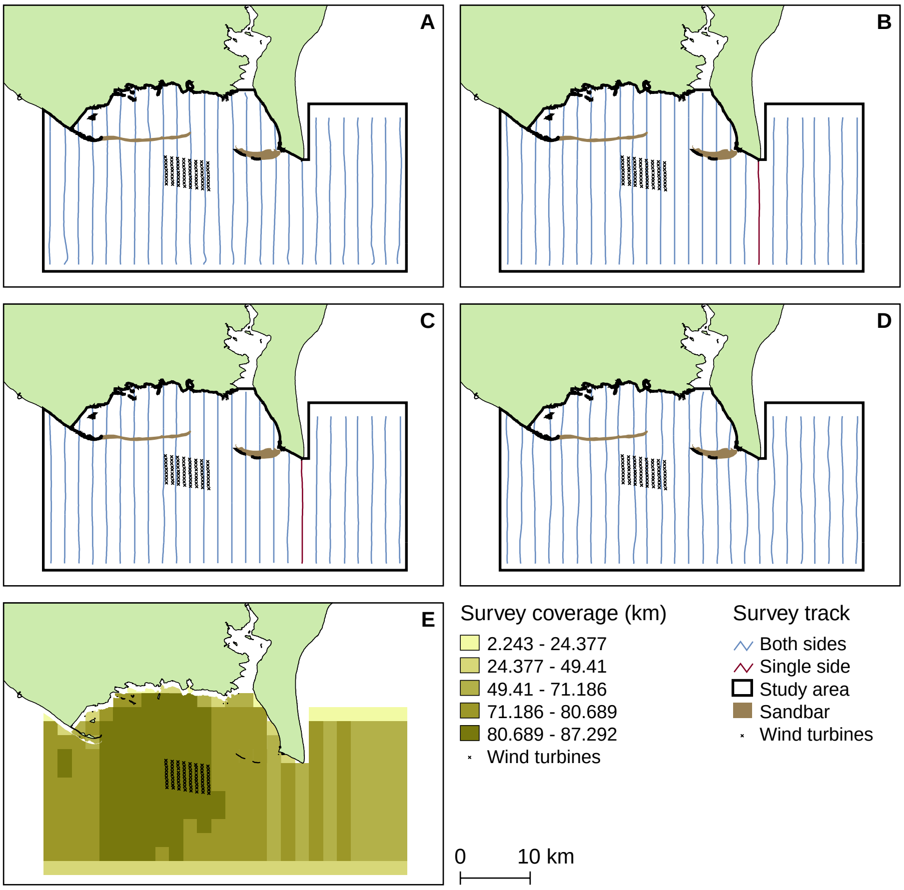
Data on migration speed collected during 1999-2002 were tested and showed (Table 9) that there was an overall statistically significant difference in migration speed between species and groups of species (One-way ANOVA: $F_{4,602}$ = 233.99, $P < 0.001$). The mean speed of all species and groups of species differed significantly (T-tests, $P < 0.05$) except between the categories “E” and “geese” (T-test, $P > 0.05$).

3.2 Staging, moulting and wintering birds

In this section the presence and distribution of the most abundant species in the study area are described. The data originate from aerial surveys, primarily from the four surveys conducted during 2002, but are combined with data from the 17 previous surveys carried out during the period 1999 - 2001.

The spatial coverage of the four aerial surveys performed in 2002 were almost complete (Fig. 21 A-D). The survey coverage, calculated for all surveys conducted 1999 – 2002, was most intensive in the central part of the study area including the wind farm site, whereas weather conditions and light conditions during short days in mid winter prevented as good a coverage in the eastern parts (Fig. 21 E).

Figure 21. Survey track and effort in the Rødsand study area for the 2002 surveys conducted at 3 January (A), 13 February (B), 26 March (C) and 22 August (D). The blue lines indicate that both sides of the aircraft have been covered, red lines that only one side was covered. The coverage for the cumulated surveys of 1999 - 2002 across the study area is illustrated as the number of covered transect kilometres by grid cell (E).



Cormorant *Phalacrocorax carbo*

At the four surveys in 2002, a total of 2,901 cormorants was recorded, most of which (2,812) were registered in August (Table 10). The distribution of cormorants was clumped, and the majority of the birds observed were roosting on sandbars (Fig. 22). Only a few records were made of individuals or few birds at sea south of the sandbar. The distribution pattern during 2002 was consistent with that of the pooled data set for 1999-2002 (Fig. 23).

Social foraging events were monitored by radar and were consistent with the findings from 1999, 2000 and 2001, which showed that cormorants visited the wind farm area during these events (Fig. 24; Kahlert et al. 2000, Desholm et al. 2001, Kahlert et al. 2002). For more details on this item, see Desholm et al. (2001). The distribution of all 15,616 cormorants observed during 1999 - 2002 was significantly different from the geographic free distribution within the study area, and showed a significant spatial avoidance of all four zones at the wind farm area (Table 11).

Table 10. Number of birds recorded at the four aerial surveys carried out in 2002.

	Date of survey				
Species	3 Jan	13 Feb	26 Mar	22 Aug	Total
Diver sp.	52	27	31		110
Red-necked grebe	14	7	13	3	37
Cormorant	21	19	49	2812	2901
Grey heron			1	1	2
Mute swan	1192	402	623	8387	10604
Whooper swan	22				22
Greylag goose	6	361	84	274	725
Brent goose		13	108		121
Canada goose	159	46	15		220
Shelduck		13	47	6	66
Mallard	1118	912	61	181	2272
Teal			202	15	217
Wigeon	8	21	159	35	223
Shoveler			2		2
Pochard	65				65
Tufted duck	1775				1775
Goldeneye	1529	360	192		2081
Long-tailed duck	393	397	3053		3843
Eider	221	457	5362	121	6161
Common scooter	14	81	412	9	516
Velvet scooter	2		17		19
Goosander	60	4			64
Red-breasted merganser	253	80	269	1	603
Coot	1705	200			1905
Common gull	11	2	4		17
Herring gull	1248	1776	872	479	4375
Great Black-backed gull	40	34	9	7	90
Black-headed gull	20	10	97	342	469
Little gull	24		3		27
Gull sp.	50				50
Arctic/common tern				3	3
Sandwich tern				5	5
Auk/guillemot	26	4	12		42

Figure 22. Number and distribution of 2,901 cormorants observed in the Rødsand study area during the four aerial surveys in 2002.

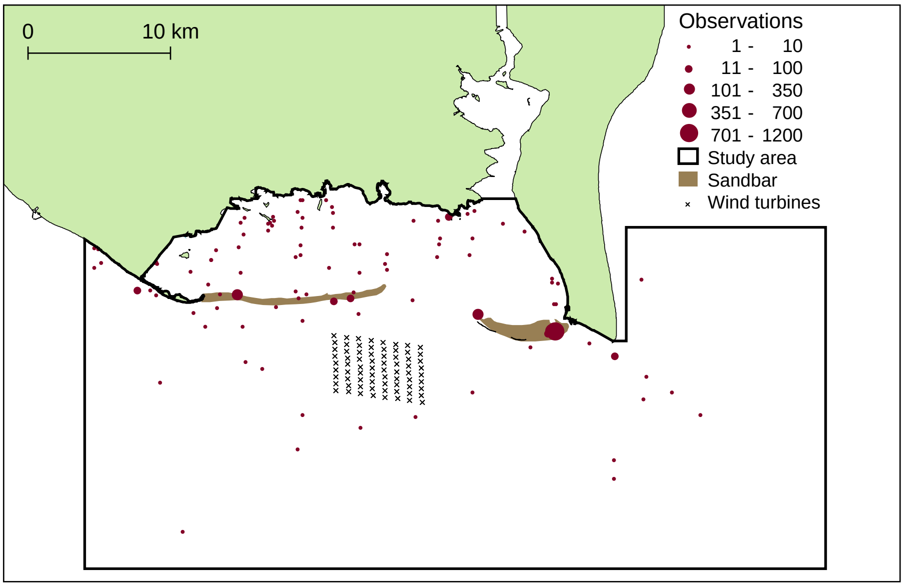


Figure 23. Relative density of cormorants in the Rødsand study area, based upon 21 aerial surveys 1999 - 2002 and expressed by numbers / covered transect kilometre.

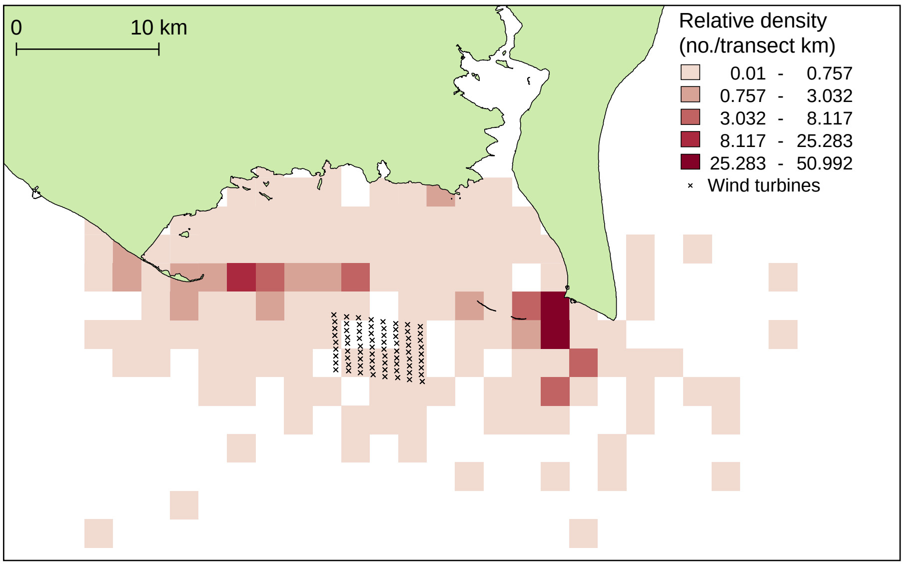


Figure 24. Social foraging events of cormorants registered by radar from the observation tower in 2002. Each foraging event is depicted by a unique colour.

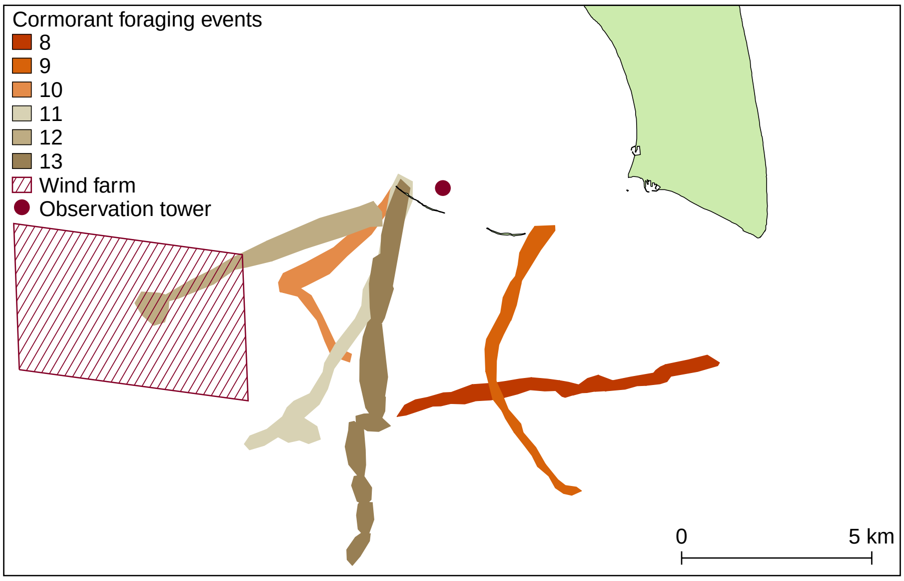


Table 11. Percentage of the total number of individuals of 10 bird species observed in the wind farm area (WF+0), in the wind farm area +275 m zone (WF+0.275), in the wind farm area +2 km zone (WF+2), and in the wind farm area +4 km zone (WF+4). Furthermore, the proportional transect length for each zone of the pooled transect length for the entire study area is given. Negative values in the selectivity index of Jacobs (D) indicate that the species avoid the area in question, positive values indicate a preference. N = total number of individuals observed at the 21 aerial counts performed during 1999-2002. P = probability values for χ^2-one sample tests to compare observed values for each area (WF+0, WF+0.275, WF+2 and WF+4) with the expected values under the assumption that birds distribute in accordance with the proportional transect length in the areas (geographical free distribution). *** = P < 0.01, n.s. = not significant.

	WF+0	D for WF+0	P	WF +0.275	D for WF+0.275	P	WF+2	D for WF+2	P	WF+4	D for WF+4	P	N
Cormorant	0.05	-0.948	***	0.06	-0.937	***	0.35	-0.899	***	7.52	-0.899	***	15616
Mute swan	0.01	-0.985	***	0.01	-0.985	***	0.04	-0.989	***	0.47	-0.989	***	47019
Mallard	0.00	-1.000	***	0.00	-1.000	***	1.39	-0.651	***	15.14	-0.651	***	12693
Goldeneye	0.01	-0.988	***	0.01	-0.988	***	0.31	-0.910	***	0.59	-0.910	***	8681
Long-tailed duck	7.55	0.618	***	8.74	0.656	***	19.59	0.571	***	30.59	0.571	***	9669
Eider	1.07	-0.279	***	1.20	-0.239	***	6.16	-0.007	***	15.93	-0.007	***	32211
Common scooter	10.90	0.728	***	11.00	0.723	***	19.32	0.565	***	35.72	0.565	***	2091
Red-breasted merganser	0.63	-0.504	***	7.13	0.589	***	33.32	0.765	***	35.76	0.765	***	3325
Herring gull	0.82	-0.398	***	0.88	-0.384	***	1.58	-0.612	***	5.88	-0.612	***	18618
Little gull	0.00	-1.000	***	0.00	-1.000	***	1.13	-0.707	***	23.48	-0.707	***	443
% of total transect covered	1.89			1.95			6.24						

Mute Swan *Cygnus olor*

A total of 10,604 mute swans was registered at the four surveys. Most swans (8,387) were counted in mid August and were likely to moult during this period (see Table 10). Similar to the previous years, the majority of the mute swans occurred in the bay north of Hyllekrog on the south coast of Lolland and north of Rødsand, with only few hundreds in the vicinity of the cable trajectory and none near the wind farm (Fig. 25). The distribution pattern in 2002 was consistent with the pattern based on the pooled data 1999 - 2002 (Fig. 26).

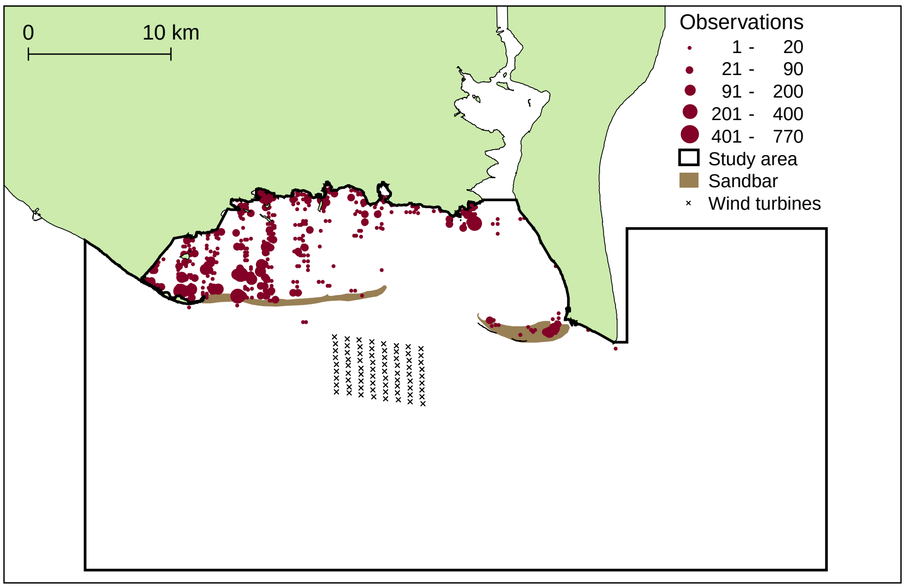
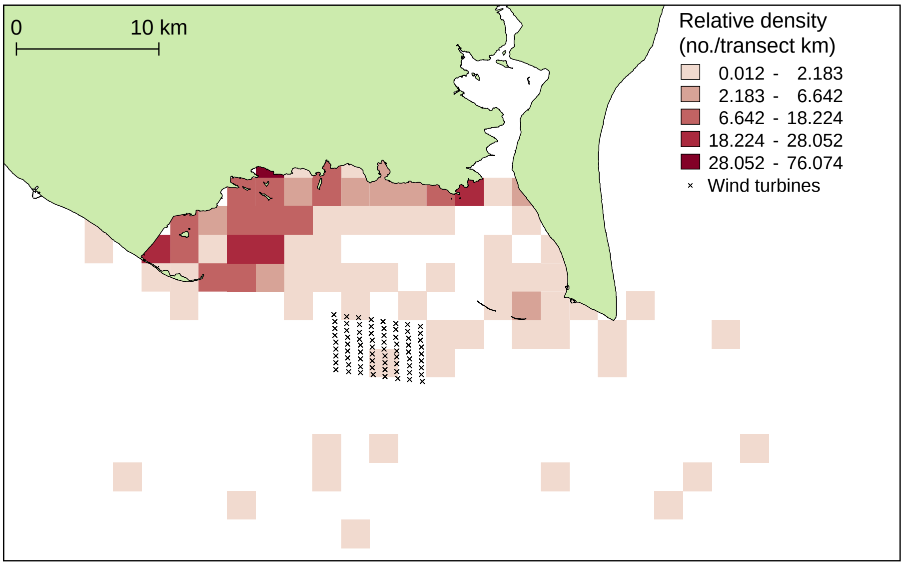


Figure 25. Number and distribution of 10,604 mute swans observed in the Rødsand study area during the four aerial surveys in 2002.

Figure 26. Relative density of mute swans in the Rødsand study area, based upon 21 aerial surveys 1999 - 2002 and expressed by numbers/ covered transect kilometre.



The seasonal variation in the number of mute swans showed a similar pattern between years (Fig. 27). Of the recorded, non-flying mute swans 92% were seen on water depths between 0 and 2 m, and only very few birds were seen in water deeper than 4 m (Fig. 28).

The 47,019 mute swans in the pooled data set for 1999 – 2002 were distributed far away from the wind farm area, and showed significant spatial avoidance to all four potential avoidance zones in the vicinity of the wind farm area (see Table 11).

Mallard *Anas platyrhynchos*

At the four surveys in 2002, a total of 2,272 mallards was counted (see Table 10). Of these most (1,118) occurred in January. The majority of the staging mallards occurred off the south coast of Lolland or along the sandbar between Hyllekrog and Gedser Odde, mainly in very shallow waters and north of the sandbar (Fig. 29).

Figure 27. Seasonal variation in the number of mute swans in the Rødsand study area, expressed by numbers/covered transect kilometre and year.

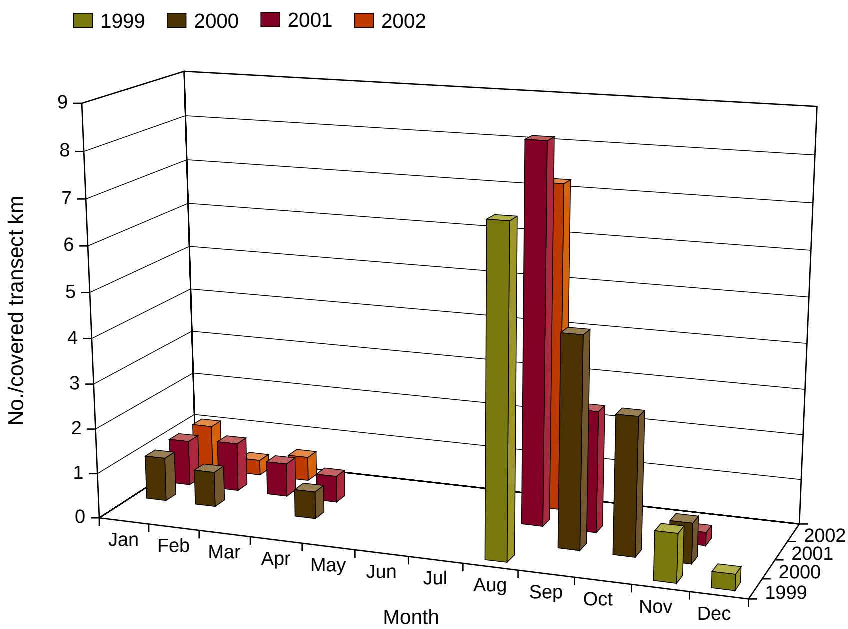


Figure 28. Water depth frequency distribution of mute swans in the Rødsand study area, based on observations of non-flying birds from 21 surveys during 1999 - 2002. The depth frequency distribution of the survey track is given for comparison.

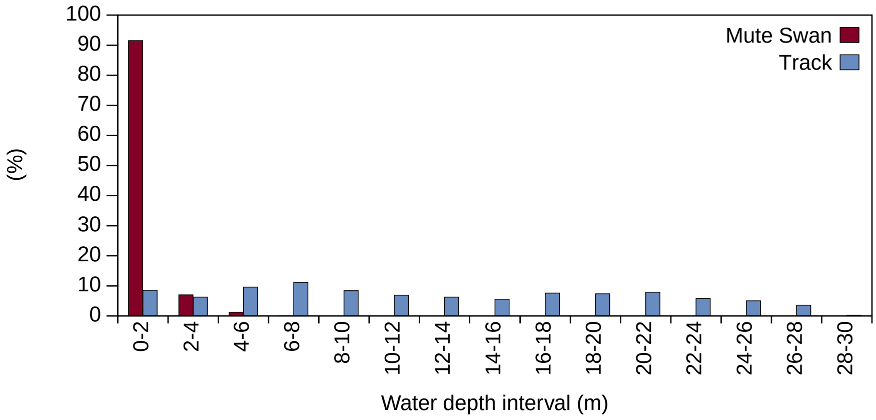


Figure 29. Number and distribution of 2,272 mallards observed in the Rødsand study area during the four aerial surveys in 2002.

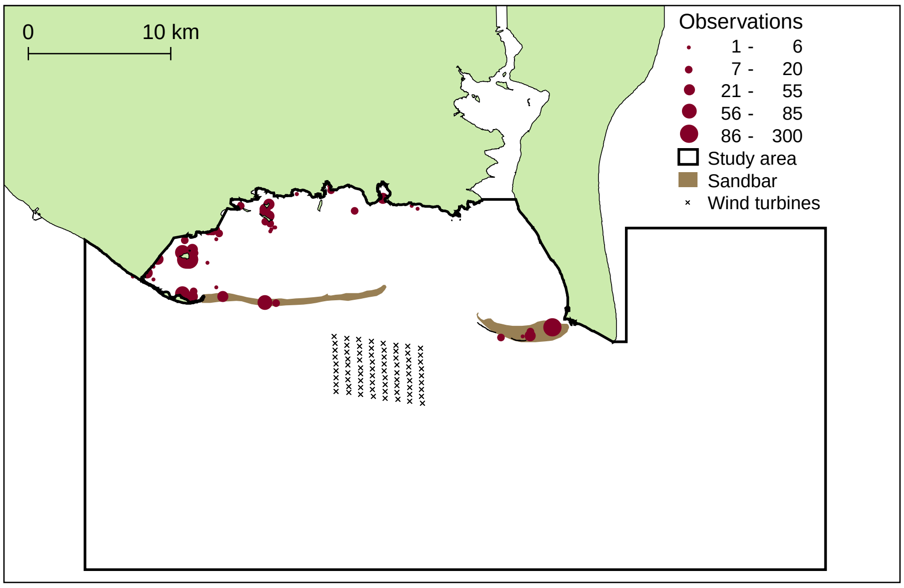


Figure 30. Relative density of mallards in the Rødsand study area, based upon 21 aerial surveys 1999 - 2002 and expressed by numbers/covered transect kilometre.

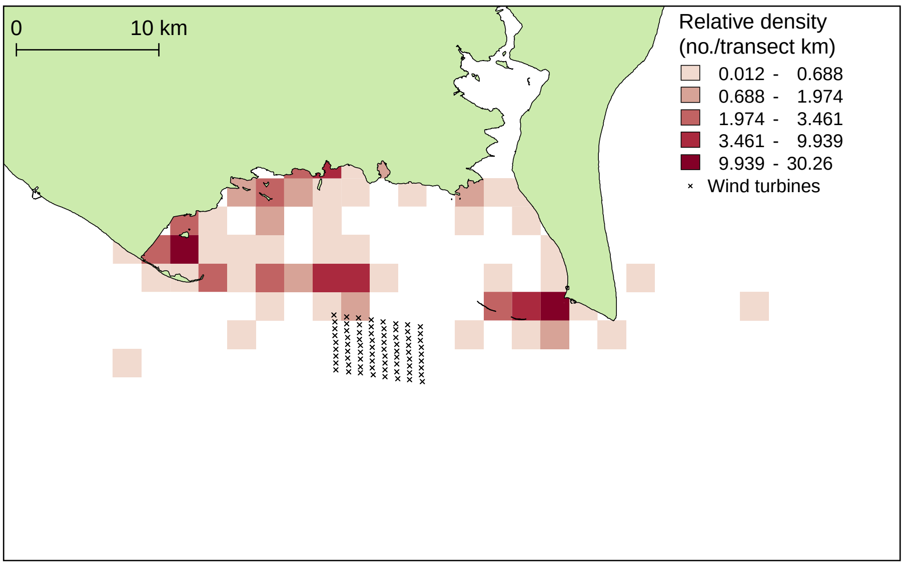
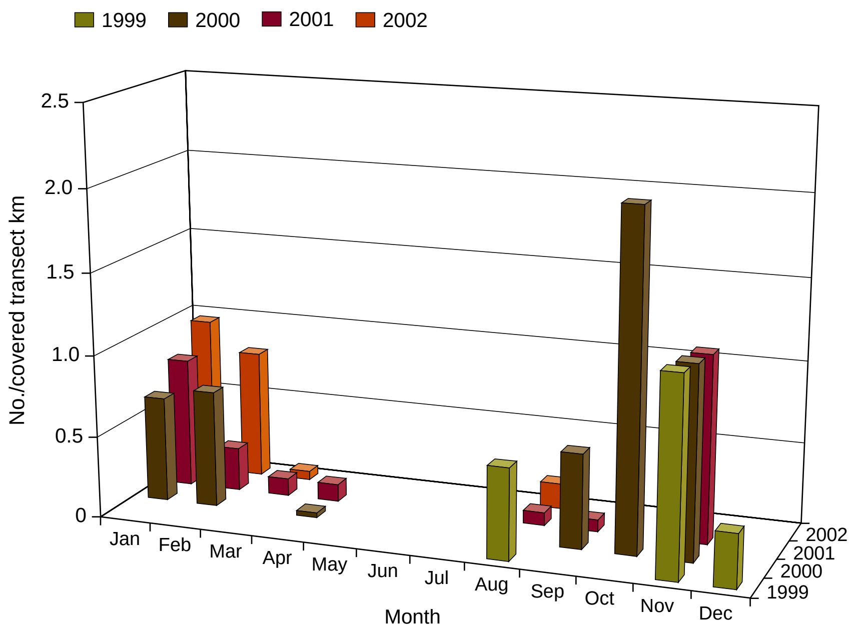


Figure 31. Seasonal variation in the number of mallards in the Rødsand study area, expressed by numbers / covered transect kilometre and year.



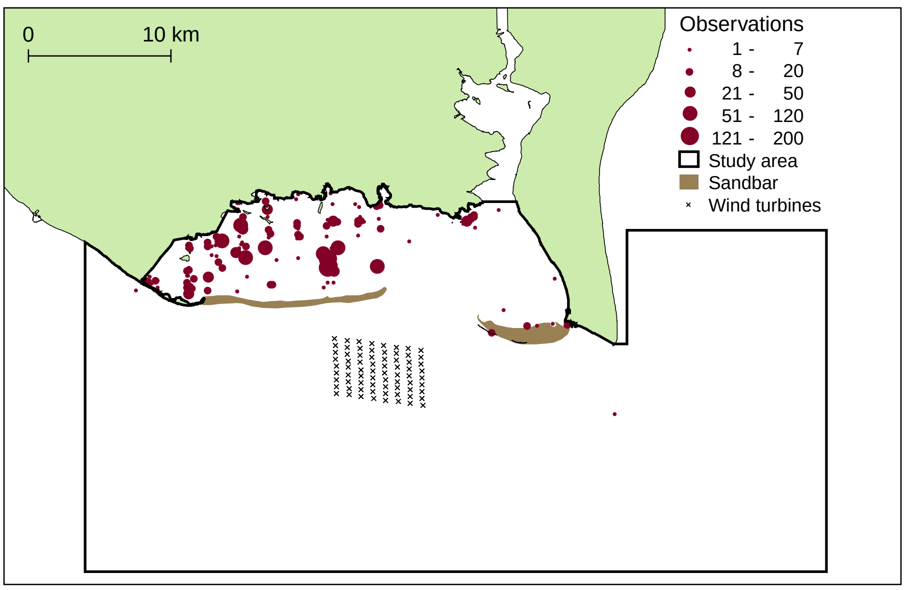
The distribution pattern of mallards during the 2002 study was consistent with that of the pooled data set for 1999-2002 (Fig. 30). Though some difference between years, the general pattern in seasonal variation in the number of mallards was a build up through the autumn. The highest numbers were recorded in October and November, followed by a slight decrease through January and February towards low numbers in March / April, when the birds leave the area (Fig. 31).

The 12,693 mallards in the pooled data set for 1999 - 2002 showed significant spatial avoidance of all distance zones around the wind farm (see Table 11).

Goldeneye *Bucephala clangula*

During the four surveys in 2002 a total of 2,081 goldeneyes was recorded. A maximum of 1,529 birds was registered in January 2002 (see Table 10). The vast majority of the goldeneyes were recorded in the waters north of the sandbar, and particularly in the Hyllekrog area (Fig. 32). The distribution pattern of goldeneye during the 2002 study was consistent with that found for the pooled data set for 1999-2002 (Fig. 33).

Figure 32. Number and distribution of 2,081 goldeneyes observed in the Rødsand study area during the four aerial surveys in 2002.



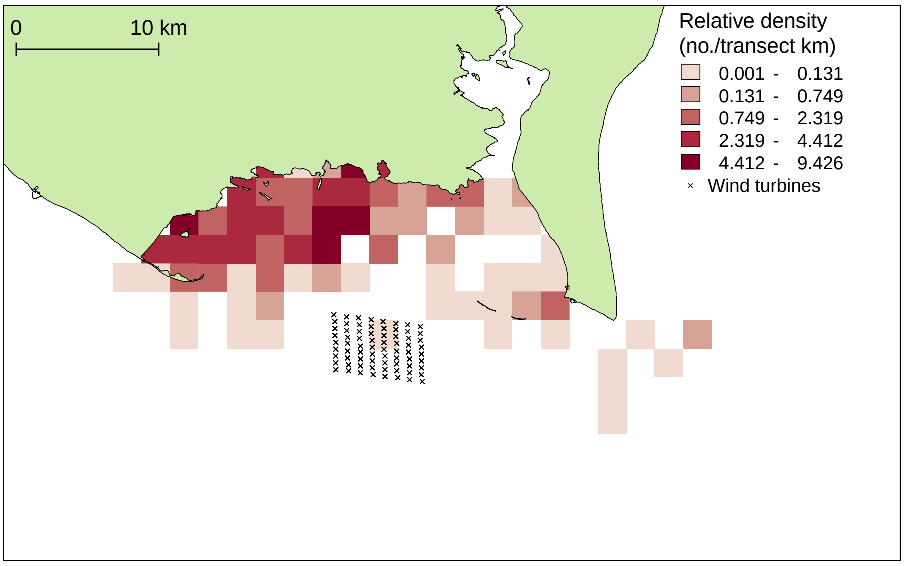


Figure 33. Relative density of goldeneye in the Rødsand study area, based upon 21 aerial surveys 1999 - 2002 and expressed by numbers / covered transect kilometre.

The seasonal variation in the number of goldeneye showed considerable differences between years, though the general pattern was that highest numbers occurred from January to March, whereas the modest numbers were recorded during autumn (Fig. 34). Goldeneyes were generally found on shallow waters; thus were 64% of the recorded, non-flying goldeneyes observed on water depths between 0 and 2 m, and only very few birds were seen in water deeper than 4 m (Fig. 35). The 8,681 goldeneyes in the pooled data set for 1999 - 2002 were distributed far away from the wind farm area, and showed significant spatial avoidance to all four zones around the wind farm area (see Table 11).

Long-tailed duck *Clangula hyemalis*

A total of 3,843 long-tailed ducks was recorded during the four surveys in 2002. Of these 3,053 birds were counted in March (see Table 10). Similar to the situation in the previous two years, the majority of the long-tailed ducks occurred south of the sandbar between Hyllekrog and Gedser Odde in 2002 (Fig. 36).

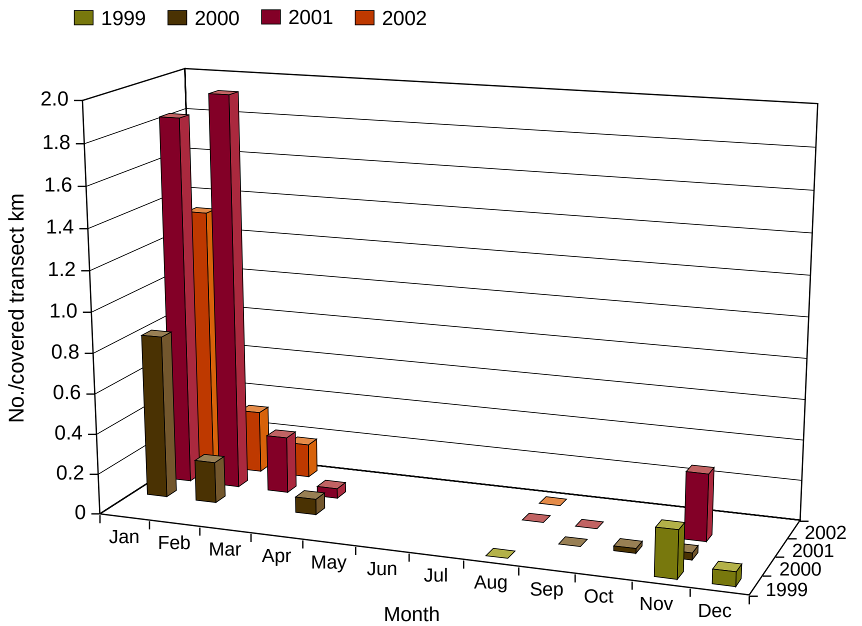
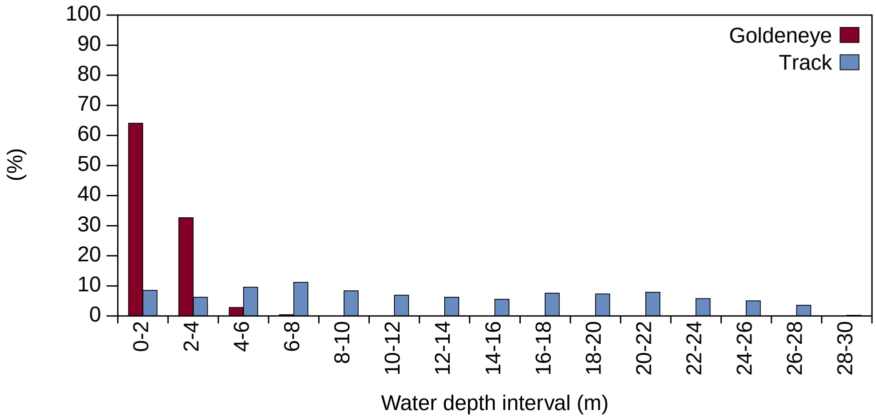


Figure 34. Seasonal variation in the number of goldeneyes in the Rødsand study area, expressed by numbers / covered transect kilometre and year.

Figure 35. Water depth frequency distribution of goldeneyes in the Rødsand study area, based on observations of non-flying birds from 21 surveys during 1999 - 2002. The depth frequency distribution of the survey track is given for comparison.



During 2002 the distribution pattern of long-tailed ducks was consistent with the findings from the pooled data set for 1999-2002 (Fig. 37). The 9,669 long-tailed ducks counted during 1999-2002 showed significant spatial attraction to all four zones around the wind farm area (see Table 11).

The seasonal variation in the number of long-tailed duck showed interannual differences, though the general pattern showed no birds in August through October, and only small numbers in November and December. Most long-tailed ducks were recorded in February, March and April (Fig. 38).

Long-tailed ducks were found on shallow waters, with 28% of the recorded, non-flying birds at water depths between 6 and 8 m, and 76% of the birds were seen onv water depths between 4 and 10 m (Fig. 39).

Eider *Somateria mollissima*

At the four surveys in 2002, a total of 6,161 eiders was registered, most of which (5,362) were seen in March (see Table 10). In 2002 the staging eiders were mainly observed in the waters south of Hyllekrog, along the southern side of the sandbar and at Gedser Rev (Fig. 40).

Figure 36. Number and distribution of 3,843 long-tailed ducks observed in the Rødsand study area during the four aerial surveys in 2002.

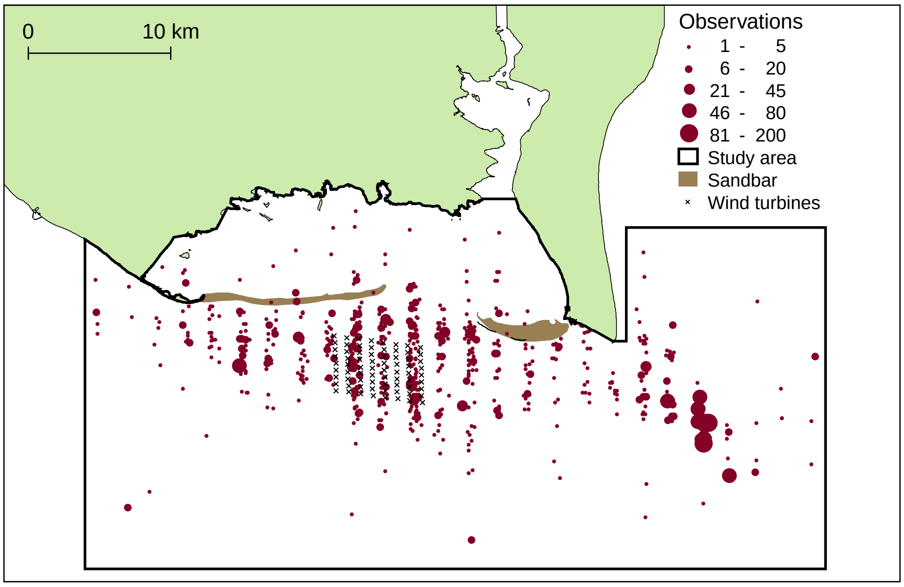


Figure 37. Relative density of long-tailed ducks in the Rødsand study area, based upon 21 aerial surveys 1999 - 2002 and expressed by numbers / covered transect kilometre.

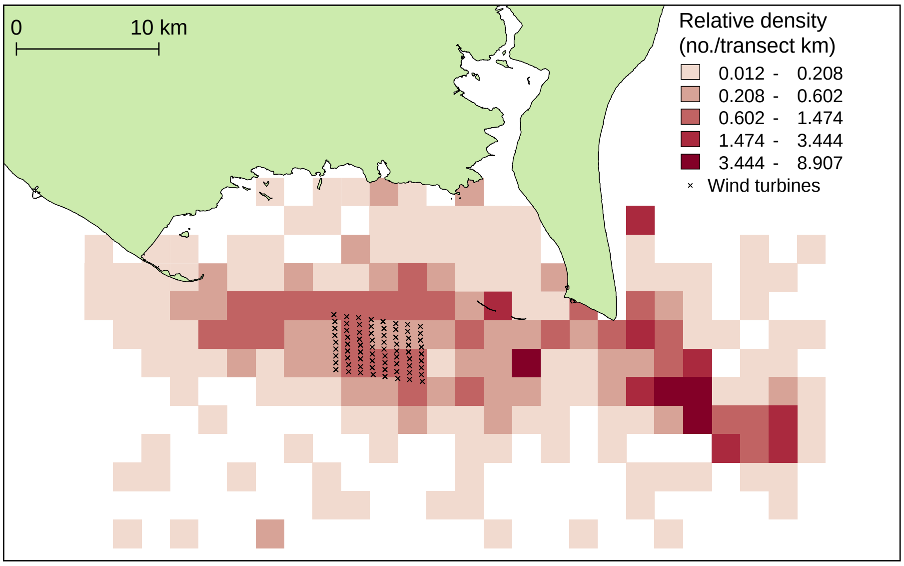


Figure 38. Seasonal variation in the number of long-tailed ducks in the Rødsand study area, expressed by numbers / covered transect kilometre and year.

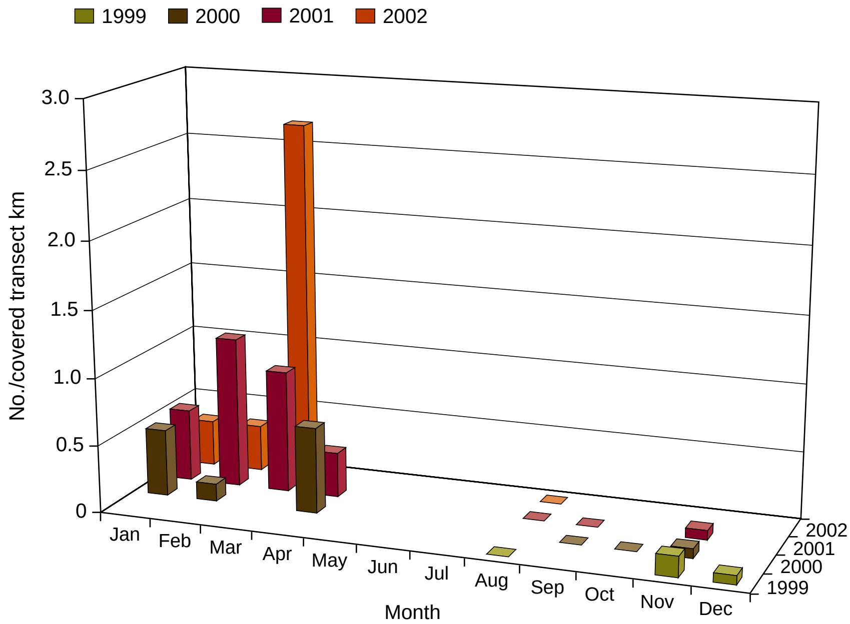
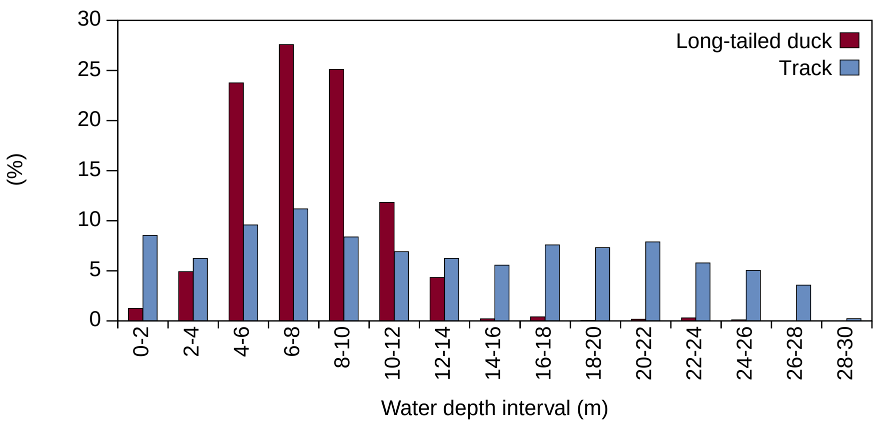


Figure 39. Water depth frequency distribution of long-tailed ducks in the Rødsand study area, based on observations of non-flying birds from 21 surveys during 1999 - 2002. The depth frequency distribution of the survey track is given for comparison.



The distribution pattern of eiders during 2002 was consistent with the findings in the data from the pooled data set for 1999-2002 (Fig. 41). The 32,211 eiders counted during 1999-2002 showed significant spatial avoidance of the three inner zones and a non-significant spatial avoidance to the outer zone around the wind farm area (see Table 11).

The seasonal variation in the number of eiders showed slight differences between years. Few eiders were recorded in August with generally increasing numbers through September and October. Then small numbers occurred from November till February, except in November 1999 when large numbers were observed. Most eiders were recorded in March and April (Fig. 42). This indicates that the eiders use the study area as stopover during autumn and spring migration, rather than as a general staging area during winter.

Eiders were found on shallow waters. Of the recorded, non-flying eiders 24% were seen at water depths between 4 and 6 m, and 68% between 0 and 6 m (Fig. 43).

Common scoter *Melanitta nigra*

At the four surveys in 2002, a total of 516 common scoters were registered, most of which (412) were seen in March (see Table 10). This low number made it one of the least commonly occurring species in the area during 2002.

The common scoters were distributed mainly in open waters south of the Rødsand-Hyllekrog bay area (Fig. 44).

The distribution pattern of common scoter during the 2002 study was consistent with the findings from the pooled data set for 1999-2002, although the 2002 distribution showed a slight concentration south of the wind farm that has not earlier been recorded (Fig. 45).

The 2,091 common scoters counted during 1999-2002 showed significant spatial attraction to all four zones around the wind farm area (see Table 11).

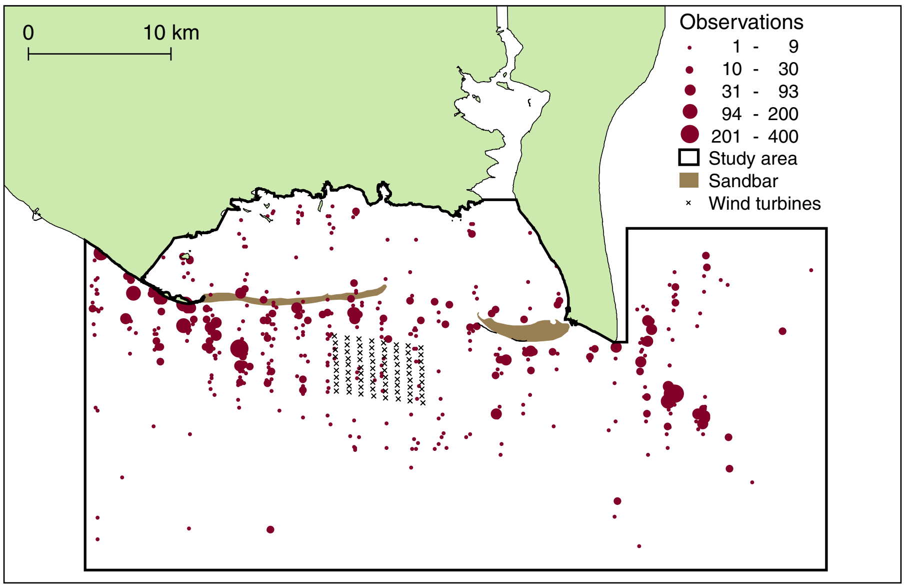


Figure 40. Number and distribution of 6,161 observed eiders in the Rødsand study area during four aerial surveys in 2002.

Figure 41. Relative density of eiders in the Rødsand study area, based upon 21 aerial surveys 1999 - 2002 and expressed by numbers / covered transect kilometre.

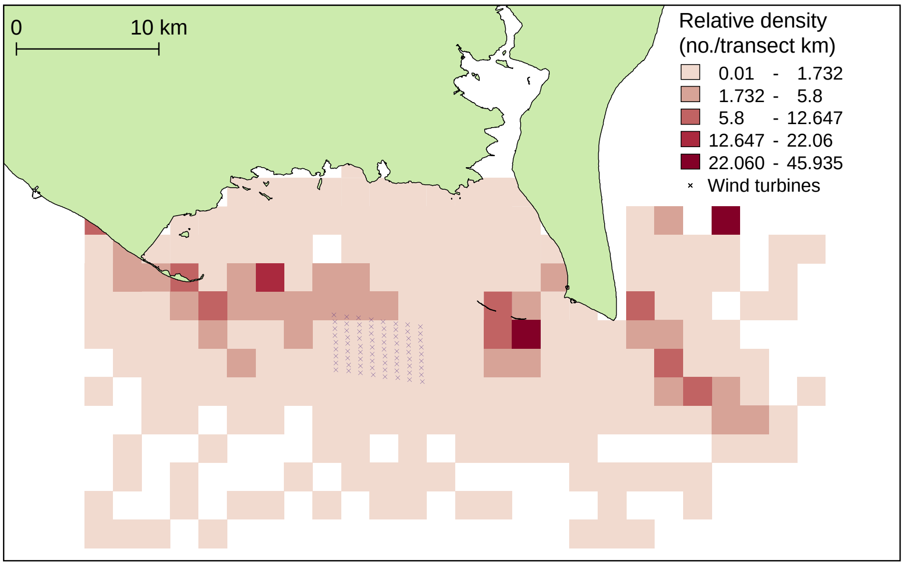


Figure 42. Seasonal variation in the number of eiders in the Rødsand study area, expressed by numbers / covered transect kilometre and year.

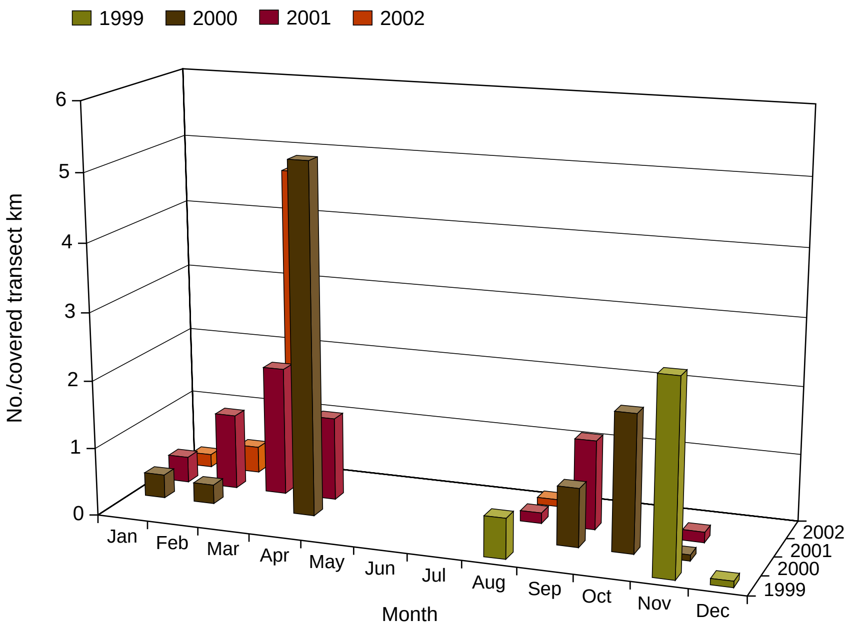
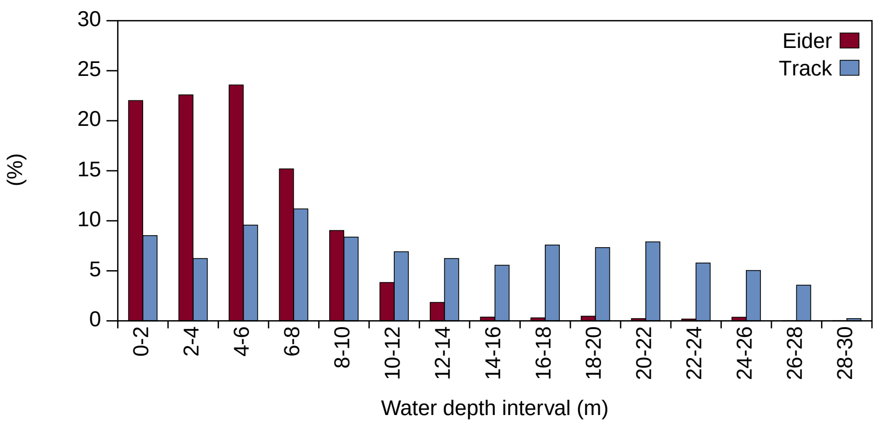


Figure 43. Water depth frequency distribution of eiders in the Rødsand study area, based on observations of non-flying birds from 21 surveys during 1999 - 2002. The depth frequency distribution of the survey track is given for comparison.



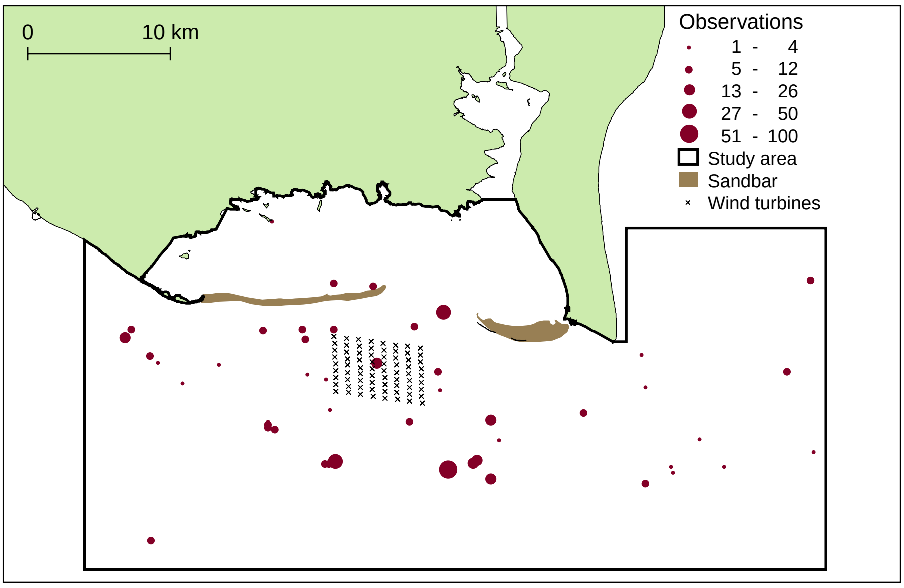


Figure 44. Number and distribution of 516 common scoters observed in the Rødsand study area during the four aerial surveys in 2002.

Red-breasted merganser *Mergus serrator*

Out of the total of 603 red-breasted mergansers counted during the four surveys in 2002, 253 were recorded in January and 269 in March (see Table 10).

Red-breasted mergansers were found in small flocks, mainly in the area north of the sandbar (Fig. 46). The distribution pattern of red-breasted merganser during the 2002 study was consistent with the findings from the pooled data set for 1999-2002 (Fig. 47). The 3,323 red-breasted mergansers counted during 1999-2002 showed significant spatial avoidance of the wind farm area, but significant attraction to the three outer zones around the wind farm area (see Table 11). This reflects the fact that large flocks of red-breasted merganser were observed just outside the designated wind farm area in November 1999.

The seasonal variation in the number of red-breasted mergansers showed large differences between years, dominated by the large number recorded in November 1999. Apart from this exception small numbers were recorded during autumn, and generally larger numbers in late winter/early spring (Fig. 48). Most red-breasted mergansers (58%) were found in the water depth interval from 4 to 6 m, and 95% in water depth of 0 - 6 m (Fig. 49).

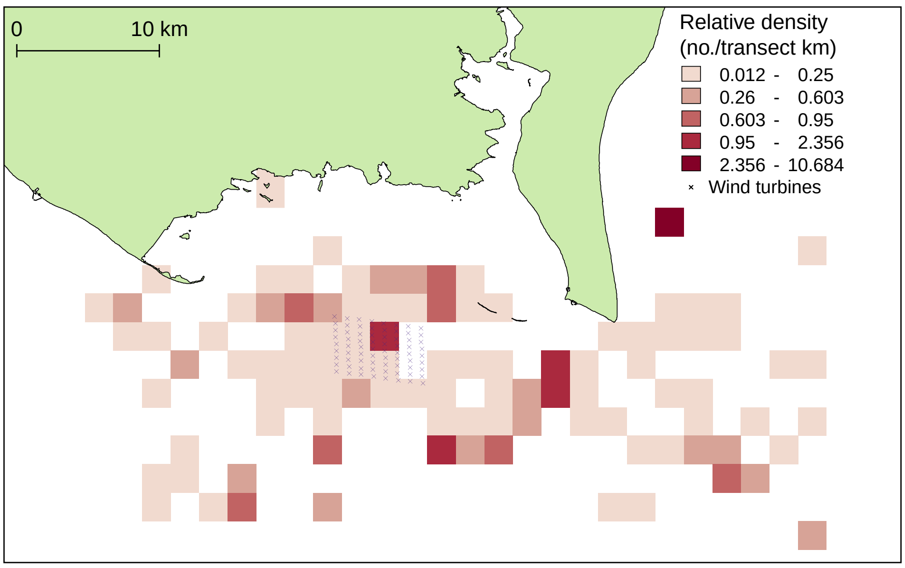


Figure 45. Relative density of common scoteres in the Rødsand study area, based upon 21 aerial surveys 1999 - 2002 and expressed by numbers/covered transect kilometre.

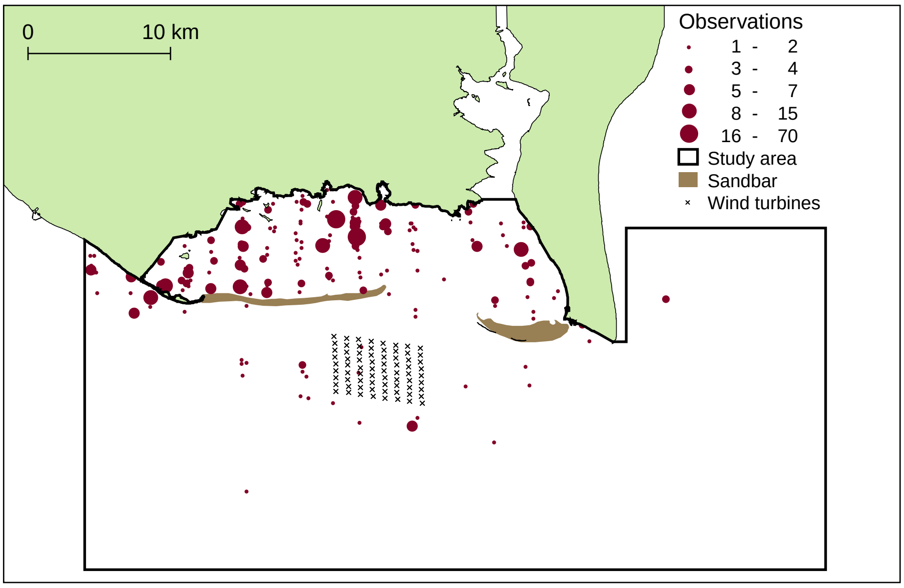


Figure 46. Number and distribution of 603 red-breasted mergansers observed in the Rødsand study area during the four aerial surveys in 2002.

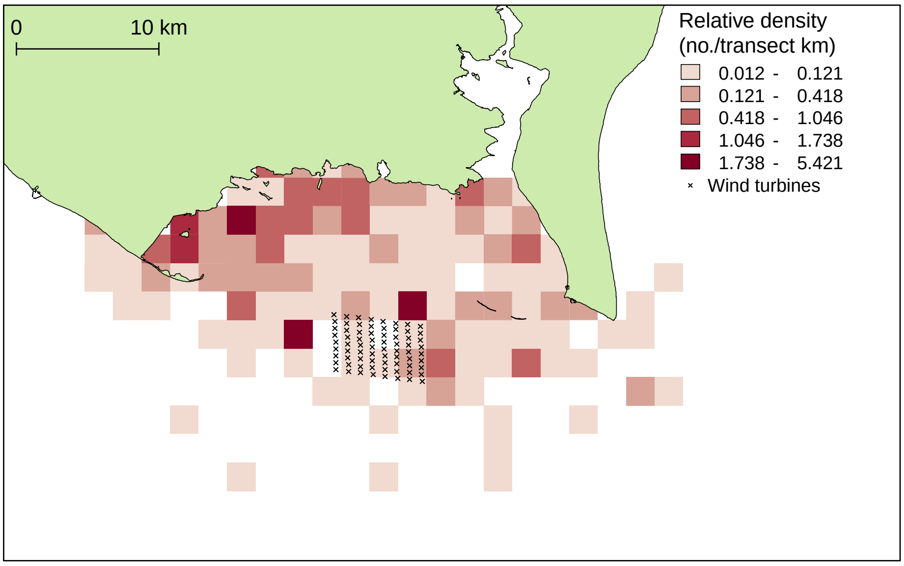


Figure 47. Relative density of red-breasted mergansers in the Rødsand study area, based upon 21 aerial surveys 1999 - 2002 and expressed by numbers/covered transect kilometre.

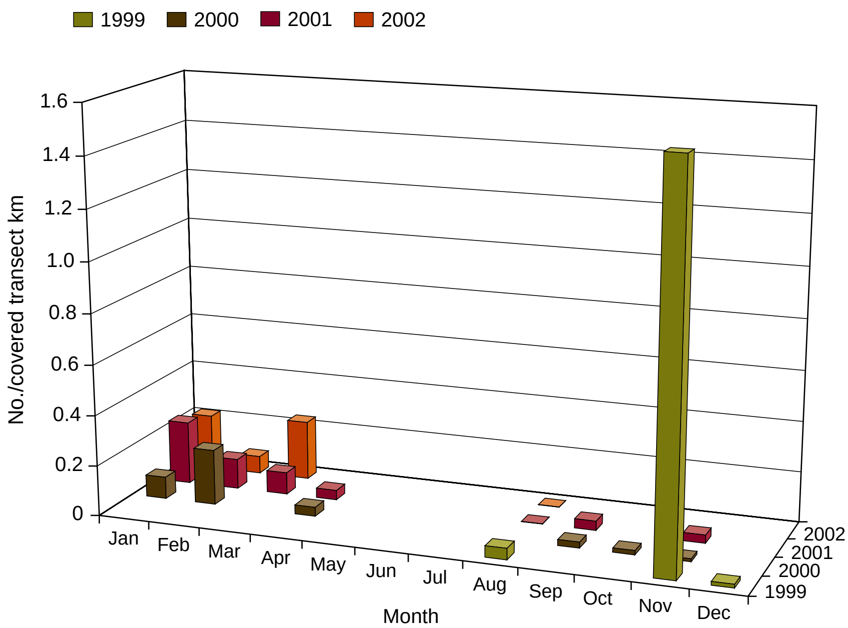
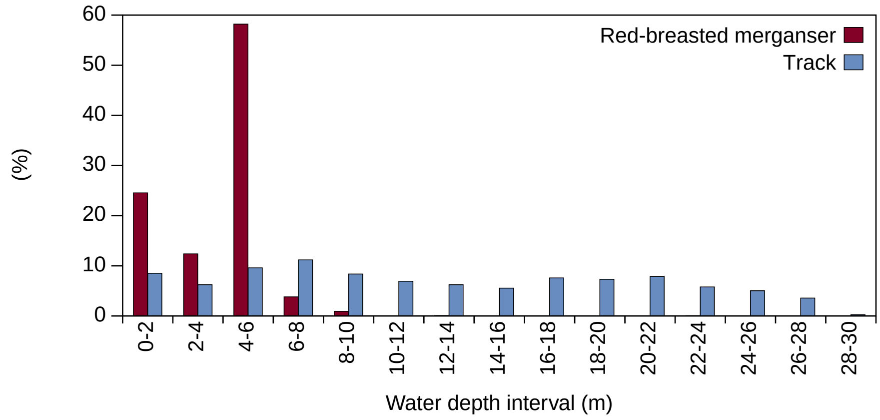


Figure 48. Seasonal variation in the number of red-breasted mergansers in the Rødsand study area, expressed by numbers/covered transect kilometre and year.

Figure 49. Water depth frequency distribution of red-breasted mergansers in the Rødsand study area, based on observations of non-flying birds from 21 surveys during 1999 - 2002. The depth frequency distribution of the survey track is given for comparison.



Herring gull *Larus argentatus*

At the four aerial surveys in 2002, a total of 4,375 herring gulls was counted. Of these most (1,776) occurred in February (see Table 10). Similar to the two previous study years staging herring gulls tended to be distributed evenly all over the study area, with small aggregations around the sandbar between Rødsand and Hyllekrog (Fig. 50).

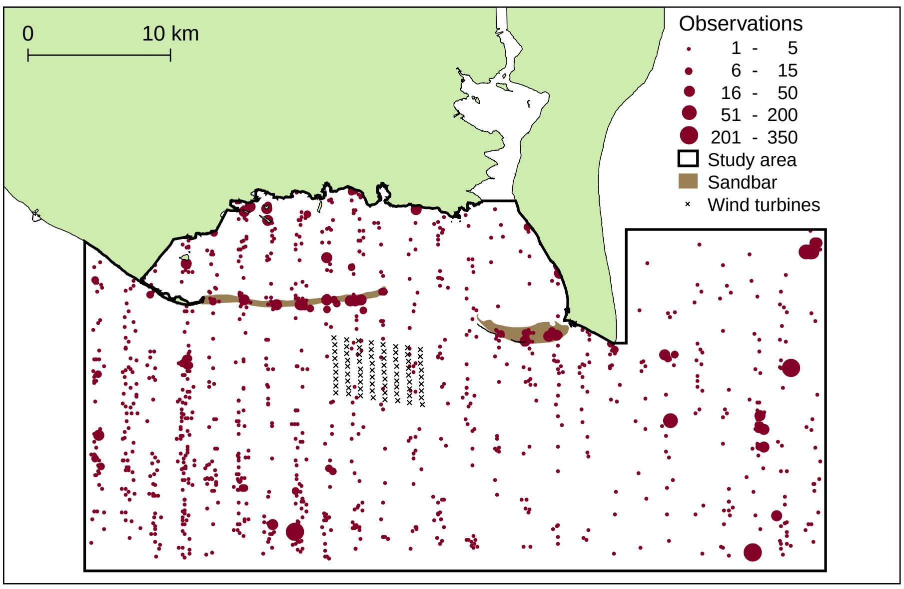
The distribution pattern of herring gull during 2002 was consistent with the findings from the pooled data set for 1999-2002 (Fig. 51). The 18,618 herring gulls counted during 1999-2002 showed significant spatial avoidance of all four zones around the wind farm area (see Table 11).

The seasonal variation in the number of herring gull showed similar patterns between years, and was dominated by large numbers in late winter/early spring and a more moderate number in autumn/early winter (Fig. 52).

Other species

A total of 110 divers was recorded in 2002 (see Table 10). Among geese, the greylag goose (725) was the most numerously occurring species, followed by the canada goose *Branta canadensis* (220) and the brent goose (121). Among diving ducks, the tufted duck *Aythya fu-*

Figure 50. Number and distribution of 4,375 herring gulls observed in the Rødsand study area during the four aerial surveys in 2002.



ligula was registered with 1,775 individuals in January 2002. A total of 27 little gulls was recorded in 2002, which was far below the number observed in 2001. This may be ascribed to the fact that no surveys were carried out during the autumn of 2002, when most birds were recorded in 2001 (Kahlert et a. 2002). The number of grebes, terns and auks did not exceed 50 individuals.

Figure 51. Relative density of herring gulls in the Rødsand study area, based upon 21 aerial surveys 1999 - 2002 and expressed by numbers / covered transect kilometre.

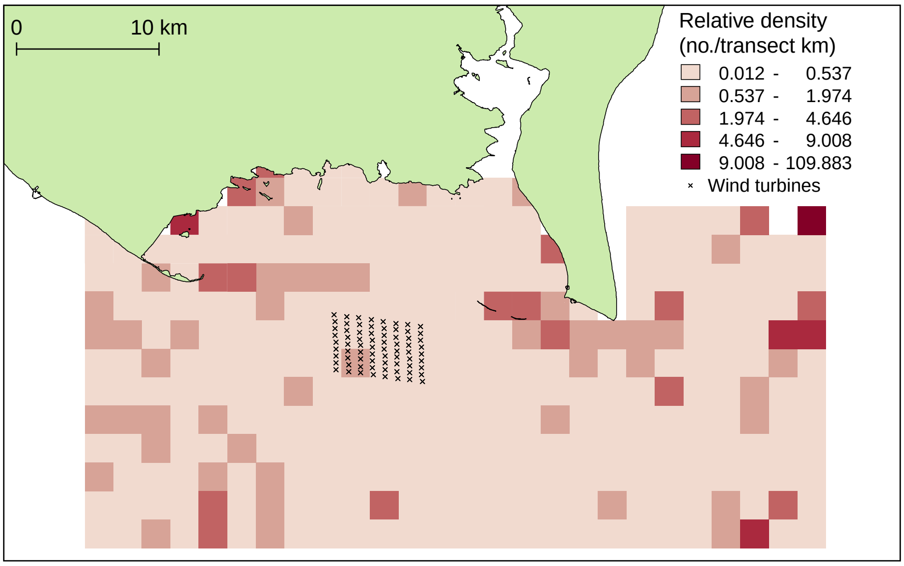
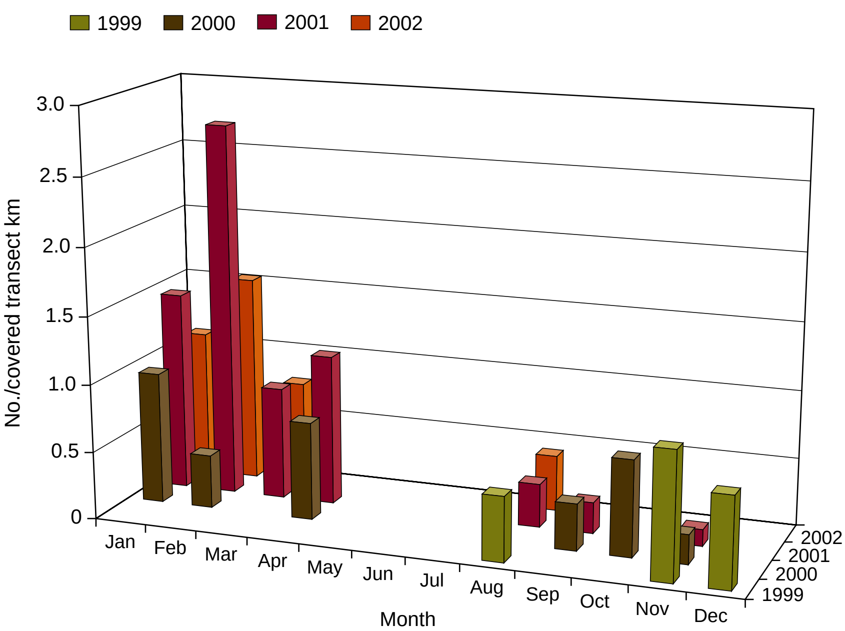


Figure 52. Seasonal variation in the number of herring gulls in the Rødsand study area, expressed by numbers / covered transect kilometre and year.



4 Discussion and conclusions

4.1 Patterns of migration

The importance of the study area at Rødsand for migrating waterfowl species was confirmed during spring and autumn 2002, even though the autumn numbers were considerable smaller than registered during autumn 1999-2001 which was primarily due to the temporary suspension of the study. Eider was still the predominant species amongst the migrating waterfowl. Previous studies in the study area have shown that the autumn migration of eiders includes a number of approximately 260,000 individuals (Christensen & Grell 1989) and up to 95,000 in one day (Kristensen 2001), and the base-line study has documented that the wind farm area is placed on a main autumn migration route of waterfowl.

Waterfowl migration during spring at Rødsand is not well described (Kahlert et al. 2000). Information about common eider numbers from the entire spring season is not available, but maximum numbers in one day may exceed 40,000 individuals. The base-line study in 2002 provided the second year of mapping of the waterfowl migration during spring, and showed in accordance with spring 2001 a migration pattern markedly different from that of the autumn. The main spring migration routes were placed north of the wind farm area and Rødsand, but in general massive eastward migration took place within all the radar range (see Fig. 12). This broad-fronted migration pattern was divided into two by the island of Rødsand, which acted to some degree as a barrier to the migrating waterfowl. Similarly, the west coast of Falster was avoided by the vast majority of the migrating waterfowl, and acted as a bottleneck around which the migration tracks were registered (see Fig. 12). In general, the waterfowl migrating during spring 2002 showed similar migration pattern as was observed in 2001, suggesting that the spring migration pattern is rather consistent between years.

As was shown during spring 2001, the dark-bellied brent geese almost exclusively used the northern migration route in May 2002. No flocks migrated in altitudes above the range of the turbine wings. As a consequence of the almost absolute absence of brent goose observations within the wind farm area, and as a avoidance response is unlikely to be detected at a significant level due to the low sample size within the wind farm area, the observations in May will be stopped by the end of 2002.

In both 2000 and 2001, daytime observations have shown that migration of passerines, pigeons and raptors is almost absent during spring, whereas during autumn, Gedser Odde and Hyllekrog northeast and northwest of the wind farm area are situated on a major migration route of these species in southern Scandinavia (Kahlert et al. 2000, Desholm et al. 2001, Kahlert et al. 2002). Due to the temporary suspension of the study in autumn 2002, no meaningful analysis could be conducted of the autumn migrating terrestrial birds for which the peak migration period lies in the late part of the season.

It can be concluded that after three years very detailed knowledge has been obtained on especially waterfowl migration in the Rødsand area, whereas information about the migration pattern of passerines is less well documented. This difference in the level of information does not only depend on the occurrence of species, but also on the efficiency of the radar to detect the different groups of birds. Waterfowl, which have a larger body and show a greater physical extent of flocks than passerines, are more easily detected by radar. Thus, tracks of waterfowl appear as solid lines of several kilometres, whereas passerines appear as diffuse short tracks often less than 2 km.

Because of the constraints on detectability of bird flocks, only crude estimates of absolute numbers of individuals in bird flocks, which cannot be counted by an observer, can be obtained (see Kahlert et al. 2000). Correction factors may be incorporated in models to obtain more accurate absolute numbers. However, to study effects on the spatial distribution of migration routes caused by the erection of the wind farm, repeated relative measurements are considered sufficient. In addition, correction factors are difficult to obtain during periods of poor visibility and darkness.

4.1.1 Lateral change in migration routes

The analysis of the orientation of autumn migrating waterfowl and terrestrial bird species was from the outset adapted to detect lateral changes in migration routes caused by individual wind turbines by only including migration tracks which passed the eastern and northern gate of the wind farm area, respectively.

In autumn 2002 it was confirmed that the orientation of waterfowl was robust to side wind effects in contrast to terrestrial bird species in 2001. However, the side wind effect (more westerly orientated migration at easterly winds) amongst terrestrial birds could not be analysed for in 2002. The migration of waterfowl in 2002 was as in 2001 orientated more to the south during daytime than during nighttime. This difference could be a consequence of the birds orientating themselves by the use of visual and non-lighted cues e.g. the coastline (Desholm 2003a). Hence, during daytime the distance to the coast may be increased due to the higher visibility. However, this difference could also be the consequence of different species registered during daytime and nighttime, respectively.

The ability of migrating birds to avoid collisions with offshore wind turbines is expected to decrease with decreasing visibility, and hence, it is predicted that the collision frequency will be higher in situations with poor visibility. As the visibility was better than 2 km for the vast majority of the main migration periods during the base-line studies, and given the above described prediction, it can be concluded that collisions may happen as relatively clumped and discrete events rather than as continuously occurring casualties. This necessitates a continuously operating collision monitoring system, which can collect data independent of human operators. The Thermal Animal Detection System (TADS; see Desholm 2003b) meets these requirements, and the final offshore testing of the system will be conducted in autumn 2003. The results of this test will form the basis for determining the extent of the future collision monitoring programme at the Nysted / Rødsand wind farm.

The increased percentage of eastern migrating geese during autumn 2002 compared to the previous years may be explained by the staging greylag geese moving between Rødsand and foraging areas on the mainland. They may simply have been registered as eastern migrating birds even though they may likely have performed local movements.

4.1.2 Probability of passing the wind farm area

A lower overall percentage of the waterfowl migration passed through the eastern gate of the wind farm area during autumn 2002 (26%) than in autumn 2001 (37%) and autumn 2000 (49%). This relatively high variance between years pays attention to the need of several base-line years in before-and-after studies.

If e.g. the 2000 data would have been the base-line year and the following two years would have made up the monitoring study after the construction of the turbines, false conclusions on the avoidance response could easily have been drawn.

In 2002 the probability that waterfowl passed the eastern gate of the wind farm area was in the same order of magnitude during spring (25%) as during autumn (26%). A statistical comparison of the proportions between autumn and spring was not possible because the calculations during autumn were based on recordings only from south of the observation tower, and thus were based on the assumption that waterfowl migration north of the tower is negligible. This assumption seems reasonable, as Falster constituted a land barrier for the waterfowl migration, which prevented birds from passing north of the tower (see Fig. 3). No land barrier existed for spring migrating waterfowl as they approached the study area from a westerly direction leading to a greater dispersal of the migration route and a relatively low proportion of crossings through the wind farm area.

The placement of the tower / radar in spring, when studying the migration of waterfowl after they had passed the wind farm area, was the same as during the autumn situation, due to logistical and practical considerations. However, the approach gives the opportunity to study the so-called shadow effect of the wind farm on bird migration, i.e. the question may be posed: if avoidance response occurs amongst the migrating waterfowl, how far in the direction of migration will the spatial distribution of the migration tracks be affected?

The probability curves, which predicted the proportion of waterfowl crossings through the wind farm area based on their position when they approached the wind farm area during autumn, will not only test the significance of a future change in the autumn migration route, but may also support future assessment of the collision risk for migratory birds.

Evidently, not all eiders, which pass through the wind farm area, are at risk of colliding with the turbine wings. During the EIA-study at Rødsand (Kahlert et al. 2000), measurement on flight altitudes showed that all eiders migrated at altitudes lower than 110 m (maximum altitude of wings on turbines at Rødsand). The proportion of migrating eiders within the altitude range of the wings (30-110 m) was highly variable (10-53% land) and depended on wind conditions and season.

4.1.3 Migration intensity in the wind farm area

It has often been pointed out that the migration intensity of birds among several factors also depends on the weather conditions, not just in the study area, but also along the entire migration route (Geil, Noer & Rabøl 1974, Alerstam 1990). Thus, even when controlling for several influential factors, a substantial proportion of the variation in the intensity may remain unexplained (Kahlert et al. 2000). For this reason migration intensity may be the least sensitive variable to detect potential effects of the operating wind farm. The apparent deviations from the normal distribution during some of the observation periods and wind directions must also be considered in future comparison of data between base-line and operation phase. Hence, models based on other statistical distributions could be more appropriate to apply.

In general, the 2002-data show higher migration intensities in tail wind situations than in head wind situations both in spring and autumn. This is in full agreement with the theory on avian migration, which states that both waterfowl and terrestrial migrating during periods of tail wind instead of periods of head wind decrease their migration energy expenditure (Alerstam 1979).

Even though other variables may be more powerful to detect changes in migration routes than migration intensity in the wind farm area, data on migration intensities are likely to contribute to the discussion of conclusions derived from other variables. Finally it is important to generate knowledge on the perspectives and constraints of different methods used to measure effects from offshore wind turbines.

4.2 Staging, moulting and wintering birds

Due to the suspension of the aerial surveys of staging birds in autumn 2002 data from this year consist of one survey in each of the months January, February, March and August. Despite the only four surveys, compared to seven in 2001, the number of observed long-tailed duck, eider, common scoter and red-breasted merganser was strikingly similar between the two years of investigations (Kahlert et al. 2002). These species, that are target species in the wind turbine impact study, are much more numerous in the study area during winter and early spring than during the rest of the year. For this reason NERI has suggested to reduce the number of aerial surveys from eight to five, which should ideally include one monthly survey from December to April.

With a maximum number of ca 4,000 the cormorant is present in internationally important numbers on an annual basis. In accordance with the results obtained in the previous years the social foraging events were conducted by more than 2,000 individuals, and as they visited the wind farm area in 2002 too, these events should be given attention in the future investigations of collision risk.

The number and distribution pattern of mute swan in the study area in 2001 and 2002 showed little difference, with peak numbers of 9,691 birds on 15 August 2001 and 8,387 birds on 22 August 2002. Special attention has been put on mute swan in order to address potential impacts on number and distribution when the cable from the wind farm towards land was established. This work was completed in October and November 2002, at a time when the bird surveys were suspended. Thus, the available data do not allow for analysis of this aspect.

Of the red-breasted merganser maximum numbers of 269, 258, 131 and 1,600 were counted in 2002, 2001, 2000 and 1999, respectively (Kahlert et al. 2000, Desholm et al. 2001, Kahlert et al. 2002). These numbers indicate that presence of internationally important numbers of red-breasted mergansers (>1,200 individuals) does not occur annually.

In all years the red-breasted mergansers were mainly distributed north of the sandbar between Hyllekrog and Gedser. In 1999, when the red-breasted merganser occurred in the highest number, three large flocks (> 80 individuals) were observed within and in the vicinity of the wind farm area (Kahlert et al. 2000). These occurrences markedly influenced the overall preference (computed index) of red-breasted merganser to the wind farm area and a zone up to 4 km around it (see Table 2). Due to the 1999 figures the species still shows preference to the distance bands of 0.275 km, 2 km and 4 km around the wind farm, and avoidance to the actual wind farm site.

The aerial surveys have demonstrated that long-tailed duck and common scoter have general preferences to the wind farm area, which make the two species vulnerable to disturbance from the wind turbines. Cormorant, mute swan, mallard, goldeneye, herring gull and little gull all showed general, significant avoidance of the wind farm site and its near surroundings. Eider showed a significant avoidance of the wind farm site and of the 0.275 km and 2 km zones, whereas a significant avoidance of the site out to a 4 km periphery could not be demonstrated.

Analyses of depth frequency distribution of selected species indicated that water depth is a key variable determining the distribution of most species, particularly those feeding on benthic food resources. In the upcoming work of spatial modelling water depth will be one of more variables incorporated, along with a suite of other available variables, as for instance distance to the nearest coast and sediment type. Fox et al. (2003) offer a thorough description of the progress of the development of spatial modelling.

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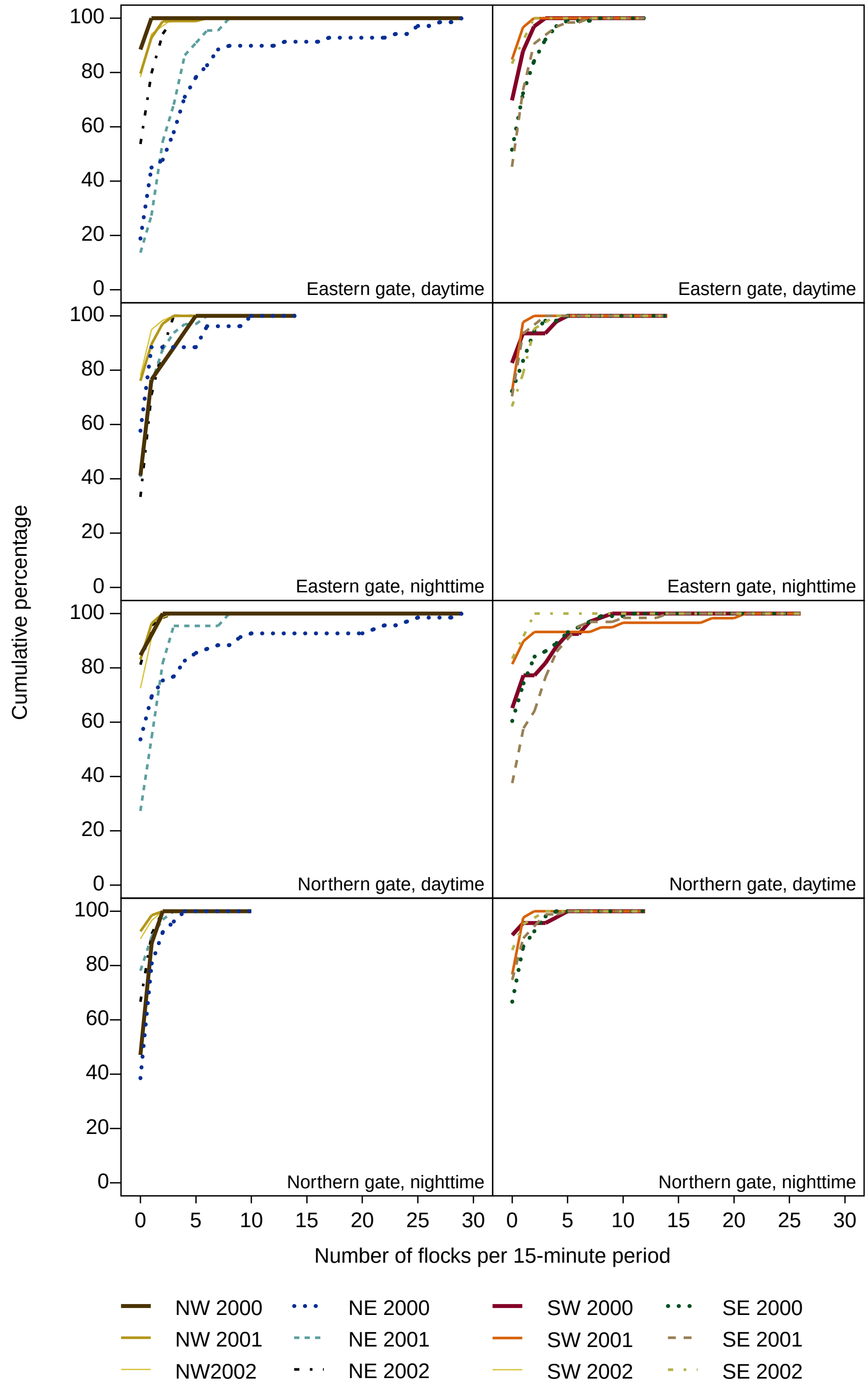
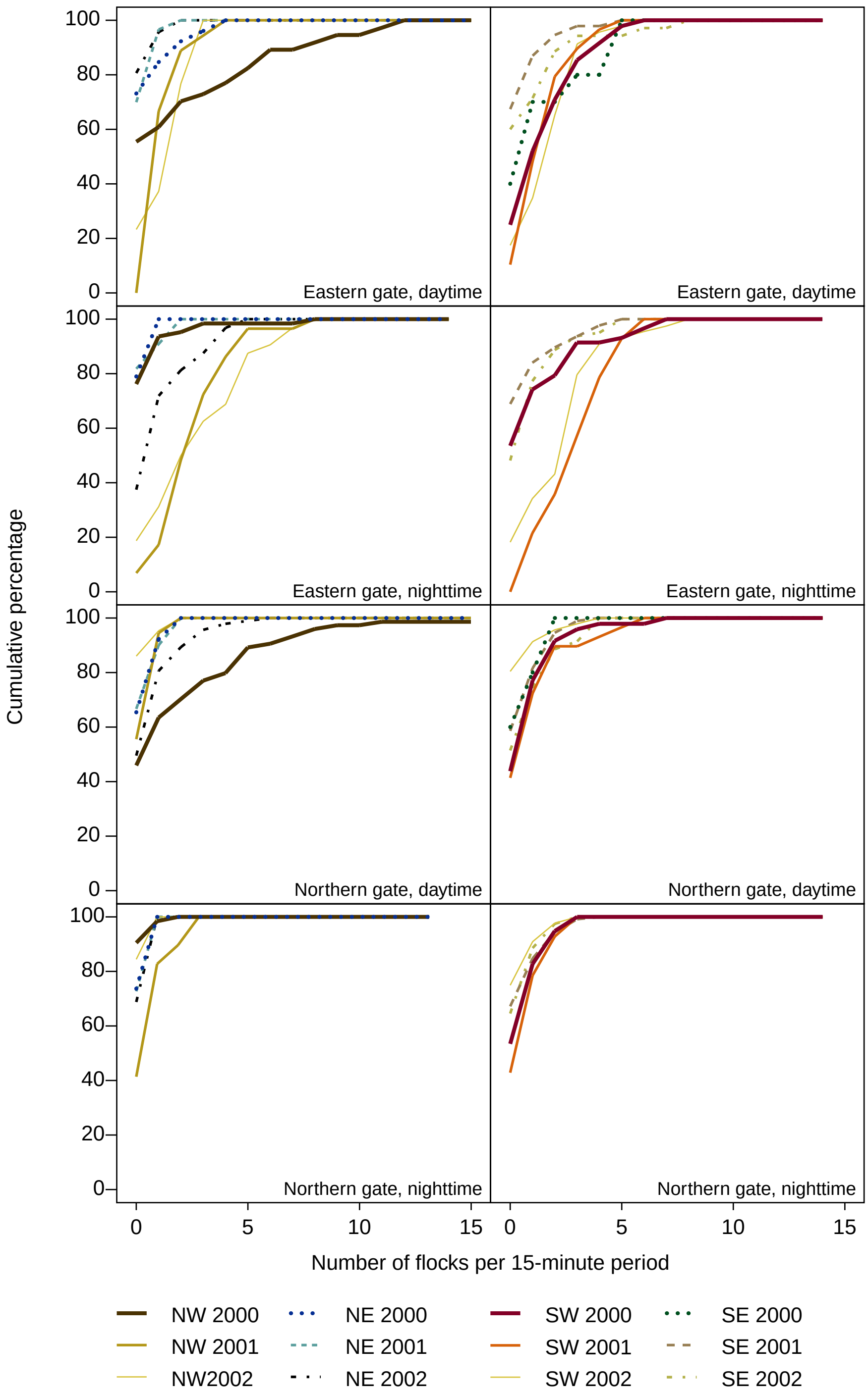
Appendix 1



Appendix 1a. Cumulative frequency distribution of the west- and southward migration intensity at the eastern and northern gate measured as the number of flocks per 15-minute period during day- and nighttime in autumn (1-30 September) 2000, 2001 and 2002. One graph is depicted for each of the following wind situations: northwesterly winds (NW), northeasterly winds (NE), southwesterly winds (SW) and southeasterly winds (SE).



Appendix1Ib. Cumulative frequency distribution of the east- and northward migration intensity at the eastern and northern gate measured as the number of flocks per 15-minute period during day- and nighttime in spring (16 March – 15 April) 2000, 2001 and 2002. One graph is depicted for each of the following wind situations: northwesterly winds (NW), northeasterly winds (NE), southwesterly winds (SW) and southeasterly winds (SE).