The Impact of Offshore Wind Farms on Bird Life in Southern Kalmar Sound, Sweden

A final report based on studies 1999–2003

Jan Pettersson
at the request of the Swedish Energy Agency

A reference group collaboration with its principal centre at
the Department of Animal Ecology,
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Lunds universitet

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Contents

The Utgrunden lighthouse has been used as an observation site from the open platform at a height of 27 m and from the side of the platform that gave shelter at the time.

Summary

An ornithological study was carried out over four spring and four autumn seasons from 1999–2003 on one and a half million migrating waterfowl in southern Kalmar Sound in Sweden. The study was conducted in connection with two groups of offshore wind farms constructed at Utgrunden and Yttre Stengrund, with seven and five wind turbines respectively.

The migration patterns of waterfowl through the Sound and the flocks' reactions on encountering the wind turbines were studied and documented during periods of good visibility by direct visual observation and by following the flocks with an optical rangefinder. During periods of poor visibility (such as fog or mist, or during the night), and similarly during the day with good visibility, radar films from military surveillance radar were analysed in order to follow the flocks' flight paths and to document their reactions and behaviour when faced with wind turbines in their migratory path.

Wind farms

In the middle of southern Kalmar Sound – which is 20 km wide at this point –seven wind turbines were erected at Utgrunden in autumn 2000. The five wind turbines at Yttre Stengrund, situated roughly 3 km from the shoreline, were erected in the summer of 2001 and are about 20–30 km south of Utgrunden.

Spring and autumn migration

The study includes a total of 859 000 spring migrating waterfowl and 674 000 autumn migrants. Up to 95% of the spring migrating waterfowl in the area consist of Eider, this figure being 56% of the autumn migration in Kalmar Sound. Other species consist mostly of ducks, geese and Cormorants. The autumn waterfowl migration occurs mainly along the west side of the Sound near the Yttre Stengrund wind farm section.

Choice of flight path

After construction of the wind farms the spring migration of waterfowl takes place to a greater extent along the Öland side of the Sound. Most of the spring migratory paths have thus been shifted up to 2 km eastwards. During spring and autumn migration most of the waterfowl flocks avoid flying closer than one kilometre to the wind turbines. In good visibility the flocks seem to make a choice at least 1–2 kilometres before the wind farm whether to pass on the right or the left of the turbines. In the spring they fly mainly to the right of the Utgrunden wind farm as the migration often takes place in westerly and southerly winds. It is probably easier to pass the turbines with the wind behind them than to turn into the wind. Naturally some of the flocks (about 3%) fly closer to the turbines (0–500 metres), but the proportion of all flocks that make some kind of change in flight path is about 30% in good visibility at Utgrunden in the spring and about 15% at Yttre Stengrund in the autumn. These flocks then have to fly in a curve around the wind turbines which extends their flight path by 1.2–2.4 km, or for a few flocks up to 2.9 km. This extension of the flight path is 0.2–0.4 per cent of the total migration distance of the waterfowl from the breeding area to the wintering area and vice versa, which can be expressed as a certain increase in energy expenditure for the birds' migration.

Night and mist

Radar monitoring of flocks showed that waterfowl migration in fog and mist is rather limited overall. About 5–6 per cent of the total number of birds passing in spring and autumn migrate in such conditions, and this corresponds very closely to the amount of time (5–9 per cent of the time studied) in which there is fog and mist. These flocks avoid the wind turbines in the same way as those that migrate in good visibility. The nocturnal waterfowl migration in Kalmar Sound is extensive and makes up 22–27 per cent of the total. The nocturnal migratory flocks fly at a greater distance from land than those that migrate by day. The waterfowl flocks seem to react to the wind turbines from a considerable distance at night too, about 500–1000 metres before they reach them. The flocks that come closer to the turbines at night (both in the autumn and spring) fly in a curve to avoid the turbines in the same way as those that migrate in the daytime.

Rare species

Only a few of the rare, red-listed species observed, or birds of prey in the area, seem to fly into the immediate area of the wind farms during migration. About 4 per cent of the somewhat rarer species observed migrating in the spring fly into the immediate area of the wind turbines at Utgrunden and 5 per cent in the autumn at Yttre Stengrund. This is comparable to the number of Eider (2–6 per cent) that during spring and autumn fly into the immediate vicinity of the wind farms. These slightly rarer bird species behave in very much the same way as the common waterfowl species on encountering the offshore wind turbines. Altogether these species make up about 0.3 per cent of the waterfowl observed.

Collision risk

In the autumn of 2003 one bird collision was observed at Yttre Stengrund. This was the only collision seen during the whole period of the research. A flock of about 310 Eider flew at about 100 m from the northernmost wind turbine at Yttre Stengrund and the outer flank of the flock was struck by the rotor. Four birds fell into the water and three of these were observed flying quickly away from the area, while one bird was probably killed. In addition, five near-accidents were observed when flocks swerved to one side or turned sharply near the turbines in order to avoid a collision. A calculation of the collision risk showed that one bird per year per wind turbine collides with the existing turbines in Kalmar Sound. One premise in the calculation of collision risk is that only flocks that fly within 100 metres from the wind turbines

run the risk of colliding. Moreover, this premise is based on the fact that these flocks continue to fly straight ahead and do not turn away when they reach the turbines. The number of waterfowl which, according to this calculation, risk colliding with the turbines must be seen as a worst-case scenario. As migration mainly occurs in different places in the Sound during the spring migration, this is primarily affected by the wind turbines at Utgrunden and the autumn migration by the turbines at Yttre Stengrund. A risk number has been calculated for the total number of birds passing for the whole of the spring and autumn respectively, from detailed studies of the actual number of flocks that pass within 100 metres of the turbines at Utgrunden wind farm in the spring (approximately 0.2 per cent of the flocks) and at Yttre Stengrund in the autumn (approximately 0.3 per cent of the flocks). According to these risk calculations for southern Kalmar Sound, a maximum of 1–4 flocks in the spring and a maximum of 10 flocks in the autumn may run the risk of colliding with one of the wind turbines. If the only observed collision is representative of an "average collision", a maximum of 11–14 birds per year might be killed and about three times as many might be injured more or less seriously in collisions with the existing 12 wind turbines in the Sound. Consequently, only about one bird per wind turbine per year would be killed in a collision with a wind turbine. This should be compared with the estimated total number of waterfowl that passed through the area during the research period, which was about 500 000 waterfowl each spring and 800 000 each autumn.

Wintering and staging birds

The area around Utgrunden is used by about 1000 to 2000 staging waterfowl during spring and autumn alike, and fewer during winter. Long-tailed Duck are the most common staging birds, but in the spring and summer some Eider and Common Scoter can be seen. The area round Yttre Stengrund is used by fewer staging waterfowl and there are no Long-tailed Duck among these. There were fewer Long-tailed Duck in spring after the construction of the wind turbines at Utgrunden. This cannot be definitely attributed to their construction as the number of birds in the reference area also decreased during the same period. This is probably due to a relatively large general variation from year to year in the area. Possibly the reference area is too near the wind turbines (approximately 3 km) to reflect such variations or possible effects of the wind turbines. Research into the positions of the different flocks of waterfowl and their daily movements was carried out at the wind farm area at Utgrunden. These studies showed differences in the various species' choice of sites and a certain daily rhythm. The visits by the wind farm service boat were disturbing during the daytime so that Long-tailed Duck as well as the Common Scoter flew away from their feeding areas in the immediate vicinity of the wind turbines. During the mornings and evenings they were to be found again in the immediate vicinity of the wind turbines. Eider occurred in the area both before and after erection of the wind turbines, but they kept mainly to the area north of the wind farm and were not disturbed so much by the service boat. It is quite clear that, in spite of the wind turbines and frequent visiting boats, there were still many waterfowl that used the Utgrunden area as a staging and foraging place. Variations in the seabed and the consequent availability of food, e.g. the occurrence of mussels, are probably the main reasons for differences in specific sites used by different species of birds.

Conclusions

- About 30% of the waterfowl that migrate through Kalmar Sound are affected to some extent by the wind farms Utgrunden and Yttre Stengrund.
- The Utgrunden wind farm has displaced the migration corridor for spring migrating Eider eastwards towards the coast of Öland.
- There has been no significant change in the autumn migration corridor.
- The majority of Eider and other migrant waterfowl avoid the immediate vicinity of the wind farms.
- The birds generally start an evasive manoeuvre 1–2 km before the wind farms.
- The birds' behaviour is generally similar, irrespective of time and visibility – the majority of all waterfowl react to avoid the wind farms at night as well as daytime, in poor visibility as well as in clear conditions.
- The waterfowl that make an evasive manoeuvre extend their migration distance and thus time by 0.2–0.5%. This entails only a marginal increase in energy expenditure for the whole migration.
- Very few waterfowl flocks fly so near the wind turbines (≤ 100m) that they risk a collision.
- A calculation of collision risk based on data collected from the Kalmar Sound studies shows that 1–4 flocks during the spring and about 10 flocks during the autumn (and only one bird in each flock) run the risk of colliding with the existing wind turbines. This translates into one waterfowl killed per wind turbine per year.
- One collision of an Eider flock with one of the turbine blades was recorded and four out of the 310 Eider in the flock were hit or affected.
- The construction of the Utgrunden wind farm has a possible negative impact on the attractiveness of the area for staging and wintering waterfowl, indirectly through the activity of the service boat.
- Utgrunden is still used by Long-tailed Duck, Eider and other staging and wintering waterfowl.
- The service boats that travel to and from the turbines are clearly a greater source of disturbance than the wind turbines themselves.

The author with the optical rangefinder

1 Introduction

1.1 Background

In spring 1998, Vindkompaniet AB gave the author, Jan Pettersson, and Lars Lindell in Kalmar the task of carrying out a preliminary investigation into bird migration and its distribution and extent in southern Kalmar Sound in Sweden. The investigation was in conjunction with a planned construction of wind farms in the area. Migration studies were carried out in the spring seasons of 1998 and 1999 in the Utgrunden area with the aim of producing the basis for a description of environmental impact, as well as a follow-up study of the planned wind farms' potential impact on bird life in the area.

During the autumn of 2000 seven 1.5 MW wind turbines were erected on the southern part of the ridge at Utgrunden. This was only half of the 13 turbines originally planned. The number had been reduced as the size of the turbines had increased.

The permit granted prescribes as a condition, in accordance with the environmental code, that a control programme to investigate the impact of the wind turbines on bird life should be set up and approved by a supervisory authority. Such conditions were also stipulated in the permit later granted to Vindkompaniet to erect five 1.5 (2.0) MW wind turbines at Yttre Stengrund, situated 20–30 km south of Utgrunden. In 2000, Vindkraftbolaget Utgrunden AB and Enron Wind Sverige AB, who then managed the wind farm at Utgrunden, received a combined investment grant and technical development and demonstration grant from the Swedish Energy Agency for the offshore wind power project at Utgrunden. As one part of this development, a research project was to be undertaken on the impact of the offshore wind turbines on bird life. In this project it was decided that Vindkraftbolaget Utgrunden AB, Enron Wind Sverige AB and Vindkompaniet AB should each pay 500000 SEK for the cost of that part of the bird project not covered by a grant. The project was designed in such a way that the inspection authorities could also approve it as a control programme for the follow-up of the wind farms' possible impact on bird life. The study which the author of this report was commissioned to make included migratory as well as staging birds in Kalmar Sound. The studies of the possible impact on bird life include both the wind farms in southern Kalmar Sound at Utgrunden and Yttre Stengrund with (as from summer 2001) five 2.0 MW wind turbines. The project was planned as a three-year project to be carried out in stages. The experience and knowledge from the different stages could then be applied to subsequent stages.

During the permit process, ornithologists pointed out that it was risky and unsuitable to place wind farms in Kalmar Sound – one of northern Europe's outstanding bird migration locations. In spite of these risks claimed, the Ornithological Society of Öland in their comments on the proposal circulated for their consideration to the County Administrative Board dated 24/9 1998 did not want to oppose construction of wind farms at Utgrunden in order to create the possibility of a better basis for assessment. They stated that it would be better to study the impact of wind turbines over a period of time and on a limited scale than to slow down development and not find time to study the impact before carrying out a large-scale extension of offshore wind power. When permits were granted for these two locations it was considered advantageous from a research point of view to locate studies of the impact of offshore wind farms on migrant birds precisely in such an area with a potentially large number of waterfowl at risk. This has provided opportunities to produce extensive research material of great value, which would not otherwise have been possible. At the same time the wind power companies exposed themselves to the potential risk of being obliged to remove the wind turbines if it was proved that they caused widespread injuries to the migrating waterfowl.

In summer 2001 Enron Wind initiated a conference with the authorities and interested organisations in order to discuss the status and need for further information related to offshore wind power and the environment. Among the participants were the Swedish Environmental Protection Agency, the National Board of Housing, Building and Planning, the Swedish Energy Agency, Uppsala University, the Swedish National Ornithological Society, Elforsk and representatives of professional fishermen, Vindkompaniet AB and Vattenfall. In autumn 2000, Enron Wind tried to start a research project within the framework of Elforsk. Hans Ohlsson (Sycon), Folke Plejmark (Tekova) and Thomas Stalin (Enron Wind) took part in this work. The project resulted in the research on the impact of wind turbines on bird life being incorporated in the decision of the Swedish Energy Agency on "demonstration project Utgrunden", budgeted at 3 014 000 SEK.

This is the final report including a compilation and evaluation of the total observation data from the whole project period 2000 until 2003. The observation data from spring 1999 makes up the preliminary study for the project proper. The project period includes observations in Kalmar Sound in three spring periods and three autumn periods. The studies were financially supported by the Swedish Energy Agency and the wind power companies Vindkraftbolaget Utgrunden AB, Enron Wind Sverige AB, GE Energy Sweden AB and Vindkompaniet AB.

1.2 Basic issues

When this research was begun in 2000, the debate about offshore wind turbines and birds focused mainly on the danger of birds colliding with the turbines in large numbers. The main issue in this study has therefore revolved around the risk of collisions between migrant birds and offshore wind turbines. The central issues of the whole research were to find answers to the following questions:

– How great is the risk of collisions between birds and wind turbines at the offshore wind farms in southern Kalmar Sound, in good visibility in day and night as well as in limited visibility, such as in fog and mist?

– Do the wind farms influence the location of bird migration corridors in the Sound?

– Do the wind farms influence the staging habits (food-searching) of birds using the shallow areas where the wind turbines are located?

1.3 Reference Group

A special reference group for the project was formed in autumn 2001. The aim of this reference group was chiefly to create a scientific group in which the members have special qualifications and experience in the subject field of the project and related problems. Apart from the scientific research group, the reference group included representatives of wind power companies responsible for the project or having a special interest in any other way, special knowledge or qualification in the subject field of the project. The main task of the reference group was to provide the project with quality assurance, since through their opinions, advice and recommendations, the group would take part in the planning of the different stages of the project, the execution of the project, and have an active part in the final evaluation.

The research part of the reference group consisted Martin Green, bird migration researcher at Lund University; Leif Nilsson, expert on waterfowl population at Lund University; Johnny Kahlert, ornithological/wind power

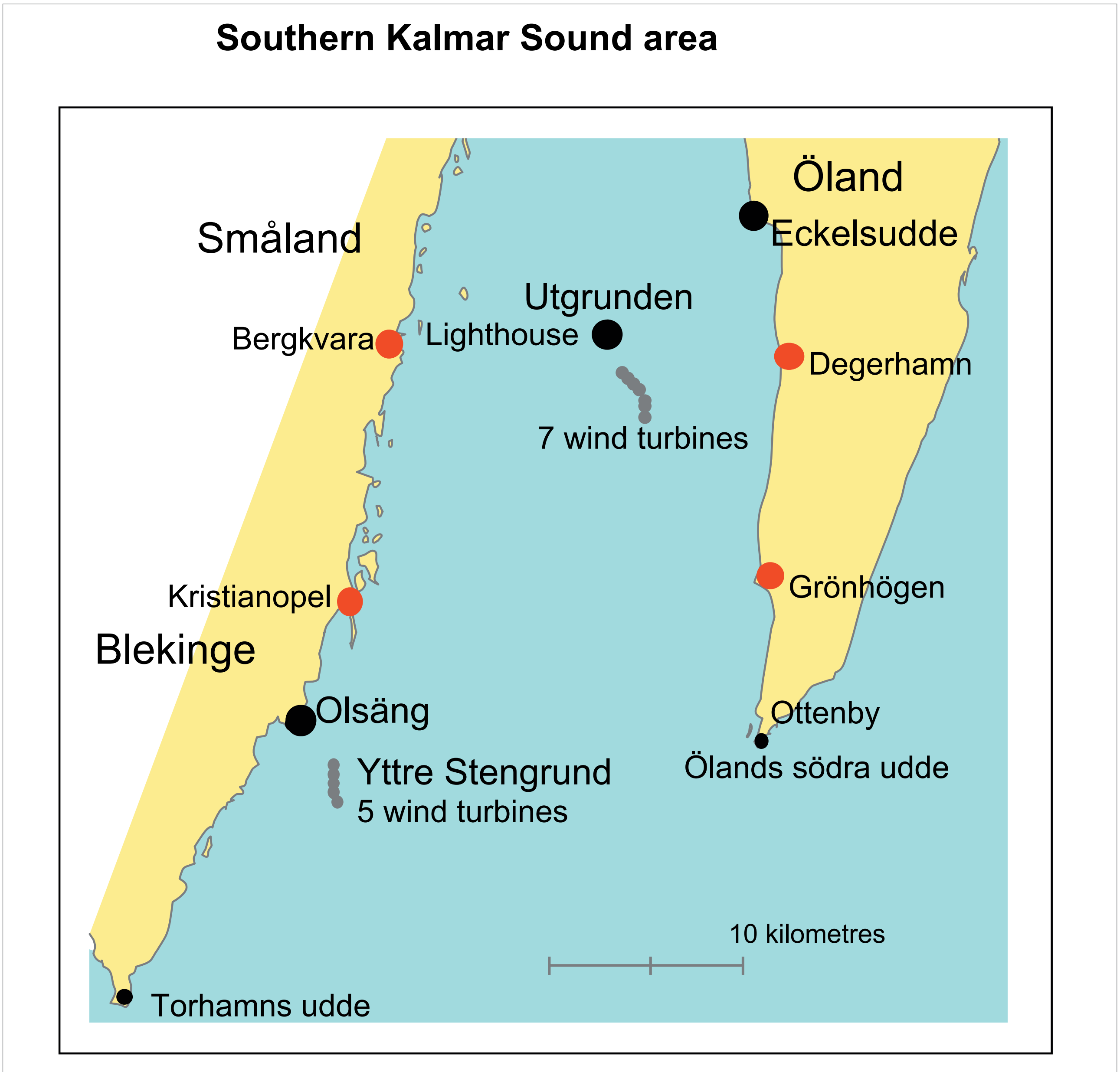


Figure 1 Map of southern Kalmar Sound in Sweden. The seven wind turbines at Utgrunden were erected in autumn 2000 and the five wind turbines at Yttre Stengrund were erected in summer 2001.

researcher, Danish Environmental Research DMU (Dansk Miljøundersøgelser) and Johnny Karlsson, ornithological/wind power researcher at Bioconsultant (previously at Lund University). The following have also formed part of the reference group: Thomas Stalin, Enron Wind and GE Energy; Hans Ohlsson, Enron Wind and Airicole; Staffan Niklasson and Per Malmén, Vindkompaniet; Per Hjelmsted Pedersen, SEAS and E2; Scott Properzi, E2; ornithologist and project leader Jan Pettersson, JP Fågelvind and the project co-ordinator Folke Plejmark, Tekova.

1.4 Research areas

The waters of southern Kalmar Sound are administered by four municipalities (Kalmar, Torsås, Mörbylånga and Karlskrona) and two counties (Kalmar län and Blekinge län). On a level with Utgrunden there are two communities in the area; Degerhamn on Öland and Bergkvara on the mainland. Other centers of population are Karlskrona at the southernmost point of the area, Kalmar in the northwest corner and Mörbylånga on Öland. The Öland Bridge (Ölandsbron) which spans the whole of the Sound from Kalmar to Färjestaden on Öland, was built in 1972. The bridge spans over 6 km of water and has a high-level section nearest Kalmar whose highest point is 42 m above sea level.

The Utgrunden wind farm is situated almost in the middle of southern Kalmar Sound, 8 km west of Öland and 12 km east of the mainland. This shoal is made up of a boulder ridge which extends mainly in a north-south direction where the depth of the water over the boulder ridge varies between 4 and 15 m. The depth of the water in the surrounding water areas is ca 20–25m. The Utgrunden lighthouse, situated on the northern part of the shoal, about 2 km north of the northernmost wind turbine (Figure 1), was built in 1945. The lighthouse is 27 m high, 3.5 m in diameter and there was a helicopter landing platform during the research period on the uppermost section above the lighthouse equipment. The water around the lighthouse is about 6 m deep. The lighthouse is situated 2650 m northwest of the nearest wind turbine at Utgrunden and the distance from the southernmost turbine is 4800 m. The lighthouse is situated approximately in the middle of the Sound at a distance of 10 km to the mainland and to Öland.

Yttre Stengrund is a shallow plateau about 3 km off the Blekinge coast and the wind turbines were constructed on this shoal at a depth of about 5–7 m where the plateau slopes gently out into Kalmar Sound (Figure 1).

Utgrunden Lighthouse

The open platform of the lighthouse, at a height of 27 m, was used as an observation site and the side of the platform provided shelter at the time. A small generator and basic overnight equipment was taken to the lighthouse for the observation periods to allow one to two people to stay there for periods of up to three weeks. During the whole of the research period it was possible to obtain exact wind information from the equipment placed 38 m above sea level.

The Airicole company actually bought Utgrunden Lighthouse in 2003; the lighthouse section itself and the helicopter landing platform was lifted off in the winter 2003–2004 and was replaced by a considerably larger superstructure of two floors with glass walls. A new 60m-high meteorology mast was erected on top of the new lighthouse. This improved lighthouse construction is intended to be used in the future as a field station for different studies of offshore wind turbines and their impact on the environment, not least bird studies.

Olsäng, observation site for Yttre Stengrund

Olsäng observation site was formerly an early-warning tower for approaching aircraft on the north side of the headland at Styrsholm. The aircraft warning tower is situated 25 m from the shore and the observer is at 9 m above sea level. The observation site has a clear view of the sector NW–E–S; the view to the west is somewhat limited by trees. The distance to the nearest wind turbine, which is also the northernmost of the five at Yttre Stengrund, is 3100 metres and to the southernmost it is 4300 metres. Öland's southern headland with its lighthouse Långe Jan is situated directly east and is an excellent landmark for observations. Styrsholm headland is relatively open country with juniper bushes and a fairly large clump of oak trees to the west of the observation site. Just south of this headland, only 600 metres from the observation site, there is a protected area for seals with about one hundred harbour seals. In strong winds an observer is able to stand in the shelter of the aircraft warning tower but is then only about 2 metres above sea level.

Eckelsudde

The Eckelsudde headland juts out into Kalmar Sound from Öland; it is made up of grazed shore meadows with juniper-bush areas up to 100 metres from the shore. The headland is situated next to a bird sanctuary with the same name. North of the observation site there are 16 terrestrial wind turbines (the nearest one being at least 75 metres from the sea) with 300 metres as the nearest distance to the observer. The observation site is situated next to juniper-bush areas at a height of about 3 metres above sea level at its highest point and about 50 metres from the shore. Observers can shelter from the wind behind these bushes and beside a stone wall. There is a clear view from this observation site over the sector SE–S–W–N; bushes obscure the view towards the east a little. The distance to the lighthouse at Utgrunden in a SW direction is 9 km and to the distance to the nearest wind turbine at Utgrunden is about 10 km.

2 The waterfowl migration in Kalmar Sound

2.1 Total extent of waterfowl migration

Annual observations of waterfowl migration in Kalmar Sound were made from 1958–1972 between March and November. The migration counts were initially made from Revsudden on the mainland side and later from Stora Rör on the Öland side, about 25 km north of Öland bridge. The data was collected in table form and shows extensive waterfowl migration both in the spring and autumn (Edberg 1960, 1961, 1965, Rodebrand 1972, 1976, Aulén and Wahlström 1974 and Blomqvist and Lindholm 1976). The annual totals of the counts varied between 150 000 and 500 000 birds in spring and between 100 000 and 350 000 in autumn. Spring migration was predominantly Eider, up to 96 per cent, whereas this was somewhat less in autumn at around 70 per cent.

Large numbers of migrating birds gather at the southern tip of Öland. The migration pattern for this area is well documented; for example, in the years 1947 to 1956, annual counts were made of all diurnally migrating birds from 1 July to 31October (Edelstam 1972). Eider were not as predominant in that data as in Kalmar Sound, but several other groups of waterfowl appeared, e.g. dabbling ducks, mainly Wigeon, Anas penelope, and Pintail, Anas acuta, of which there were up to 40 000 each autumn. This data also showed that thousands of waders pass the southern headland of Öland when migrating. These waders, however, hardly come near the wind farm areas in Kalmar Sound as most of them migrate to the east of Öland and/or at higher altitudes and particularly during the spring (v. e.g. Green 2003).

At Seby on the south-east coast of Öland (about 15 km north of Ottenby) more recent waterfowl counts have been carried out (Breife 1994) which illustrate the large extent of waterfowl migration along the east coast of Öland. At Segerstad (about 20 km north of Ottenby) relatively regular counts have been carried out for some years both in spring and autumn. Observations confirm that the numbers in spring are smaller here than in Kalmar Sound. The more recent counts are only available on Internet and in SOF's annual bird year reports ("Fågelåret"). Unfortunately these counts are only sporadically issued and often only the most extreme values.

During the autumn at Ottenby and southern Öland a large number of Cranes, Grus grus, have been reported, some of them from observations at Olsäng when they come in towards the Blekinge coast (24 km W of the southern headland). Some of the birds of prey and larger flocks of diurnally migrating small birds that come in towards the mainland at Olsäng and just north of there are probably birds that have passed southern Öland and the southern headland during their migration. In certain cases this was confirmed by analyses of radar trackings as the echoes on radar films were correlated with observations made at Olsäng. Such radar verification was possible for White-tailed Eagle, Rough-legged Buzzard, Starling, Sky Lark and Arctic Tern (the latter during the month of September).

2.2 Migration and extent of predominant species

This chapter describes the predominant species in waterfowl migration through southern Kalmar Sound. An account of the behaviour of the species in the area is given here and of their breeding and wintering quarters. Information about the migration period and its peaks in spring and autumn is also given. There is a description of our current knowledge of migration patterns of the species in the region.

Eider *Somateria mollissima*

Eider feed by diving down to the seabed for mussels and crustaceans. The species breeds in numbers along the whole of the Swedish east coast from Northern Scania (Skåne) and along the coasts of Öland and Gotland. The densest population is to be found in the Stockholm archipelago, approximately 100 000 pairs (Andersson & Staav 1980). The total Swedish population was estimated at 270 000 pairs in the 1980's (Svensson et al 1999).

Finnish Eider and probably some Russian Eider migrate through Kalmar Sound on their way to and from their wintering regions in Danish waters. The Eider which breed in the southern part of the Baltic Sea overwinter mainly in the southern Danish waters east of Jutland, which has been shown by the findings of ringed birds (Fransson & Pettersson 2001). Only a few Eider remain in the southern Baltic Sea during the winter.

The spring migration begins in March and reaches its peak at the end of March and beginning of April, but does not end until May (see counts for the last five years in Kalmar Sound, Figure 2). Eider migration is so clearly linked with the sea that the birds do not readily fly over land. Radar trackings and field observations (Alerstam et al 1947) have shown, however, that Eider fly over inland Scania to some extent during their spring migration. Some Eider also migrate overland at Laholm Bay (Laholmsbukten) and pass over southern Sweden in the direction of Hanö Bay (Hanöbukten) or north of it

(Alerstam et al 1947b).

Eider migration in the spring is a fantastic phenomenon in Kalmar Sound and in the whole of the southern Baltic Sea region. Over the years extremely high day figures have been reported. On 4 April 1996, 287 000 Eider were counted at Kåseberga in Scania on their way north. In Kalmar Sound, too, very high figures have been reported, as for example on 5 April 1992 when 130 000 migrant Eider were counted at Beijershamn on Öland (SOF 2002b).

As early as the end of May a southbound moulting migration of Eider begins, which may rise to a peak in the second half of June. This early southbound migration consists mainly of male Eider that fly down to Danish waters for their annual moult.

The autumn Eider migration culminates in October, but the movements begins in September, probably at first consisting of males from northerly populations. In October migration consists mainly of young birds and females, probably both from the Baltic Sea and the Arctic Ocean. On 20 October 1990 an extremely high autumn day figure of 240 000 migrant Eider was reported from southern Öland, mainly east of the island (SOF 2002b). On 20 October 2000 a total of 125 000 southbound migrant Eider were seen at Utlängan and Utklippan in south-east Blekinge (SOF 2002). On that day the observer at Olsäng reported about 62 000 southbound migrant Eider. An analysis of radar film from the area on that particular day showed a migration pattern almost equally large to the east and west of Öland.

The above description should be compared with older data from studies during the 1970's that showed 70% of the Eider migrated through Kalmar Sound while 30% flew east of Öland (Pettersson 1981).

Cormorant *Phalacrocorax carbo*

Cormorant breed locally in colonies on the islands, particularly off the east Swedish coast where their strongest foothold is to be found along the whole of the Kalmar Sound (about 10 000 of the country's 30 000 pairs according to SOF 2002). For the last 15 years Cormorant have increased significantly in the Baltic Sea and it is quite certain that more Cormorant migrate through southern Kalmar Sound today than when this study was started at the end of the 1990's. The wintering quarters of the species extend from the southern Baltic Sea southwards as far as the North African coast, in Tunisia for example (Fransson & Pettersson 2001).

The species in southern Sweden shows an extended migration period during both spring and autumn. The spring migration peak in the area occurs in March and April, whilst the most intensive autumn migration takes place in October.

The 875 Cormorant observed migrating southwards by the author of the report at Olsäng on 27 October 2000 is still a record, according to the statistics (SOF 2002).

Barnacle Goose *Branta leucopsis*

This little black and white goose is a vegetarian and grazes on grass and herbs, and has even been observed grazing on fresh corn stubble. There are about 4000 pairs that breed on eastern Öland and on Gotland, 500 of which are on Öland. There are probably about 1000 more pairs that breed along the Swedish east coast as far north as Norrbotten (SOF 2002b).

The large numbers of Barnacle Goose that fly over south-eastern Sweden migrate from their breeding quarters on the Russian tundra down to the Atlantic coast where they overwinter. The Russian population of Barnacle Goose that migrates via the Baltic Sea was estimated at 360 000 (Delany

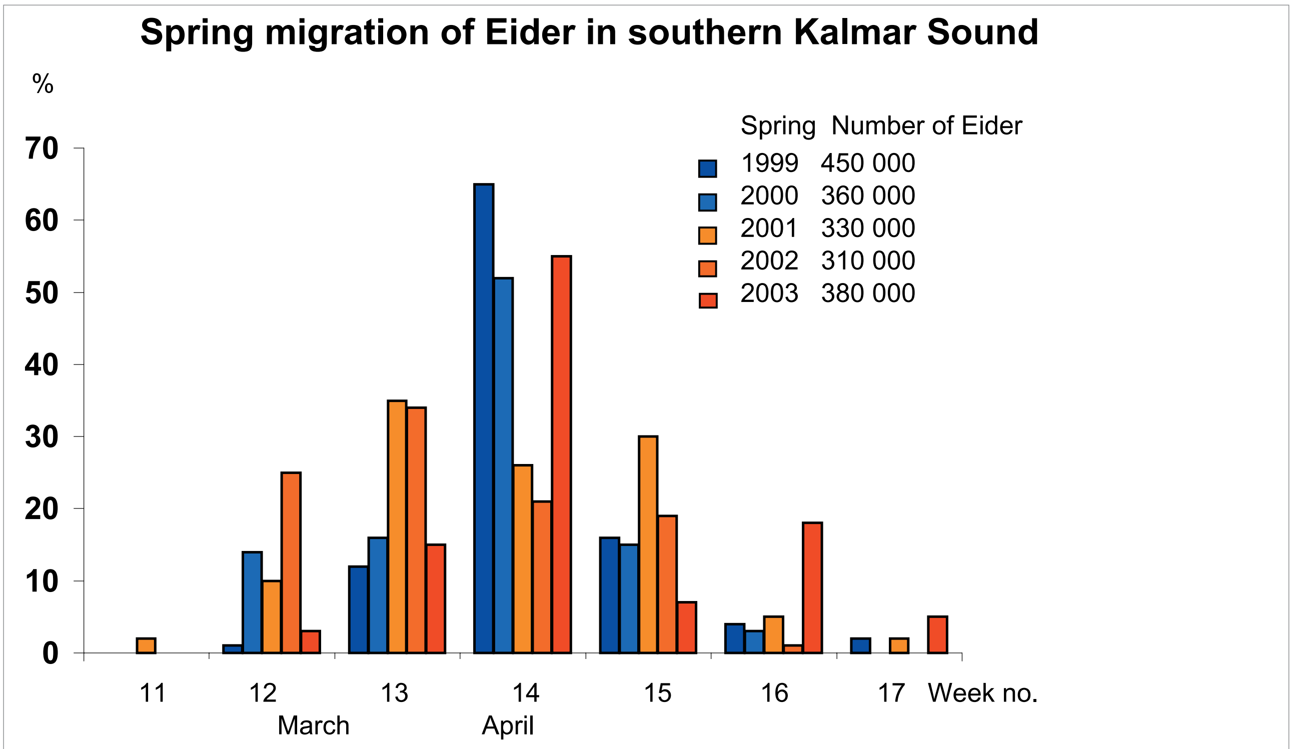


Figure 2 Spring migration of Eider in southern Kalmar Sound during the last five spring seasons. The diagram is mainly based on counts made by amateur ornithologists at Kalmar and Färjestaden. Some information was been gathered from the report system Svalan, and via SOF's report "Fågelåret" for each year – carried out by ornithologists from other parts of the country. Coverage of the migration time by observers is far from complete for all days or whole days, but counts were made for 40–75 per cent of the time.

& Scott 2002). The migration period for this species of goose is during the autumn from August to November with a peak around the second half of October. South-eastern Öland is affected to a greater extent by the Barnacle Goose migration than Kalmar Sound itself (SOF 2002b).

In the annual reports of bird observations, migration peaks have been reported for the species from south-eastern Öland with high diurnal figures. On 11 October 1997 at Ottenby 50 000 birds were reported and at Segerstad on 24 September 2001 a southbound flight of 58000 birds was observed.

The spring migration of Barnacle Goose from their over-wintering quarters takes place from March to May, with peak reports in the Baltic Sea region of 36 000 migrant geese on 19 April 1994 at Ottenby on Öland and 62 000 from 10 to 13 May 2001 at Kåseberga in Scania (SOF 2002b).

Brent Goose *Branta bernicla*

The Brent Goose is a little black and grey goose that only feeds on vegetables such as herbs and grass for most of the year. It is probably during the winter season that it feeds mainly on grass wrack and other underwater plants in the marine shallows. The species does not breed in Sweden. All the Brent Goose that pass Kalmar Sound are birds that breed along the coastline of the Russian tundra and over-winter along the Atlantic coast or in the British Isles. The size of the population is estimated at about 250 000–300 000 individuals.

A considerable number of Brent Goose fly over the southern Baltic Sea and their migration has been described on several occasions, both spring and autumn, as like an avalanche for a few days (v. Hjort & Alerstam et al 1976). That these migrations of Brent Goose pass through the Kalmar Sound region in general without following the direction of the Sound is shown in the long satellite trackings that have been made from the overwintering quarters to the breeding quarters (Green et al 2002). Large numbers of Brent Goose have been observed in the area on several occasions, such as 53 000 at the northern headland of Öland on 27 May 1995, 35 000 on 26 May 2000 at Beijershamn, Öland and 24 000 on 27 May 2003 at Grönhögen, Öland (SOF 2002 and reports by the author). The highest spring observation that was made in one day during the project period was reported from Lilla Karlsö, southern Gotland on 25 May 2002 when 108 000 Brent Goose passed by. These had probably passed east of southern Öland during the night before they set their course directly for Gotland (Smittenberg & Hjernqvist 2003).

Crane *Grus grus*

Crane have increased in number throughout the whole country. Their number today is estimated at about 20 000 pairs (SOF 2002b). The Crane that from time to time pass over southern Kalmar Sound in large numbers are probably birds that breed somewhere in Sweden. Öland is the staging area for the species nearest Kalmar Sound, often with Mörbylångadalen as the centre, where nowadays up to ten thousand birds stage in autumn. The flight out from Öland occurs mainly over Ottenby for a few days in autumn, either in northerly or westerly winds (Pettersson 1991). The autumn migration of Crane over southern Kalmar Sound is observed mainly in north-easterly or easterly winds when the flight path from Öland crosses the Sound towards the mainland.

Johan Petersson observing at Olsäng

Wigeon *Anas penelope*

Wigeon is a medium-sized dabbling duck which feeds mainly on parts of plants which it grazes on land, and vegetation from the surface of the water along the shores. The species is a very rare breeding bird in southern Sweden, with a total of about 50 pairs on Öland, Gotland and in Scania.

Its main breeding area is to be found in the northernmost part of Sweden, in the mountains, inland and along the coast (Svensson et al 1999). The observations of ringed birds show that Wigeon migrating past southern Kalmar Sound and southern Öland come from breeding sites east of Sweden, mostly from Russia (Fransson & Pettersson 2001), and are on their way to overwintering quarters in western and southern Europe. The autumn migration culminates, as the older Ottenby material shows (Edelstam 1972), around the middle of September. This is confirmed by the annual report on highest migration figures by SOF, with peak days as on 13 September 2000 when 8 000 Wigeon passed Olsäng (SOF 2001) and on 24 and 25 September 2001 when 15 000 passed Utlängan and Torhamn headland in south-eastern Blekinge (SOF 2002). The older Ottenby data shows intensive autumn migration of Wigeon along the south-eastern coast of Öland. This was confirmed in more recent years when, for example, about 25 000 Wigeon were counted at Segerstad on 24 September 2001.

The spring migration of Wigeon in the southern Baltic Sea area is much less extensive than the autumn migration. Several peak observations for one day reported in SOF's Fågelåret are 800 Wigeon at Kåseberga in Scania on 30 March 2001 (SOF 2002) and 982 birds on 30 March 2002 at Kåseberga (SOF 2003).

Red-breasted Merganser *Mergus serrator*

The Red-breasted Merganser is a diving duck that feeds mainly on small fish and crustaceans which it catches in fairly shallow water. The Red-breasted Merganser is fairly common, breeding generally along a large part of the Swedish coast. It also occurs on lakes and streams inland, mainly in the northern part of the country.

The species may migrate in winter as far south as the Mediterranean, but the majority seem to choose the Atlantic coast off Denmark down to France (Fransson & Pettersson 2001). Many Red-breasted Merganser very probably overwinter in the southern Baltic Sea and the Kattegat.

The autumn migration in southern Kalmar Sound probably includes birds from breeding areas in Sweden and the Baltic Sea and there is nothing to suggest that these visitors come from far away. The autumn migration culminates in this region during October. Confirmation of this is perhaps the highest number observed in one day at Segerstad on Öland in this month: 4 000 Red-breasted Merganser observed on 7 October 2001. The highest number from Sandhammaren in Scania was also in October: 5039 birds observed on 23 October 2001 (SOF 2002).

The spring migration to the more southerly breeding sites obviously starts earlier as the species is seen at the breeding sites on Öland at the end of March. Migration in this region culminates with the highest day figures later in the spring, most likely because it is the northerly breeding populations that pass through the area at that time. Observations were made of 200 northbound migrant Red-breasted Merganser over Stora Rör (western Öland) on 29 April 2001, and 700 migrants were observed at Olsäng on 30 April 2001 (SOF 2001, plus the author's reports).

3 Methods

3.1 Project planning and different stages

In order to find out where in the Sound waterfowl fly in different conditions, it was considered necessary that ornithological monitoring should take place in three different places simultaneously. The study was focused on the three-week period each spring and autumn when waterfowl migration is at its most intense in Kalmar Sound.

Experience from the preliminary research period showed that it was more or less necessary to complement visual field observations with some form of radar data to monitor and describe bird migration routes near the wind farms in a satisfactory way. There were no radar trackings saved from the military surveillance radar in spring 1999 on southern Öland, so it was not possible to make radar-tracking comparisons of bird migration patterns before and after construction at Utgrunden. The visual observations of the spring migration in 1999, particularly those from Utgrunden lighthouse, still form a good basis for assessing and comparing changes in the distribution of the spring migration after construction at Utgrunden. Co-operation with the military authorities has since developed so that the project was able to obtain radar data a few months later from the radar stations on southern Öland and in Blekinge. In this way, radar trackings were available from some or all of the periods when field observations were carried out.

Stage 1 – autumn and winter 2000

The aim at this stage was to obtain information and knowledge about the extent and distribution of waterfowl migration in southern Kalmar Sound in autumn 2000. The areas around Utgrunden, where the wind farm construction was completed in the autumn, and around Yttre Stengrund, where wind farm construction was planned for 2001, were to be monitored, particularly with regard to staging birds. The aim was also to evaluate and assess the usefulness of military surveillance radar for the study of bird movements in the Sound.

Stage 2 – spring and autumn 2001

As the results from stage 1 showed a deficiency in the radar's sensitivity in providing details about the bird flocks' movements in the vicinity of the wind farms, further detailed information about those movement patterns was collected at this stage. A special optical rangefinder (v. section 3.2.5) was tested and used to follow some flocks' movements in more detail in the vicinity of the wind farms.

Stage 3 – spring and autumn 2002

In order to obtain radar trackings from reduced visibility migration days, radar films from longer periods in the spring and autumn were collected, which also included periods when field observations were not made.

Stage 4 – year 2003

This stage became possible when the project was extended for an extra year compared with the original plan. The research at this stage concentrated on increasing field data, increasing radar analyses and carrying out further flight altitude measurements.

3.2 Monitoring of migration flights

In order to make a thorough analysis of the impact of the wind farms on bird behaviour and migration patterns, investigations are essential both before and after their construction. The project was not started until the autumn of 2000 when the seven wind turbines at Utgrunden were erected. They were in operation during the first observation period in October. There was however a preliminary study made in spring 1999 with good observation coverage. At the wind farm site, Yttre Stengrund, studies of the autumn 2000 and spring 2001 migration could be carried out before construction started in summer 2001. As Eider is the predominant waterfowl species migrating through Kalmar Sound, their main migration period was chosen as the observation period for both autumn and spring studies. Observations of all other waterfowl species occurring were also collected, but Eider had priority over gulls and terns for example, which were included during these periods whenever there was time. The monitoring periods only included early mornings and mornings when there was migratory activity. However, the observer that was stationed at Utgrunden lighthouse covered the whole day in his observations almost every day during the period. This observation material was not used to show the distribution of migration corridors over the width of the sound, but was used primarily to document and, through correlation with radar analysis and optical rangefinder trackings, to describe how flocks of different species and size fly near the wind turbines.

3.2.1 Field observations

Throughout the whole of the project, the observation periods were 22 March – 8 April and 6 – 28 October. These observation periods were chosen to cover the most intense Eider migration in the area. Observations were also made on separate days or several consecutive days from one of the observation sites.

Observations started each day just before dawn. An hour or so after dawn the observers made a joint assessment by telephone of the current migration intensity and the conditions for continued migration, and came to an agreement about when to end the day's observations. The "stationary" observer at Utgrunden lighthouse, however, tried to cover as many daylight hours as possible to obtain information on the extent of migratory activity in the Sound during the daytime. When the other observation sites were unmanned the Utgrunden observer also tried to observe large flocks along the shores of the Sound. In this way, radar information could be correlated with visual data for periods without complete observer coverage at all observation sites.

There were three sites selected for visual field observations: Eckelsudde north of Degerhamn on Öland, Styrsholm Udde at Olsäng in northeast Blekinge and Utgrunden Lighthouse in the middle of Kalmar Sound (see Figure 3). The choice of sites was made to cover the whole of the sound and so that the existing and planned wind farms at Utgrunden and Yttre Stengrund could be monitored from as closely as possible.

Before the observations were started at each observation site, a survey was carried out of suitable points of reference such as navigation marks in the sound and landmarks. With the aid of these, an observation line could be drawn up along whose length each bird flock's passage could be recorded. At each observation site a zone division was made along the observation line. A rough zone division with about 5 kilometre wide zones (zone A-D) was made which covered the whole Sound, including a narrow band of coast on both sides of the Sound (Figure 3). In order to make more detailed observations of the flight path, these 5 kilometre zones at each observation site were divided into 1–2 kilometre wide zones (zones 1–5, Figure 7). After an optical rangefinder (see description section 2.2.5) was borrowed in autumn 2001, all distances to reference points and zone divisions were calibrated to within 10–100 metres.

The exact time (to within a minute) for the separate bird flocks' passage of the observation line was written in the observers' records. The time of day in the records has been adjusted to normal Swedish time (GMT+1h) for the point in time when the radar observations and weather data were received, or adjusted to this time. All waterfowl, in flocks or single birds, plus single birds of prey were always recorded. Various gulls in dense flocks were always recorded, while gulls in sparser flocks were only recorded when there was time to do so. All waterfowl flocks were identified by species and if the species' identification was doubtful either the group name was given or a question mark was written after the name of the species. For cases with lower migration intensities and when the migration mainly consisted of smaller flocks, the observer usually had time to count all the individuals. Often however an estimate of the numbers had to be made and the flock was then divided into groups

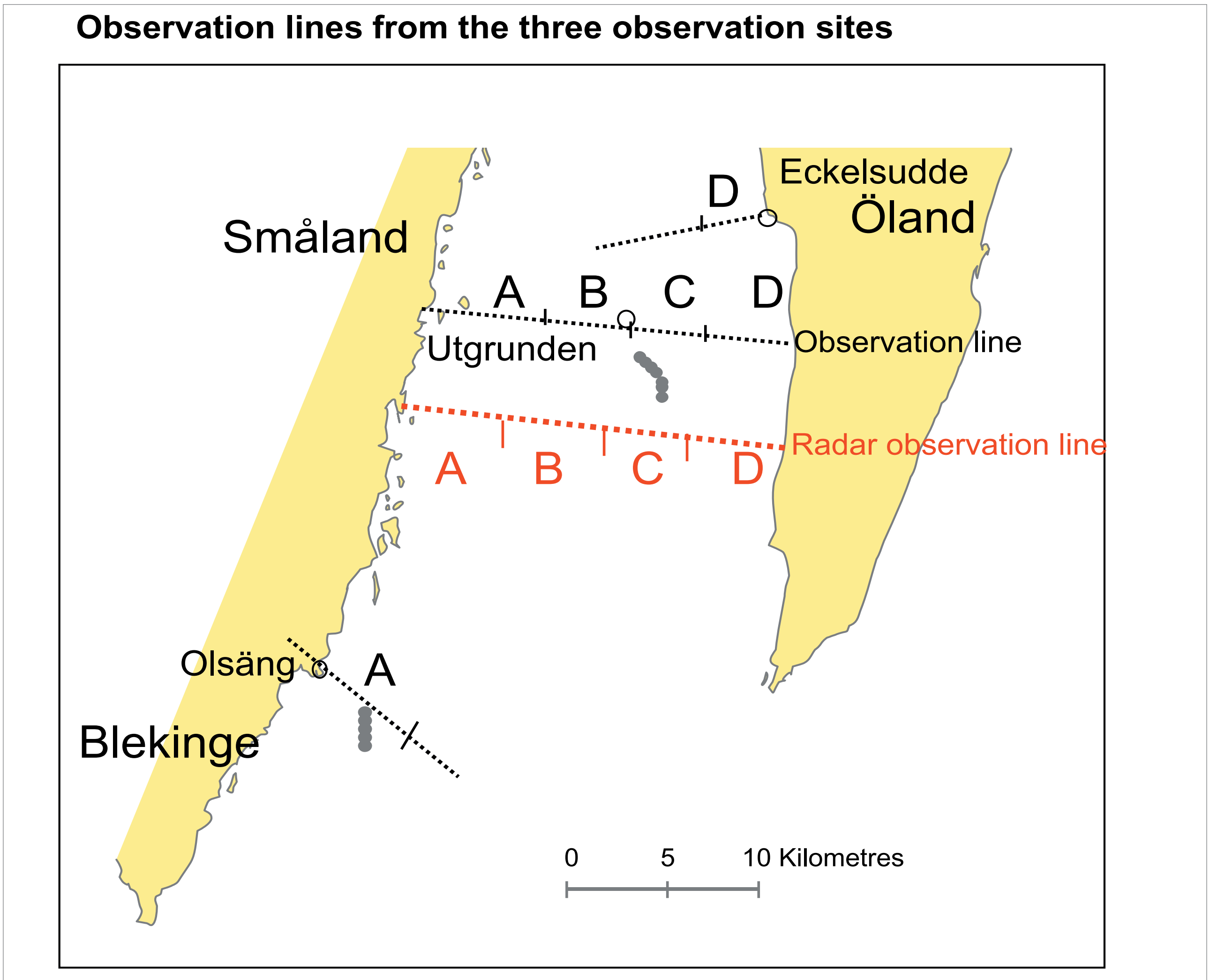


Figure 3 Map of southern Kalmar Sound showing the three observation sites with observation lines and the accumulated observation line across the Sound with the four zones A–D, each five kilometres wide. The red line is the observation line used for recording radar echoes from migrant waterfowl during the spring.

of five or more individuals. When making such an estimate the birds are counted as whole units of ten. Flocks that turn, hesitate, behave abnormally, or cross the Sound in an easterly-westerly direction or vice versa have only been recorded when they crossed the observation line.

All recordings in the field were made on pre-printed forms where each flock was noted for time, species, number of birds, zone, flight altitude and direction. Flight altitude was estimated in 10 to 50-metre intervals (0=0–9 metres; 1=10–19 metres, from 50 metres 50–100, 100–150 etc). As reference points for flight altitude observers used assessment boats, existing wind turbines or other height reference points in the vicinity of the observation site. With the aid of the optical rangefinder these reference points were measured to within 10–20 metres and from autumn 2001 it was possible to estimate altitudes with greater accuracy at all the observation sites.

When dense waterfowl migration occurs, the observers were to take care not to count or note flocks as one unit when they flew near each other, but to record them as separate flocks as stated in their instructions. If flocks flew as near as 30 metres to each other this was to be recorded in the notes with a connecting dash. This is important as the observation material was to be compared with radar trackings and the flock separation which could be made at that stage. When there is high migration intensity it was sometimes necessary to use a simplified recording procedure where only time, number, zone and altitude were recorded and the other information was filled in later, or, alternatively, the most important information was recorded on tape to be transferred later to the form.

Estimation of the number of flocks, the assessment of where they were flying and assessments of distance and altitude were calibrated on several occasions between the observers, particularly during the time of recorded migration when it was possible to calibrate the flock sizes by telephone contact. Differences in the estimates of numbers could occur, for example, as a result of distance, as flocks that were further away from the observer may seem to have contained a smaller number of birds. On those occasions when flocks were recorded by several observers and there were differences in the estimates of numbers, the number recorded by the nearest observer was judged to be the most accurate. Differences between observers estimate's of distance and altitude were found, but since autumn 2001 this was corrected with the aid of the optical rangefinder and observers consciously worked to co-ordinate assessments for each season throughout the studies.

Observers noted in their recordings basic types of weather information such as rain, fog, and mist, and when these weather events started or ended at the observation line. The observer at Utgrunden lighthouse wrote a weather report each hour (every quarter in 1999) plus an assessment of the wave height and visibility conditions (see also under weather data).

The observers were equipped with binoculars (10x magnification), a telescope (20–60x magnification), a watch, mobile telephone, pre-printed forms and pens, and at two of the observation sites a micro tape-reorder. Since autumn 2001 the observer at Utgrunden lighthouse had the use of an optical rangefinder. For certain observation times outside the intensive observation period this instrument was also used at Olsäng and Yttre Stengrund.

The observers employed all had at least ten years of ornithological experience of waterfowl migration and counting and were all active amateur ornithologists on Öland. It was generally the same observers that carried out these counts each season with Lennart Carlsson at Eckelsudde, Johan Petersson at Olsäng and the author at Utgrunden lighthouse, occasionally with the assistance of Åsa Bodenmalm. In spring 2001 the observations at Olsäng were made by Johan Joelsson. Lennart Carlsson at Eckelsudde was relieved mainly by Mats Wallin and for shorter periods by Jonas Johansson and Björn Sigurdsson.

3.2.2 Evaluation of field observations during the spring and autumn migration

The report and conclusions about waterfowl migration distribution in Kalmar Sound is based only on observations from those occasions and time periods when observations could be made and recorded all over the Sound at the same time. In Table 1 there is a compilation of the number of 15-minute periods day by day during observation periods when the visibility conditions were such that they allowed an overall coverage of observations for the whole of southern Kalmar Sound. As a rule this overall coverage of observations required all three observation sites to be manned. In general, all three observation sites were manned simultaneously only during early mornings and mornings as it is usually at this time of the day when the most intensive waterfowl migration takes place. Observations were made during most of the daylight hours from the observation site at Utgrunden lighthouse. During daylight hours when all observers were at their posts, the observer at Utgrunden concentrated on migration through zones B and C and on detailed observations of the flocks' choice of flight path and behaviour in the vicinity of the wind turbines. On these occasions the observer at Eckelsudden covered zone D and the observer at Olsäng zone A (Figure 3). During spring 1999 migration was monitored in the whole of the Sound by two observers at Utgrunden. In order to avoid double counts during periods with several observers, special attention was directed to bird flocks that flew in the boundary areas between the different observers' "responsibility zones", or the boundary areas C/D and A/B. On some occasions observers correlated their observations by mobile telephone. A good estimate of the risk of double counts was obtained later when the data were compiled for all crossings over the observation line and through radar tracking. A particular double-count risk occurred during the spring for flocks that passed near the coastline through zone A at Olsäng and turned towards Utgrunden so that they then passed through zone B, which only happens in tailwinds to any great extent (Figure 13). In the compilation for the whole of the Sound, these flocks were removed from zone A and were only reported for zone B at Utgrunden. These flocks, Number of 15-minute periods with observations

Spring	March 22	23	24	25	26	27	28	29	30	31	April 1	2	3	4	5	6	7	8	Total
1999								31	54	54	29	30	49	53	22				**322**
2001		18			9	18	27	10	10	25	17	10	18		24				**186**
2002								22	20	19	18	18	14	22	18	7	16		**174**
2003				26	17	21	15	23	24	24	25	11	18	16	20	12	16	10	**278**

Table 1 Number of 15minute periods with full coverage observations in southern Kalmar Sound during spring seasons for the whole study periods 1999–2003. The periods marked in yellow show when monitoring took place and the figures show the number of quarters when full coverage observations were possible in daytime in good visibility.

however, were reported in zone A in the local recordings for Olsäng. When revising and reporting the whole of the Kalmar Sound data, a total of only 3 per cent of recorded flocks were removed to eliminate the risk of double counts. Assessment of the distribution of migrating birds in the Sound during the night and in poor visibility was only possible through radar studies (v. section 4.3.2).

In this final report all the observation material was re-calculated so that the number of passing birds is reported at 15-minute intervals. In earlier partial reports (Pettersson 2001, 2002 and 2003) the number of birds per hour was stated instead. This more detailed report was made possible, as the available weather data were so accurate that the weather situation for every quarter of an hour could be produced and reported. Thus, it was also possible to compare this data with the extensive waterfowl study made in Denmark as a preliminary study of the bird situation before construction of a large planned wind farm (Kahlert et al 2002). The division of time into 15-minute intervals selected in the Danish study should function as a standard pattern, so that it will be possible to make direct comparisons between this and similar studies in the future.

During periods when total coverage of observations of the Sound with three observers did take place (Tables 1 and 2), the observer at Utgrunden lighthouse limited his observations to the two nearest 5-kilometre zones B and C. The observers at Eckelsudde and Olsäng then concentrated on their observation zones, D and A respectively (see zone division in Figure 3). During the afternoons and evenings, when the migration intensity is usually lower, the observer at Utgrunden still tried to cover the whole of the Sound. These solo observations did not, however, fulfil the requirements for full-coverage observations and are not included in the reported full-coverage observation material.

In order to avoid double counts, the exact time for the flocks crossing the observation line was recorded and later, in doubtful cases, a comparative reading of observers' reports was made. The observers sometimes kept contact by mobile telephone in order to follow the flocks that were moving in the border area between different zones. During the autumn the risk of double counts was greatest between Eckelsudde and Utgrunden, but mainly it appeared that flocks flying near Öland on observation from Eckelsudde kept their position near to Öland when they continued out into the Sound, see Figure 3 and Figure 37. A certain risk of double counts arose between flocks through Utgrunden, zone B, and flocks flying in the outer parts of zone A at Olsäng. Most of the observed flocks retained their migration position within the zone however, and only a few flocks could possibly have been counted twice there. There was also a risk of double counts of flocks that crossed over the Sound from east to west and thus passed the observation sites twice or even all three times. Most of the flocks observed with such a flight path were only recorded when passing the northernmost observation line and were omitted as much as possible from other observations. Between 10 and 20 flocks in total were removed. When presenting observations from the separate sites, these flocks were included to show the correct local flight distribution.

3.2.3 Military surveillance radar

In order to study the course of nocturnal migration and to analyse the extent of the migration in poor visibility in southern Kalmar Sound, two of the surveillance radar units of the Swedish Armed Forces were used. The units, which are situated on southern Öland and in Blekinge, are designed for military reconnaissance, which means that coverage of bird movements is seldom complete. Radar data is stored digitally by the Swedish Armed Forces for

Number of 15-minute periods with observations

Autumn	Ootober 3	4	5	6	7	8	9	0	111	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	Total
2000			21								10	25	8	24	12		18	8		13	8				17	**164**
2001					10	22	10	17						10	25	20	24	16	24	16	23	9				**226**
2002										25	12	8	13	11	10	27	15	20	7	13		15	12	12		**200**

Table 2 Number of 15minute periods with full coverage observations in southern Kalmar Sound during autumn seasons of the study periods 2000–2002. The periods marked in yellow show when monitoring took place and the figures show the number of quarters when full coverage observations were possible in daytime in good visibility.

subsequent transfer to VHS tapes. Everything that moves across the landscape and reflects radar waves appears as dots on these tapes, so-called radar echoes. In general there is a filter function in the system which removes stationary echoes. That is, all metal objects (for example airplanes and boats), but also objects that contain water (for example, living creatures such as birds) produce radar echoes, so it is possible to track their movements with radar equipment.

Radar has been used with great success in bird migration research for the last 40 years (v. Eastwood 1967 and Alerstam 1978 and 1982 for further details on this technique and fields of application). As it is mainly the three types of object mentioned above (airplanes, boats and birds) that give radar echoes in the Kalmar Sound area, it is necessary to have procedures to distinguish between them. This is relatively easy as the speed at which the three move generally differs greatly. Airplanes fly at 150–1000 kph, boats sail at up to 30 kph and birds fly at 30–130 kph.

The VHS tapes can be analysed with regard to the number of radar echoes (i.e. migration intensity), flight direction, flight speed, etc. It is possible to study particular flight behaviour, for example on encountering a wind farm, if not yet in detail. The current surveillance radar units do not respond to all bird groups. Small birds that fly alone, for example nocturnally migrating passerines, do not give any radar echoes, quite simply because the birds are too small. It is possible to track flocks of small birds, however. Thus, the migration patterns which can be studied with current radar data are those of larger birds and birds that migrate in flocks. In general it is large birds flying in large flocks that give the clearest radar echoes. The method is therefore very suitable for migrant waterfowl (ducks, geese and waders). The current study showed that flocks must have a certain minimum size to produce radar echoes (see below). Moreover, radar does not show bird movements at the lowest altitudes (<5 m) due to interference problems from the water surface and the relatively small bodies of the birds. On the other hand, radar covers higher altitudes where migrant birds normally fly, at least when it concerns larger flocks. It is not possible to estimate altitude with these surveillance radar units.

The path of the flock (the radar echo) can be plotted as a track on a map and thus a relatively accurate flight path for the bird flock can be drawn. In this study we chose mainly to compare radar echoes from the supposed bird flocks with visual field observations and, together with comparisons of time, were able to judge whether the visually observed flocks were identified as radar echoes or not. To be entirely sure that it was is the same flock that the observer and the radar detected, at least one radar echo had to be recorded every third minute (the flock would have flown about 3km in this time). This method enabled a large proportion of the radar trackings that had been observed with the aid of film data from the military radar units to be identified, the bird

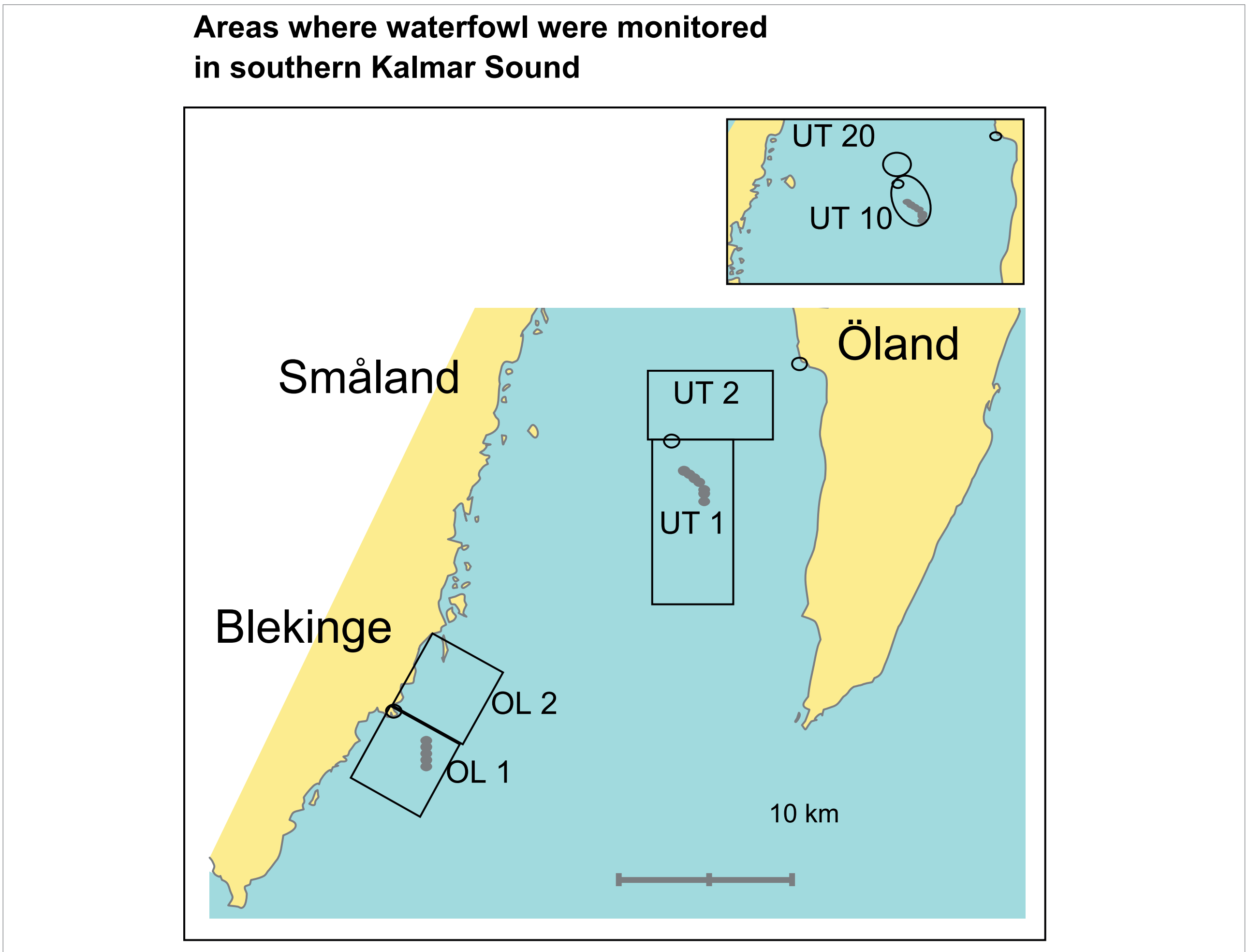


Figure 4 The four slightly larger areas were chosen to enable a boat or air survey and observations from the lighthouse or from land (the Blekinge coast). The study areas UT 10 and UT 20 can only be monitored from the lighthouse at Utgrunden and at the same time they are the most studied areas with regard to waterfowl.

species determined and furnished with information on the size and flight altitude of the flock and the zones through which the birds had flown.

This type of surveillance radar cannot, however, cover waterfowl migration completely. The reason for this is that migrant waterfowl often fly very low over the water and in such small flocks that they do not produce any echoes. This resulted in evaluation of radar material during from limited periods of time ranging from 6–15 days per migration season, and in total 29 days and 26 nights.

Sound under different conditions with the aid of the available radar units. This somewhat coarse method functions as follows: a radar observation line was drawn across the Sound (about 7 km south of the ordinary observation line) and the flock was judged to have passed this line when a bird echo was identified on either side of the line (”radar track over a transect”). For the radar echo to be classified as a bird echo at least one echo every fourth minute must be reported. With this method of analysis it was possible to register 21 per cent of the total number of flocks at this

Radar observed waterfowl migration in number of 15-minute periods

	2001				2002				2003			
	Daytime		Night		Daytime		Night		Daytime		Night	
Date	Good	Mist/fog	Good	Mist	Good	Mist/fog	Good	Mist	Good	Mist/fog	Good	Mist
25.3									47		13	5
26.3									39	7	27	12
27.3									45		39	
28.3									55		39	
29.3									34	8	38	
30.3									44		38	
31.3	24	27	20	21					38		37	
1.4	19	33	27	14					32		36	
2.4	23	15	41						24	24	28	10
3.4	32	9	24		23	26	16		29		36	
4.4	3	24			45		39		45		37	
5.4	47		40		38		39		42	7*	36	
6.4	27		24		56		38		28	15*	37	
7.4					58		38		44		22	
8.4					25		23		12			
Sum	175	108	176	35	245	26	193		558	39	263	27
										22*		

Table 3 Number of 15minute periods (”quarters”) over 24 hours when migration was monitored with distribution in different visibility conditions. A total of 1867 periods of 15 minutes were monitored.
* shows a total of 22 quarters when heavy snow showers reduced visibility in the Sound during the day. Visibility conditions were referred to as mist or fog.

Radar material from both day and night within the same 24 hours was used and compared when analysing the proportion of waterfowl migration at night and in fog in comparison with diurnal migration in good visibility. For best analysis results, the 24-hour periods selected were when there was radar coverage over the Sound at the same time as complete coverage by field observations during the day. In this final report a new and partly amended evaluation of the observation data was carried out with respect to the figures for 24-hour periods as well as the choice of division into different periods of time during those 24 hours. Total figures and partial figures for the various 24-hour sections are reported differently from those in the partial reports.

If only long radar trackings of bird flocks (at least one echo per minute over 45 minutes) are used to describe the extent of the spring migration in southern Kalmar Sound, this means that only one per cent of the total number of flocks counted using field observations could be distinguished as radar echoes. Thus another internationally used method was used to study spring migration and its distribution in the line (compared with field observations). Altogether during three spring seasons 1400 flocks were recorded with this method, while only about one hundred were recorded by long radar tracking. The method of using a radar observation line, with its larger amount of data, provides a better basis for assessing the spring migration distribution in the Sound in different conditions than the method requiring long radar trackings. For Eider flocks to be recorded as long trackings on radar, the flock must consist of at least 100 birds and the flight altitude in the middle of the Sound must be at least 40 metres or higher. With the coarser method of analysis it appeared that the radar would record flocks of 45 or more Eider as long as their flight altitude was over 20 metres. In the radar analysis of autumn data, however, only the method with long radar trackings was used. This was because the average flock of migrant waterfowl in Kalmar Sound during the autumn was much larger and was therefore more easily recorded by the radar.

3.2.4 Evaluation of field observations during spring and autumn migration

Spring migration

Information about the path of spring migration gained with the aid of radar data, especially in fog, mist or at night when visual observation not feasible, shows that radar is a superior study method. The pitfall with radar surveillance in this area is the very low altitude of the waterfowl, on average 10–40 metres above sea level, and moreover in relatively small flocks. For all of the waterfowl flocks observed in this study in spring migration (17462 flocks) the average size of flock was 28 birds (the median size of flock was 40 birds for all flocks together), which made it difficult to observe most waterfowl flocks on radar. This means that no matter how we analyse data, even using descriptive counts at a radar observation line, we still only receive radar information about large flocks flying at a reasonably high altitude.

Radar coverage was better in spring 2003 when all 15 days and 12 nights could be mostly covered by radar observations (Table 4), compared with 6-8 days and 6 nights each in spring 2000 and 2001. These radar interpretations were also cross-referenced with observation information about the weather. Information about fog and mist during the day for the whole area was based on reports on the conditions at Utgrunden, where the observer recorded visibility and weather information every hour.

Autumn migration

Radar trackings of flocks were mainly used to get a clear picture of where birds occurred in the Sound. It was a complement to information that visual observations passed on about bird distribution in the Sound. Radar observations were also used to obtain information on the overall extent of migration in times when we cannot make direct observations – mostly in fog and mist and at night. On the other hand, nocturnal radar surveillance was only carried out when there were periods of both overall radar coverage and visual observation during the previous day in light conditions. Observations and recording of fog and mist were made at all the observation sites, but in this study only hourly observations from Utgrunden were used, meaning that on some occasions visibility could have been better or worse at the other two observation sites. In order to determine whether there had been mist or fog during the night, humidity data was acquired from the SMHI (Swedish Meteorological and Hydrological Institute) meteorological station on the southern headland of Öland.

In the autumn studies, the only radar analysis method used was direct tracking of flocks since they are generally larger than spring flocks. Autumn Eider migration has an average of 75 Eider per flock. However, the same problem exists as in spring, namely that flocks often fly too low for surveillance radar to record them.

In Table 4 shows total time used for radar studies for the whole project. The number of quarters radar surveillance carried out are divided into day and night in different visibility conditions.

Military surveillance radar cannot track waterfowl flocks close to or between the wind turbines. This type of radar can only provide data from some of the flocks that fly closer than 200–500 metres. In addition, as pointed out above, only a small proportion of waterfowl flocks can be recorded using this type of radar with its limited resolution.

3.2.5 Position and altitude measurements

A most important step in estimating collision risk was made in autumn 2001 when the Zoo-ecological Department of Lund University lent us an optical rangefinder (WILD,

Radar observed waterfowl migration in number of 15-minute periods

	2000				2001				2002			
	Daytime		Night		Daytime		Night		Daytime		Night	
Date	Good	Mist/fog	Good	Mist	Good	Mist/fog	Good	Mist	Good	Mist/fog	Good	Mist
12.10									36		20	
13.10	14	28		20					35		48	
14.10	27	8	30	18					35		48	
15.10	12	30	40						26	7	48	
16.10	40		40						41		40	8
17.10	7	33	15	33	43		14		34		48	
18.10		42		28	40		44		30	12	48	
19.10					44		48		37		48	
20.10					40		38		41		48	
21.10					42		34		36		48	
22.10					32	16	33	7	23		48	
23.10					18		18		12	32	43	5
24.10									37		48	
25.10									35		10	
26.10			20						12		26	
27.10	19		48									
Sum	119	141	193	99	259	16	229	7	470	51	619	13

Table 4 Number of 15 minute periods when migration was monitored over 24 hours with distribution in different visibility conditions.

80 cm, 11.25x magnification) to measure flight altitudes and determine the position of flocks flying near the wind turbines. The instrument was mounted on a stable tripod and supplied with scales for reading horizontal and vertical angles. The instrument can measure the distance to a bird flock within about 10 metres from a distance of up to 500 metres and 100 metres at a distance of 2000 metres or more. The greatest distance that the instrument measured was about 4000 metres. Reported uncertainties were obtained through different studies at the Ecological Department of Lund University (M. Green, pers. com.).

The instrument can measure the flight altitude of a bird flock by reading the altitude angle of the instrument to within half a degree. From localization and altitude above sea level of the observation site (27 metres at Utgrunden lighthouse) the position of a bird flock can be plotted, giving almost the same information as that obtained from a small radar unit. From the flock's distance and position, the flight altitude can be calculated afterwards by means of simple vector mathematics to within 10–50 metres (uncertainty is dependent on the distance, see above).

The instrument was first used for measuring the movements of waterfowl flocks in autumn 2001. A testing, learning and experience phase produced good, detailed flock tracking data from spring 2002 onwards. As it takes time to read and note data for distance, times and angles, primary data were partly recorded on a tape recorder and written down later. The fastest and most effective performance achieved with these instruments is when two people operate them, as was the case in spring 2003 at Utgrunden lighthouse. After tracking a large number of flocks the author gradually increased his skills and was able to read flock positions every 20 seconds at best, or every 35 seconds on average, which can usually give a good picture of the flock's true flight path. By tracking a flock in the viewfinder, adjusting the distance screw (parallel motion displacement in the viewfinder) and recording distance, angles and time, a whole series of altitude and position definitions for the flock can subsequently be obtained.

This technique was developed at Lund University and is used to measure and record flight speeds and altitudes for many different kinds of bird flight; for example, the Eleonora falcon when hunting (Hedenström et al 1998). With this instrument, the technique of recording flocks passing a pre-determined position can be used, enabling a large amount of data to be quickly collected on flocks' distance from the wind turbines and their flight altitude. This alone, however, does not describe their movement. A large amount of such material was collected during spring and autumn of 2002. Data collected later concentrated on tracking flocks. In order to add to data on how flocks fly in the vicinity of the wind turbines, flock tracking was carried out in autumn 2003 at Olsäng. When the project started to use the rangefinder, a detailed map of the location of the wind farms was used to record positions of flocks being tracked, parallel with the reports from field observations. At the same time as flock was measured, the observer quickly drew on the map his impression of the flock's migration. As this notation on the map could be made very quickly, the method was also used for some flocks when there was no time to make a reading with the instrument. The author found after some practice that the correlation between quick map notation and instrument calculation of the flight path was satisfactory. However, only a few of these results were included in the account below.

In order to have time to measure the flight altitude of flocks near the wind turbines in autumn 2002, measurements was made at Yttre Stengrund at three pre-determined points: one kilometre before the wind turbines, level with the wind turbines and one kilometre after the passing the wind turbines.

3.3 Surveys of staging waterfowl

The areas chosen to study possible disturbances of staging waterfowl by the wind turbines are situated in the vicinity of the wind farm areas at Utgrunden and Yttre Stengrund, and immediately north of these (Figure 4). The areas were chosen so that the studies could be carried out simultaneously and conditions would be as similar as possible in the reference and wind farm areas. All the study areas were offshore, separate from the coastal staging areas which often have better conditions than the open shoal areas. The surveys and studies of the behaviour of staging birds were co-coordinated as far as possible with migration studies at Utgrunden and Yttre Stengrund. In addition, studies of staging birds were also made on other occasions in all the study areas, especially at Utgrunden. Counts and positioning are better made in calm weather conditions with fewer wave formations.

During the preliminary part of the project in autumn 2000 and spring 2001, aerial surveys were carried out on three occasions. A Cessna 172 was used for these surveys: a high-winged type of aircraft suitable for making surveys of birds. These surveys required good weather conditions and good visibility. They were carried out as line transects along pre-determined north-south lines through the area. The flight speed when making the surveys was about 150 km/h and the flight altitude was approximately 100 metres. There were usually two observers in the aircraft, enabling observations from both sides. The counted and recorded waterfowl were marked on the map as well as in the records. In order to check the accuracy of aerial surveys, a terrestrial count of staging birds was made on the shore strip between Eckelsudde and Mörbylånga the day after an aerial survey. The result is described in the report.

Counts of staging and wintering birds were also carried out from boats during the first autumn/winter and spring season of 2000–2001. These counts were made by one observer. Two observation boats were used: a 14-metre long boat from the Swedish Lifeboat Service and an 8-metre fishing boat. The observer was equipped with binoculars (10x40). All observations were plotted on a sea chart. When making observations from the Swedish Lifeboat Service boat which had GPS, a more flock positions could be noted with greater accuracy.

After the surveys of staging and wintering birds had been carried out during winter 2000–2001, the aerial and maritime surveys gave such limited information that it was decided to concentrate on monitoring numbers of birds and their behaviour in the immediate vicinity of the wind turbines, in addition to observations of migration. Regular counts of staging waterfowl have been made since 1969 along the whole of the Baltic Sea coast. From this large amount of data, Leif Nilsson made a special compilation for this project of the counts from the stretch of coastline in southern Kalmar Sound (Nilsson 2003).

3.4 Positioning staging waterfowl flocks

In order to chart in detail where the staging and foraging birds are to be found in each area, accurate data for positioning the flocks were collected during the periods when an observer was at Utgrunden lighthouse to survey migration. Measurements were only carried out when weather conditions allowed monitoring of the whole Utgrunden area (UT 10, Figure 4) and the reference area just north of the lighthouse (UT20, Figure 4). Position data were produced in spring 1999, autumn 2000 and spring 2001 with the aid of a compass and estimates of the distance from the lighthouse using the many features in the sea round the bank. From autumn 2001 until spring 2003, all the position data were obtained using the optical rangefinder, with an error of between 10–100 metres depending on the distance. The furthest position data are about 5000 metres distant from the observation site and the measurement error was just over 100 metres.

Detailed data were collected as early as spring 1999 to chart the places used by resting and foraging birds in each area in relation to the projected wind farm area at Utgrunden. The exact positions of the birds were recorded with the aid of a compass, a sea chart and a distance estimate using features in the sea. However, from spring 2001 the flocks' positions were measured using the optical rangefinder described above. These position observations were made in spring and autumn and particularly in the areas nearest Utgrunden lighthouse and on those occasions when an observer was at his post on the lighthouse. Not all the original areas UT 1 and UT 2 were covered by these detailed studies as the position data were limited to sections that were within the range of the instrument. The areas that were studied in detail were therefore named UT 10 and UT 20, these being sub-sections of UT 1 and UT 2. It was mostly during hours and days when the weather was been relatively calm that these counts and position assessments were possible. They were mainly carried out in the afternoon when migration monitoring was somewhat calmer and there was time to make these observations.

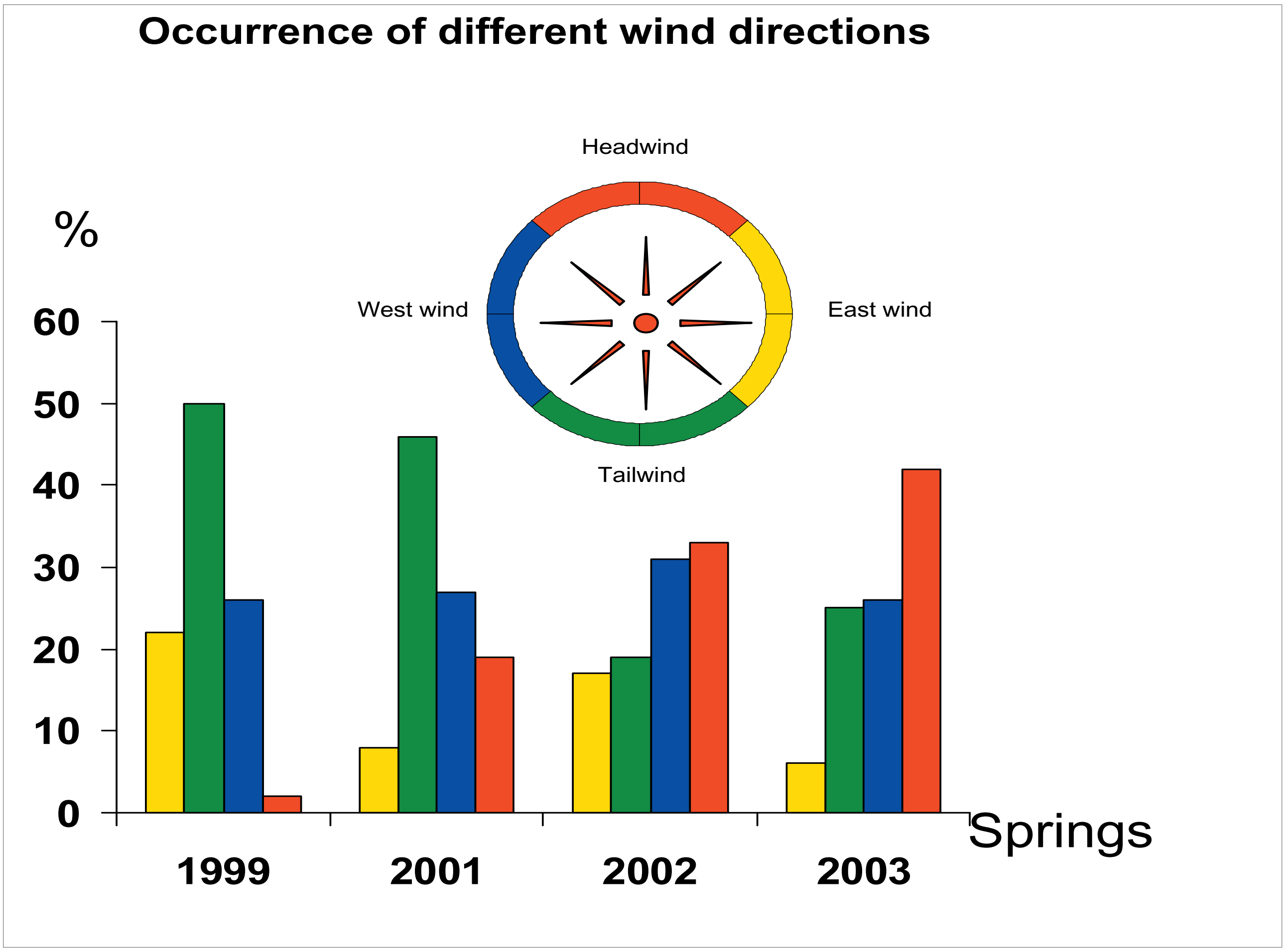


Figure 5 Distribution of wind directions during the whole project period. The wind distribution data includes only times when full coverage observations for Kalmar Sound were possible (see table 1).

3.5 Meteorological data

Information about wind direction and speed were obtained as an average for each 5-minute interval. There are continuous data from all observation sites, but in spring 2002 there were no data from the first days in March, so these days were excluded from the wind analysis. The measurements come from a meteorological mast installed on the top of Utgrunden lighthouse in February 2000, with instruments at a height of 38 metres above sea level. The wind data were obtained in detail from the Meteorological Department of Uppsala University, which collects and records all wind data from the measuring station. In spring 1999 data were only obtained every half hour from measurements at a slightly lower level (28 metres above sea level) collected by the observers at Utgrunden. All these wind data, for wind direction and speed, were re-calculated as an average value for each 15-minute period of a direction value and number of metres/second, which were used for all of the migration data as the lowest unit of time in accordance with the Danish studies (Kahlert et al 2002).

In the evaluations, all the re-calculated wind data were validated for all three observation sites in the Sound. This procedure was not entirely correct as a change in the wind, the extent of which is dependent on whether the wind comes from the north or the south, has a certain time lag between the wind farms. There was no assessment of these relatively small time lags. On those occasions when observers recorded a change in the weather this was been entered into the database. Fog (defined as visibility of less than 300 metres) and mist (visibility between 300 and 2000 metres) was only estimated by the observer at Utgrunden lighthouse, who recorded this every hour during the hours of daylight.

In order to obtain information regarding poor night-time visibility when radar films were analysed, humidity data for those nights were obtained from the SMHI weather station on the southern headland of Öland, situated about 22 kilometres SE of Utgrunden lighthouse. High humidity figures most often occur when there is mist (more than 65% water/ unit of air) or fog (more than 75% water/unit of air) and consequently visibility is reduced. Naturally this is a rough measure to estimate reduced visibility as different types of rain also produce high humidity, but there were no other usable types of data available. At the beginning of most nights the observer at Utgrunden lighthouse checked whether the light on the nearest wind turbine 2600 metres away could be distinguished or not. On two nights when visibility was recorded as reduced at Utgrunden this correlated with simultaneous data on high humidity at the weather station on the southern headland of Öland (probably mist or fog but is described in the report as mist). It was difficult to assess the extent of reduction in visibility during these hours and it is even more difficult to know how much it might affect migrating birds.

3.5.1 Evaluation of wind data

Wind data, as mentioned above, were obtained from the anemometer at Utgrunden lighthouse (38 metres above sea level) and were considered valid for all observation sites for that time or time interval. The wind types were been divided into four groups: easterly winds, headwinds, westerly winds and tailwinds with a 90-degree range as shown in Figure 5. This follows the international standard (see Green et al 2003 and Kahlert et al 2002). The direction of the wind was measured to within a tenth of a degree and the wind speed within two decimal places, but whole numbers were used as the smallest unit. Naturally there are great differences in the occurrence of different wind types in the spring seasons of the project period (Figure 5). In general, spring 1999 was a period almost devoid of headwinds. In spring 2001 they occurred 20 per cent of the time. During both study periods in spring 2002 and 2003, headwinds were the prevailing type for more than 30 per cent of the time, but there were fewer tailwinds. Wind speed was divided into three groups: 1–3 m/s, 4–8 m/s and >9 m/s. These categories follow an international standard used in a series of articles on migrant birds' wind dependency (see Alerstam 1978 and 1982).

Table 5 shows the average wind speed at Utgrunden for the spring seasons of the study period in different visibility conditions around the clock averaged at 15-minute intervals. During foggy days it is less windy than in clear

Average wind force [m/sek]

	Daytime good visibility			Daytime mist			Daytime fog			Night		
Springs	n	m	sd	n	m	sd	n	m	sd	n	m	sd
2001	175	**9.4**	1.1	42	**7.3**	0.8	66	**7.1**	0.8	211	**7.1**	1.2
2002	245	**6.2**	1.8	7	**3.0**	1.1	17	**4.5**	0.9	193	**5.8**	1.7
2003	558	**8.4**	1.1	24	**3.3**	0.8	15	**4.9**	1.1	490	**7.6**	1.2
Total	978	**8.0**	1.2	73	**5.5**	0.9	98	**6.3**	1.0	894	**7.1**	1.3

Table 5 Average wind speed in different visibility conditions, both day and night, for all 1867 quarters. The number of quarters on which this material is based is shown under "n", while "m" shows the wind speed as m/s and "sd" shows the standard deviation.

conditions, and in the spring it is somewhat less windy at night than by day.

3.6 Quality control and statistical analyses

The field data was collected by experienced observers and assessors of bird migration, and instructions were followed exactly to ensure uniformity of observations and recordings. There was no need for re-evaluation. The observers themselves entered their recorded values and cross-checked them with the original forms or tape-recordings. The evaluation followed the internationally approved division of time (Kahlert et al 2002) and wind data (Green et al 2003). Martin Green gave advice on radar data evaluation, otherwise the rules made by Gudmundsson et al (1995) were followed, as were the norms for reporting radar data from the Swedish Armed Forces radar stations. Statistical tests followed the evaluation made for the areas in Denmark in which offshore wind farms were planned (Kahlert et al 2002). The statistical tests used in this report were chosen from those recommended for biological data (Ennos 2000). The computer-aided statistical tests were done with SPSS for Windows (version 10.0.4). All reports of observation data used the quarter (15-minute period) as the time unit. In all reports, compilations, analyses and revisions, the number of birds and flocks of birds for each separate quarter was used throughout. Thus no average values for hours, wind periods, other types of periods or whole seasons were included or tested in the tables or figures. Most of the statistical analyses were done with the Kolmogrov-Smirnov test in SPSS for Windows and with the data divided into quarters. For some of the larger data calculations, a $\chi 2$-test was also done on possible differences total values of the larger groups, which are stated in the table or in the passage text. Wilcoxon's double-sided pair test was also used in a few tests of whole groups to confirm differences, and this is also explained in the text. The reason for generally using the number of birds per quarter (only wholly-monitored quarters were included) is that it should be possible in the future to compare results from different projects and the number of birds per time unit on different occasions and in different conditions. Through

4 Results

4.1 Field observations of spring migration

The account of waterfowl migration in Kalmar Sound in this chapter is wholly based on observations made simultaneously from three observation sites in the migration corridor. All observations were compiled in 15-minute periods and are divided into all observed species. Eider predominate entirely during the spring in all observation periods 1999–2003. Of the total number of waterfowl registered during these studies, Eider represent 95 per cent. The distribution in space and time of Eider migration through the Sound is shown in figure 2. Of the other waterfowl species noted in the spring migration, the largest numbers recorded were Cormorants, swans and geese but other waterfowl and mergansers represent a few per cent as well (see Table 6). Divers, grebes, auks, Long-tailed Ducks, Velvet Scoters

Number and percentage of different groups of waterfowl

Spring migration	**1999**		**2001**		**2002**		**2003**		**Total**	
Species/groups of species	Number	Perc. %	Number	Perc. %	Number	Perc. %	Number	Perc. %	Number	Perc. %
Diver, Grebe and Auk etc.	862	1	762		1 521	2	1 022	1	**4 167**	**1**
Cormorant	807	1	1 935	2	1 494	2	1 230	1	**5 466**	**1**
Swan and Goose	1 208	1	826	1	1 888	3	860		**4 782**	**1**
Eider	120 097	96	122 289	94	55 988	88	153 130	97	**451 504**	**95**
Dabbling Duck	405		1 250	1	975	2	431		**3 061**	**1**
Light diving Duck & Merganser	890	1	2 729	2	1 547	3	1 317	1	**6 483**	**1**
Crane	62		92		180		78		**412**	
Wader	134		601		235		298		**1 268**	
Total	**124 465**		**130 484**		**63 828**		**158 366**		**477 143**	

Table 6 Number of waterfowl observed during the whole project period with full coverage observations in all spring seasons. Observation times for Kalmar Sound with full coverage observations are indicated in table 1. Species included in different bird groups are presented in table 21.

Number of Eider per quarter and total

Year				**Zone A**			**Zone B**			**Zone C**			**Zone D Total/year**		
	m	sd	n	m	sd	n	m	sd	n	m	sd	n	m	sd	n
1999	**22**	7	6 957	**121**	35	38 989	**137**	54	43 969	**94**	41	30 182	**373**	137	120 097
2001	**39**	14	7 297	**100**	24	18 508	**43**	19	7 975	**476**	87	88 509	**658**	144	122 289
2002-2003	**13**	5	5 951	**45**	20	20 573	**29**	11	13 056	**373**	67	169 538	**460**	103	209 118
Total	**21**	6	20 205	**81**	31	78 070	**68**	23	65 000	**300**	71	288 229	**470**	131	451 504

Table 7 Number of spring migrating Eider in southern Kalmar Sound shown as number of Eider per 15minute intervals (quarters) and as a total of distribution in the four observation zones A–D. Compare text and figure 3. "m" shows the number of Eider per quarter as an average value, "sd" the standard deviation and "n" the total number of Eider during the observation time. The numbers of quarters which are valid for these values are shown in table 1, and only fully covered quarters are counted.

and Common Scoters only make up one per cent of the whole spring total. To clarify the presentation and facilitate comparison, the data was later divided into different groups of species, (groupings: see Table 21). The crane and wader groups make up less than one per cent of the spring data and are left out of some compilations.

4.1.1 Distribution of migrating Eider in the Sound before and after construction of wind farms.

The largest number of spring migrating Eider recorded passing through Kalmar Sound during a 15 minute period were 4542 registered between 07.45-08.00 on 1 April 2003. The number of Eider per observation period is shown in Table 6, while the geographical distribution of Eider in the different zones is shown in Table 7.

After construction of the wind turbines at Utgrunden, a change in flight paths occurred so that the Eider flocks fly along the Öland side to a much greater extent (Figure 6, Table 8). In addition, a test of the whole zone material from spring 1999 in comparison with 2002–2003 with wind turbines at Utgrunden (zone C) shows a decrease in the number of migrating Eider in zone C (χ^2=7.7, df=1, p<0.01) and also an increase in zone D, closer to Öland (χ^2=11.2, df=1, p<0.01). The construction of the five wind turbines at Yttre Stengrund in summer 2001 led to a statistically significant reduction of the number of Eider passing through zone A along the mainland side during 2002 and 2003 in comparison with 2001 (Figure 6, Table 8). A test of the whole zone material in spring 2001 in comparison with 2002–2003 with wind turbines at Yttre Stengrund (zone A) (χ^2=5.3, df=1, p<0.05) shows a reduction after construction in zone A. It was not possible to establish a statistically sig-

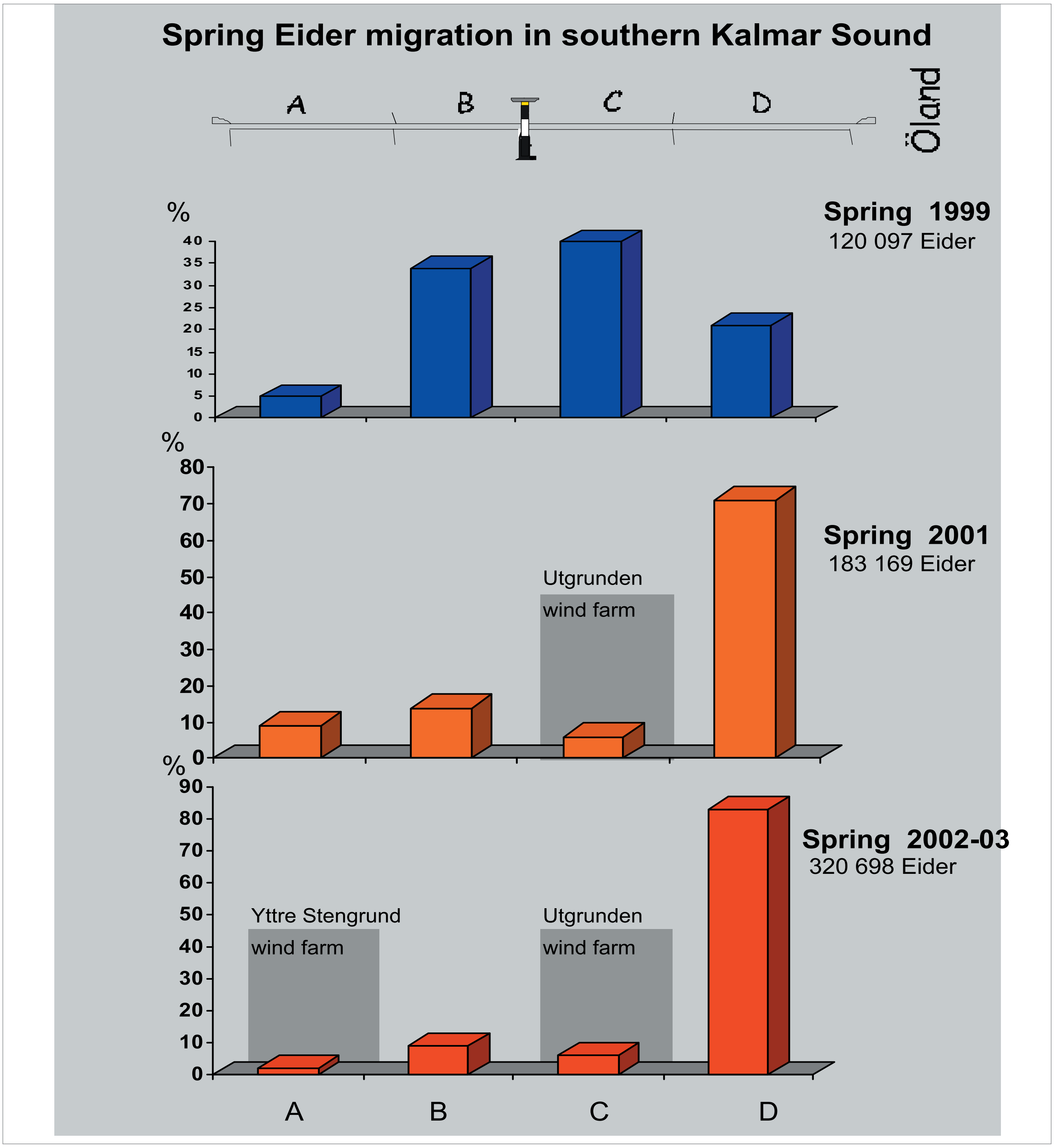


Figure 6 Spring migration of Eider in southern Kalmar Sound with distribution as a percentage of the four zones A–D, each five km wide.

nificant change in the Eider flight distribution in different zones between 2002 and 2003 (Table 8).

Statistical significance test of Eider flight paths

KS-test spring	Observation zones in southern Kalmar Sound	B	C	D Öland
1999comp. w. 2001	d=0,441	0,531**	0,881***	0,862***
2001comp. w. 2002-2003	0,542**	0,560**	0,561**	0,543**
1999comp. w. 2002-2003	0,534**	0,739***	0,822***	0,912***
2002comp. w. 2003	0,103	0,201	0,133	0,411

Table 8 Statistical test of the displacement of the Eider flight paths towards the Öland side after construction of wind turbines at Utgrunden. The test refers to the number of Eider per quarter in the different observation zones A–D. "d" values are shown and the "n" values for different years can be seen in table 1. Red figures show areas and years when the numbers decreased, blue figures when increases occurred, and black where there were no significant changes. This is a Kolmogrov Smirnov test ((**=P<0.01 and ***=P<0.001).

Utgrunden and Yttre Stengrund local zones

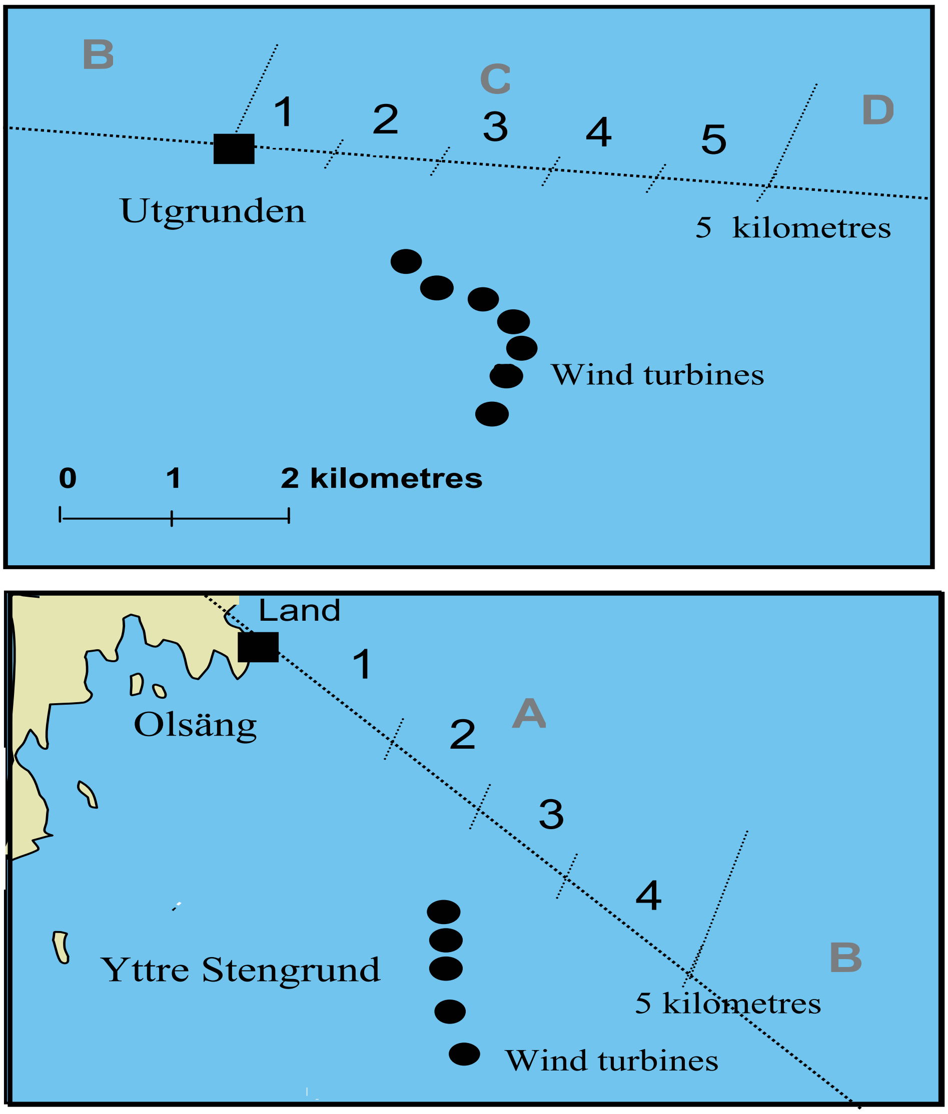


Figure 7 Local division into partial (local) zones of the observation line in zone C (at Utgrunden) and zone A (at Yttre Stengrund).

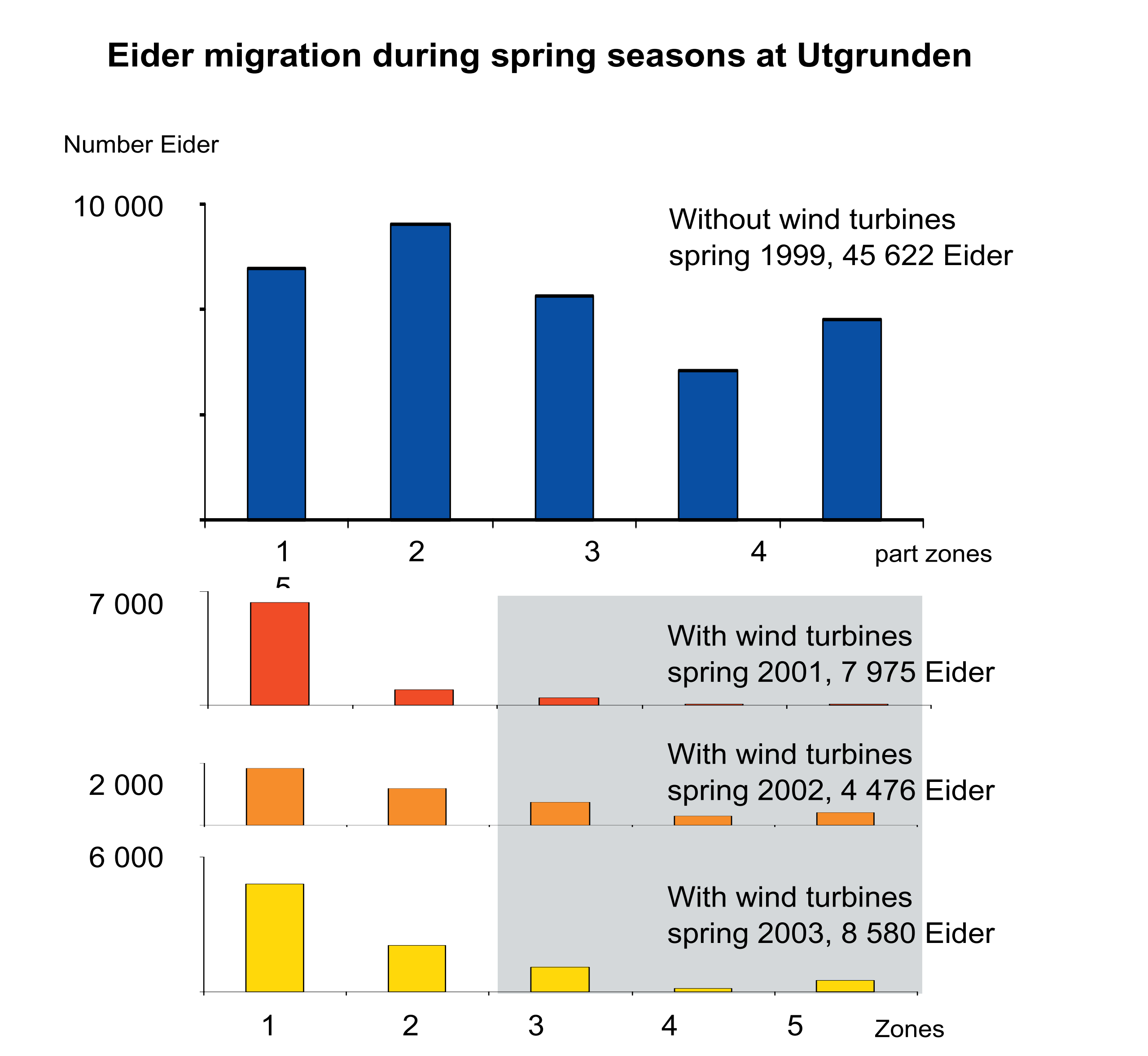


Figure 8 Distribution of Eider migration for the five local zones, each of them one kilometre wide, (= zone C in the division of the Sound as in Figure 3) at Utgrunden before and after the wind farm construction (the division into local zones of one kilometre wide is shown in Figure 7). The wind turbines were erected in local zone 3–5 in autumn 2000.

4.1.2 Eider flight paths in the immediate vicinity of the wind farms

A more detailed zone division was also made at the Utgrunden wind farm where zone C is divided into five local zones, each one kilometre wide, zones 1 – 5 (Figure 7). The wind farm "overshadows" local zones 3–5 for the flights from the west and southwest. After the wind farm extension, the choice of path of the Eider changed and they avoid all local zones 3–5, in all a 3 km-wide band (Figure 8). The reduction from spring 1999 to the spring periods 2001–2003 is statistically significant (1999 n=322 quarters, 2001–2003 n=638 quarters, d=0.766, p< 0.01 Kolmogrov-Smirnov test). Also local zone 2, nearest to the west of the wind turbines, shows a reduced presence of birds after construction (d=0.544, p<0.01). The number of migrating birds through local zone 1 nearest the lighthouse cannot be statistically proved to have changed after the wind turbines were erected. It is worth noting that even though the change is small, the Eider studies during the spring of 2002 and 2003 show that a slightly larger number of birds fly between or over the wind turbines than in the first spring (2001) after construction. Of the total migrating Eider flocks through zone C, 13–14 per cent used the path over or between the turbines during 2002 and 2003 while only 5 per cent followed these migration paths in spring 2001. Perhaps one could ask if the birds become accustomed to the turbines (Figure 8).

The five wind turbines at Yttre Stengrund, seen from the south, only take up one kilometre of the width of the Sound. From the observation site at Olsäng, zone A was divided into four local zones, 1–4 (Figure 7). As shown in Figure 9, only a very small number of Eider passed through that wind farm zone (local zone 3) during the spring, before as well as after the wind farm extension. The total number of Eider passing through the whole observation zone A varied greatly between 2002 and 2003. A statistically significant change in the distribution through the different local zones after the wind farm establishment can only be seen from the spring 2003 data, when a greater number of Eider passed through local zone 4, i.e. outside the wind turbines (2001 n=175 quarters, 2003 n=558 quarters, d=0.587, p<0.01 Kolmogrov-Smirnov test).

4.1.3 Size and flight altitude of the Eider flocks

In section 4.1.1 among others, the density of waterfowl migration is expressed as the number of birds per 15-minute intervals (quarters). Almost the whole migration occurs, however, in flocks of different sizes and it is also known that the size of the flocks is proportional to the migration intensity. There is good reason for reporting the sizes of the flocks, since the capability of radar for registering waterfowl is largely dependent on the size of the flock, but also on the flight altitude and the behaviour of the flocks - which will

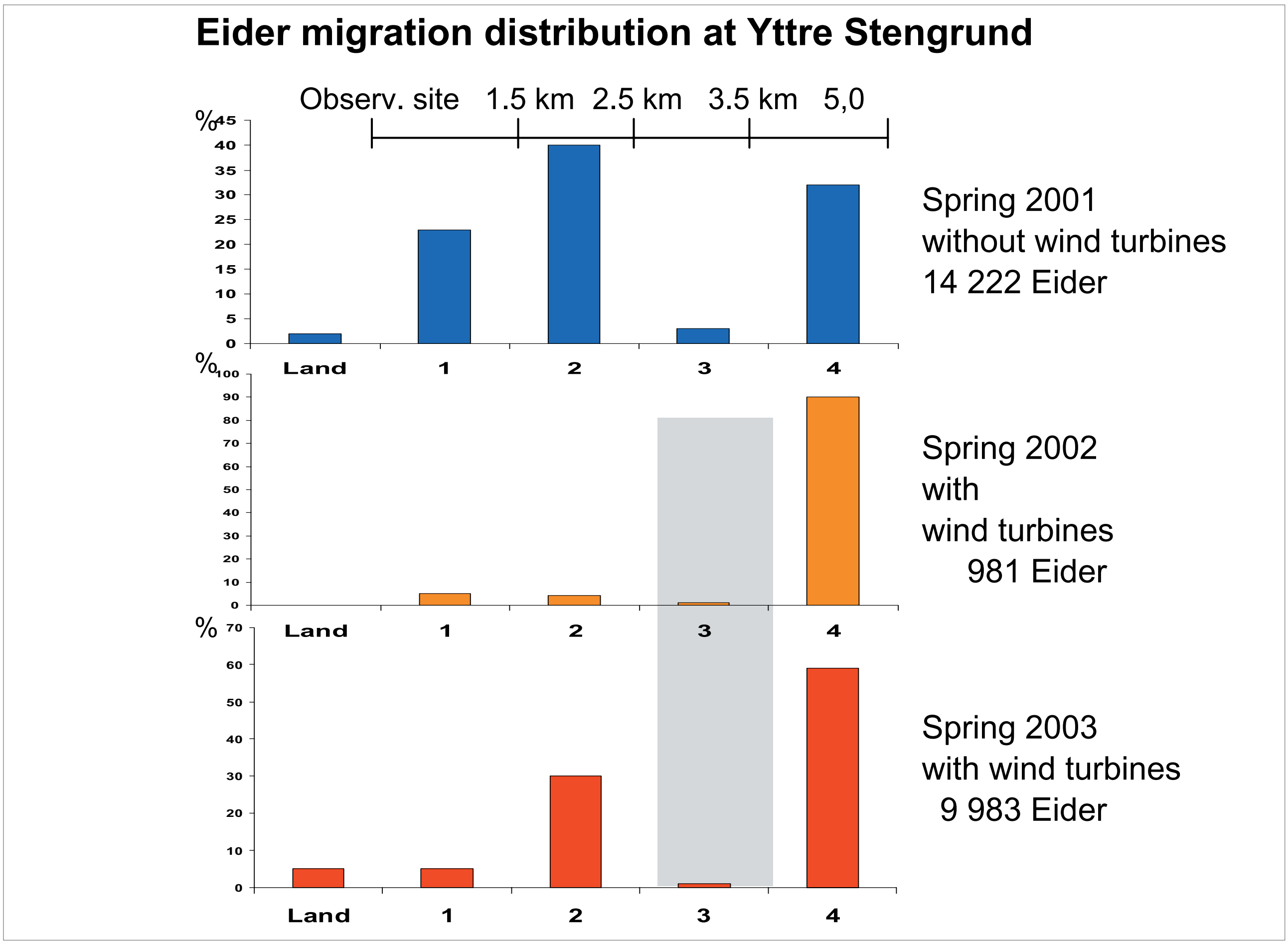


Figure 9 Distribution as a percentage of Eider migration in the local zone division (Figure 7) at Yttre Stengrund before and after the wind farm construction. For spring migration in both 2002 and 2003 the picture of distribution in the different zones shows that the migration corridor after construction was to a larger extent further out in the Sound, outside the wind turbines. The number of Eider decreased and has varied greatly from year to year. The information is based on recordings made when full coverage observations have been possible.

Eider flock size and flight altitude

Spring	Utgrunden				Yttre Stengrund			
Flock size	**Spring**	**m**	**sd**	**Number flocks**	**Spring**	**m**	**sd**	**Number flocks**
Before construct.	1999	**36**	5	1 307	2001	**32**	4	449
After construct.	2001	**32**	6	251	2002	**10**	2	99
After construct.	2002	**33**	5	137	2003	**26**	3	379
After construct.	2003	**33**	7	259				
Estimated flight altitude shown as metres above								
Before construct.	1999	**10**	4	1 307	2001	**40**	4	449
After construct.	2001	**50**	12	251	2002	**20**	6	99
After construct.	2002	**20**	5	137	2003	**30**	7	379
After construct.	2003	**20**	4	259				

Table 9 Comparison of flock size and flight altitude of migrating Eider before and after construction of wind turbines at Utgrunden (zone C) and at Yttre Stengrund (zone A). "m" shows the average value and "sd" the standard deviation.

become clear in later sections of the text (4.3.1). As mentioned above, the spring migration consists of 95 per cent Eider. If the whole spring flight data for Kalmar Sound is considered during the entire project period, the average Eider flock consists of 40 individuals (sd ±3.4 n=11445 flocks). In both the five-kilometre wide observation zones A and C where the wind farms at Yttre Stengrund and Utgrunden are located, the number of birds per flock decreased after the wind farms were erected, as shown in the figures in Table 9. The average size of the flocks of 32 Eider birds at Yttre Stengrund during spring 2001 before construction decreased after construction in 2002 and 2003 to an average of 23 birds per flock (Table 10). The reduction is not statistically significant but worth mentioning. In zone D along the Öland side where the Eider numbers have increased since the wind turbines were built, there is an increase from 40 to 47 Eider during the same time period. The median value of the size of the flocks is 40—50 Eider per flock in the whole of the Sound, which is the same for the whole spring data for all spring seasons. The differences are small and as it is a matter of estimates, they are uncertain – the changes are in any case not particularly great.

Observations show that during the first spring (2001) after the wind turbines had been constructed at Utgrunden, on passage of the observation line in zone C (the wind farm zone) the flocks had a flight altitude which was 40 metres higher than before the wind turbines were in situ (Table 9). Also during the spring migrations in 2002 and 2003 the Eider flocks showed on average a flight altitude of 10 metres higher at the observation line than during the flights in 1999 before construction, although this is not a statistically supported difference (Table 9, r=0.233, Wilcoxon two-sided pair test).

At Yttre Stengrund the Eider flocks show on average a slightly lower flight altitude when passing the wind turbines in comparison with flight altitudes before the turbines were erected. This difference in flight altitude cannot be statistically supported.

The average value for the flight altitude of Eider flocks in the different zones in the Sound varies on average between 10 and 40 metres (Table 11). Some Eider flocks can fly at a considerably higher altitude, sometimes up to about 300—400 metres, which has sometimes been noted in the Kalmar Sound area. All the same, these differences in flight altitude are within levels of uncertainty estimates. It can be shown that the changes of flight altitude in the Sound have been only marginal since the wind turbines were built.

4.1.4 Other waterfowl before and after extension of the wind farms

Other waterfowl amount to only 5 per cent of the total spring migration through southern Kalmar Sound (Table 6). The flight path distribution in different zones for the different species before and after wind farm construction shows a considerable variation (Table 12) but there are more swans, geese and Cormorants that choose to fly in zone A (closer to the mainland) after construction of the wind farms in the Sound (for division into groups of the different species, see Table 21).

After extension of the wind farms the migration of all waterfowl groups decreased, except for waders during spring 2001 through zone C at Utgrunden. Similar differences in comparison with the period before the extension do not exist for 2002 and 2003. In zone D along the Öland side of the Sound all groups of other waterfowl species show a statistically significant increase during spring 2002 and

Flock size before and after construction

Spring		Zone A*		Zone B		Zone C		Zone D*	
Species/groups of species		Flock size m	sd	m	sd	m	sd	m	sd
Diver, Grebe and Auk and others	Before	2	0,2	2	0,4	2	0,4	3	0,5
	After	4	0,6	2	0,3	2	0,4	3	0,6
Swan and Goose	Before	18	2,1	13	1,4	11	2,3	7	0,7
	After	9	1,8	11	1,9	13	2,4	6	1,1
Cormorant	Before	6	1,1	7	1,0	8	1,3	3	0,9
	After	3	1,2	6	1,3	8	1,5	4	1,4
Eider	Before	32	5,2	36	5,4	36	4,8	40	8,1
	After	23	6,2	42	7,2	32	6,1	47	9,0
Dabbling Duck	Before	4	0,4	3	0,5	7	0,7	6	0,3
	After	5	1,0	8	0,7	6	0,8	7	1,1
Light diving Duck and Merganser	Before	9	0,4	4	1,8	4	1,8	12	2,1
	After	14	1,4	6	1,4	4	2,0	11	2,5

Table 10 Flock size as an average of the different waterfowl groups (Table 6) before and after construction of the wind farms. The different groups of species and their composition are shown in table 21. No differences are classified as conclusive and therefore no tests have been carried out.

2003, i.e. after construction of the two wind farms in the Sound (Table 12).

4.1.5 Flock size and flight altitude of other waterfowl species

Most of the other waterfowl species appear in small flocks during the spring migration and it has not been possible

Bird flocks, altitude

Spring Species/groups of sp.		Zone A* m	Zone A* sd	Zone B m	Zone B sd	Zone C m	Zone C sd	Zone D* m	Zone D* sd
		Estimated flight altitude							
Diver, Grebe and and Auk etc.	**Before**	**20**	4,1	**10**	1,5	**10**	1,4	**10**	2,1
	After	**20**	3,4	**10**	3,1	**20**	3,5	**10**	1,8
Swan and Goose	**Before**	**20**	3,4	**20**	2,1	**20**	2,5	**20**	2,1
	After	**20**	2,8	**20**	2,7	**20**	2,5	**20**	2,0
Cormorant	**Before**	**20**	3,4	**20**	1,9	**20**	1,3	**30**	4,5
	After	**20**	4,1	**20**	2.1	**30**	2,7	**30**	5,1
Eider	**Before**	**40**	5,1	**10**	2,8	**10**	1,8	**10**	2,1
	After	**20**	4,7	**20**	3,7	**30**	3,4	**20**	2,0
Dabbling Duck	**Before**	**20**	2,8	**10**	2,2	**20**	2,8	**30**	1,8
	After	**20**	3,8	**20**	2,4	**20**	2,7	**20**	1,7
Light diving Duck and Merganser	**Before**	**20**	3,3	**10**	2,5	**20**	2,7	**20**	2,3
	After	**20**	4,1	**20**	2,9	**30**	2,8	**20**	3,4

Table 11 "After construction" includes spring migrations in 2002 and 2003 for the zones A to D, while for the zones D and C "after construction" includes spring migrations in 2001 and 2002. The estimated flight altitude of waterfowl flocks in different zones is shown before and after construction of the wind turbines.
The estimate of flight altitude is relatively uncertain and therefore none of these differences of flight altitude has been tested, but probably they fly about as high with or without wind turbines.

Number of migrating other waterfowl per quarter during spring seasons

Spring Species/groups of sp.	A 1999 m	A 2001 m	A 2002-2003 m	B 1999 m	B 2001 m	B 2002-2003 m	C 1999 m	C 2001 m	C 2002-2003 m	D 1999 m	D 2001 m	D 2002-2003 m
Diver, Grebe and Auk etc.	0,1	0,3	0,6	1,5	1,4	1,6	0,9	0,1	0,7	0,3	2,2	2,8
Swan and Goose	1,1	1	1	0,6	0,2	1	1	0,2	0,5	1	1	1
Cormorant	1,2	2,9	3	1,1	0,8	1	1,4	1	1,7	1,3	2	3,4
Dabbling Duck	0,3	4	0,9	0,3	1	0,5	1	0,5	2,2	0,8	7	9
Total other Water-fowl except Eider	3,1	12	5,5	4,1	4,1	4,1	4,3	1,9	5,1	3,9	15	16

Table 12 Number of waterfowl (other species) which generally flew through the different zones during the whole project period. The differences are relatively small between the situation before (blue figures) and after (red figures) the wind turbines. In total for all these species, zone D shows an increase after 1999 in comparison with 2001–2003 when the turbines were built (1999 comprises 322 quarters, 2001 comprises 186 quarters and 2002 –2003 comprises 452 quarters). A statistical test of the total figure in zone D for other waterfowl (except Eider) gives 3.9 birds per quarter but 16 per quarter after the construction χ^2=11.4 df=1. p<0.01. The species of different bird groups are shown in table 21.

to establish any marked changes in flock sizes in zones A and C. All waterfowl groups that migrate along the Öland side, including Eider, show an increased flock size after construction of the wind farms, which may be the result of the increased migration intensity here. It has not been possible to prove this statistically however (Table 10).

The only unambiguous change in flight altitude of other waterfowl (Table 11) is that the flocks passing through zone C (the Utgrunden wind farm) now fly on average 10–20 metres higher than before the wind turbines were in situ. If all other waterfowl groups are put together, the average increase in flight altitude is 10 metres after construction in comparison with the situation before the extension. This is probably within the margin of error as it is a question of estimating the flight altitude with an accuracy, at best, of 10 metres or even more (for higher altitudes 50 metres, see method section).

4.2 Field observations of the influence of wind on spring migration

To be able to make a relevant wind dependency test for the choice of flight path, wind readings at Utgrunden lighthouse were used. Wind information every 60 minutes was assumed to be valid for all observation sites and has therefore been used for wind dependency tests for the different observation sites.

4.2.1 Eider distribution in the Sound in different wind directions

Observations show that the wind turbines at Utgrunden and later at Yttre Stengrund displaced the spring migration

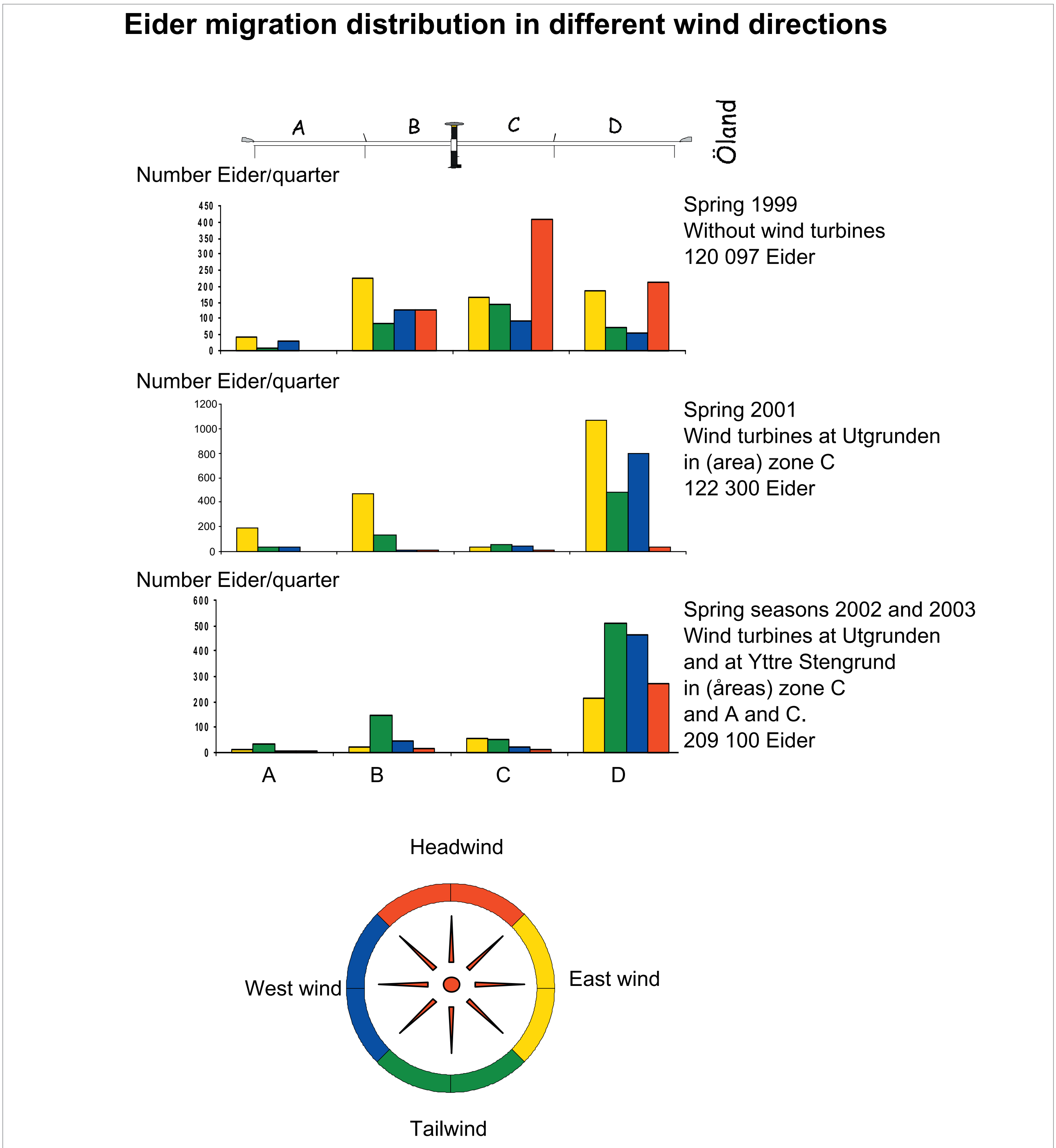


Figure 10 Average number of Eider per quarter-hour through the different zones in different wind directions.

of Eider towards the Öland side for all the studied wind directions (Figure 10). During spring 1999 when there were no wind turbines in the Sound there was intense Eider migration in different wind directions through all zones, but the number along the mainland side (zone A) was lower. However, in easterly winds intense Eider migration could be seen along the mainland side, but even on such occasions most Eider were observed on the Öland side, see spring 2001 (Figure 10). The displacement of the migration path towards the Öland side must therefore be mainly due to the

Number of Eider per quarter through Kalmar Sound

Spring			East	East	Tail	Tail	Tail	West	West	West	Head	Head	Head	Total
Zone in Sound			1-3 m/s	4-8 m/s	1-3 m/s	4-8 m/s	9- m/s	1-3 m/s	4-8 m/s	9- m/s	1-3 m/s	4-8 m/s	9- m/s	
A	1999	n	21	19	25	40	24	21	49	21		24	19	263
A		m	**15**	**61**	**0**	**11**	**47**	**9**	**43**	**0**		**0**	**6**	**22**
A	2001	n		22	33	34	17	17	26	15	3	8		175
A		m		**189**	**0**	**2**	**70**	**12**	**17**	**46**	**4**	**3**		**40**
A	2002-	n	21	23	47	27	21	42	29	51	34	56	51	402
A	2003	m	**5**	**0**	**9**	**1**	**125**	**4**	**6**	**12**	**3**	**11**	**6**	**13**
B	1999	m	**57**	**318**	**7**	**109**	**267**	**5**	**164**	**215**		**0**	**29**	**119**
B	2001	m		**475**	**0**	**192**	**74**	**2**	**9**	**11**	**19**	**16**		**100**
B	2002-	m	**21**	**0**	**21**	**44**	**542**	**14**	**12**	**4**	**11**	**15**	**21**	**43**
B	2003													
C	1999	m	**61**	**255**	**77**	**179**	**106**	**42**	**124**	**27**		**0**	**408**	**126**
C	2001	m		**38**	**3**	**32**	**75**	**37**	**11**	**86**	**17**	**3**		**31**
C	2002-	m	**58**	**0**	**17**	**40**	**119**	**42**	**17**	**18**	**17**	**16**	**11**	**27**
C	2003													
D	1999	m	**36**	**138**	**57**	**84**	**42**	**92**	**47**	**0**		**0**	**213**	**66**
D	2001	m		**1068**	**56**	**427**	**565**	**58**	**525**	**845**	**42**	**13**		**445**
D	2002-	m	**216**	**0**	**420**	**956**	**525**	**478**	**467**	**436**	**173**	**352**	**252**	**387**
D	2003													

Table 13 The number of Eider as an average per quarter through the zones A–D in different wind directions and speeds. The annual grouping is made with regard to construction of the wind farms: there were no wind turbines in the Sound in 1999; in 2001 the Utgrunden turbines were erected; in 2002–2003 there were also wind turbines at Yttre Stengrund. The number of quarters in the different winds is shown collectively for all the zones as "n" under zone A.

Eider flight paths in different wind directions and wind force before and after wind turbine

Number quarters 1999/2002–2003

Direction, m/s	Zone A		Zone B	Zone C	Zone D
East1-3	21/21	d=0.122	0.542 **	0.157	0.621 **
East4-8	19/23	0.377	0.628 **	0.578 **	0.533 **
East 9-					
Tail 1-3	25/47	0.066	0.339	0.535 **	0.698 **
Tail 4-8	40/27	0.244	0.188	0.577 **	0.521 **
Tail 9-	24/21	0.333	0.331	0.309	0.623 **
West1-3	21/42	0.122	0.257	0.023	0.726 ***
West4-	49/29	0.537 **	0.601 **	0.416	0.631 **
West 9-	21/51		0.676 **	0.222	0.719 ***
Head 1-	0/34				
Head 4-	24/56	0.201	0.231	0.221	0.522 **
Head 9-	19/51	0.101	0.223	0.516 **	0.248

Table 14 Have Eider flight paths in southern Kalmar Sound changed after construction of the wind turbines? The table shows tests of the number of Eider per quarter (Table 13) in different wind directions and speeds, and for the different zones. Values from spring 1999 were tested in comparison with the spring seasons 2002–2003, i.e. values before and after construction. Red dvalues show decreases and blue dvalues show increases, while black dvalues show uncertain changes (statistical tests with a Kolmogrov Smirnov test: **=p<0.01 and ***=p<0.001). The number of quarters tested for all zones are shown under zone A (the first value shows spring 1999 without wind turbines and the other value shows 2002–2003 with wind turbines).

wind farms and can only to a smaller extent be explained by wind dependency.

4.2.2 Eider distribution in the Sound in different wind forces

If the number of Eider per quarter is used as a measure of migration intensity then the highest intensity occurs in moderate (4–8 m/s) to strong (>9 m/s) winds with the highest average value of 1068 Eider per quarter in moderate easterly winds (Table 13). The main part of the migration takes place when there is a tailwind or westerly winds. But it is not easy to predict which wind directions give high migration intensities as relatively large migration has been shown to take place even in strong headwinds and moderate east winds, as in spring 1999 for example, when 408 Eider per quarter were noted in strong headwinds. If the intensity values are tested statistically from spring 1999 (without wind farms) and on the values from 2002 and 2003 (with erected wind farms), divided into four zones, a large statistically significant increase in migration intensity along the Öland side (zone D) is obtained in all wind directions except strong headwinds (Table 14). A statistically significant decrease in intensities after the wind farm extension was noted for the other three zones A–C, except for C on occasions of strong westerly winds. Even in tailwinds and easterly winds (mainly moderate and light breezes) lower intensities were noted in zone C (the wind farm zone) at a statistically significant level. The decreased intensity in zone B in light easterly winds in favour of migration along the Öland coast may seem a little surprising (Table 14). Moderate westerly winds are the only wind group which correlates with a significant decrease in Eider along the mainland side after the wind farm extension, the Eider now choosing to a greater extent to migrate on the Öland side.

4.2.3 Other waterfowl in different winds before and after the wind farm extension

The observation period for spring studies was chosen specifically to include the peak period of Eider migration. The other waterfowl species amount on average to 5 per cent of the total, and these species have been aggregated in groups to enable the analysis of their choice of flight path before and after the wind farm extension. This grouping of species was also used to analyze wind dependency in the group of other waterfowl during migration through the area. A separate analysis was made for the group of most commonly occurring individual species of other waterfowl, namely the Cormorant.

The observation material shows quite clearly that the spring migration of other waterfowl extends over the whole Sound, but the largest numbers migrate along the Öland coast and were therefore recorded at Eckelsudde (Table 12). The only waterfowl group which deviates from this tendency is the group of divers, grebes and auks, of which 39 per cent migrated in the middle zones B and C after the wind farm extension at Utgrunden (see Tables 12 and 15). In spring 1999 before the wind farm extension, as many as 86 per cent of this group of birds migrated through these two zones.

As almost all groups of waterfowl species appear in very small flocks in Kalmar Sound (on average 2–8 birds per flock, see Table 10) it is possible that the observations during spring 1999 from Utgrunden did not detect and register these other waterfowl species closer to the coasts to the same extent as the later spring observations. This means that the data for other waterfowl should be considered and interpreted carefully and restricted to a wind dependency analysis chiefly for Cormorants and the group of divers and others (Tables 15 and 16). The group of divers and others shows (Table 15) a higher intensity of migration in tailwinds and westerly winds, which corresponds to the picture for

Average number of birds per quarter of the group Diver, Grebe, Auk etc.

Year	Zone A								Zone B				Zone C				Zone D			
	n	East	n	Tail	n	West	n	Head	East	Tail	West	Head	East	Tail	West	Head	East	Tail	West	Head
1999	40		89	**0,1**	91	**0,1**	43	**0**	**0,1**	**0,6**	**0,7**	**0,1**		**0,3**	**0,4**	**0,1**	**0**	**0**	**0,1**	**0,2**
2001	22	**0**	76	**0,2**	66	**0**	11	**0,1**	**0,1**	**0,5**	**0,1**	**0,8**	**0**	**0,1**	**0**	**0**	**0,3**	**0,7**	**0,5**	**0,7**
2002	50	**0,6**	63	**0,4**	4	**0,1**	128	**0,3**	**0,6**	**0,6**	**0,6**	**1,5**	**0**	**0,3**	**0,4**	**0,4**	**0,9**	**0,3**	**0,9**	**0,8**
2003	33		161		140	**0**	224	**0,1**	**0**	**0,1**	**0,4**	**0,1**	**0**	**0**	**0,1**	**0,1**	**0**	**0,7**	**1,1**	**1**

Table 15 Number of birds per quarter of the group divers, grebes, auks, Velvet Scoters, Common Scoters and Longtailed Ducks, and their average numbers in different wind forces and different zones. The number of quarters in various winds is shown under zone A where all zones, however, are included.
General comment on migration pattern of the group: In the compilation of observations it is clear that this group flies out into the central parts of the Sound to a larger extent than other waterfowl groups. On a closer examination of the wind dependency a relatively high figure of migration intensity is shown in headwinds in spring 2001 and 2002. If all migrating birds are taken into consideration for the whole project period, then 40% of them migrate in tailwinds and 45% in westerly winds while only 12% migrate in headwind. This corresponds with the picture of Eider migration.

Eiders. During certain spring periods, both Cormorant and the group of divers and others show a relatively high intensity even in headwinds, which scarcely occurs among the Eiders. The group of Divers and others shows a higher intensity than other species out in the Sound, but in certain wind directions shows the same avoidance tendency as Eider for zone C. As many as 32 per cent of migrating divers and others during spring 1999 flew through zone C, while during the spring periods of 2001–2003 after the wind farm extension this only amounted to 8 per cent. Cormorants, although far fewer in number than Eider, seem to deviate from the pattern of other species in avoidance of the wind farm in zone C. Before wind farm construction, 22 per cent of the Cormorants were observed in zone C whereas after the extension, during the spring periods of 2001—2003, 25 per cent of Cormorants migrated through this zone (Table 16).

The wind dependency of Cormorant

Year	Zone A								Zone B				Zone C				Zone D			
	n	East	n	Tail	n	West	n	Head	East	Tail	West	Head	East	Tail	West	Head	East	Tail	West	Head
1999	40	**0,2**	89	**0,2**	91	**0,1**	43	**0,7**	**0**	**0,2**	**0,2**	**0,1**	**0**	**0,1**	**0,2**	**0,2**	**0**	**0**	**0,1**	**0,1**
2001	22	**0,6**	76	**2,7**	66	**2**	11	**0,6**	**0**	**0,6**	**0,1**	**0,1**	**0**	**0,3**	**0,3**	**0,1**	**0,2**	**0,5**	**0,2**	**0,2**
2002	50	**0,4**	63	**1,9**	4	**1**	128	**0,6**	**0,3**	**1,5**	**0,3**	**0,3**	**0,1**	**1**	**1,3**	**0,1**	**0,3**	**0,2**	**0,3**	**0,7**
2003	33	**0**	161	**0,1**	140	**0,6**	224	**1,3**		**0,1**	**0,2**	**0,3**	**0,1**	**0,1**	**0,2**	**0,4**	**0,1**	**0,8**	**1,3**	**2,1**

Table 16 Spring migration of Cormorants with number of birds per quarter distributed in each zone and according to wind speed. The number of quarters is shown as "n" when counts were made in zone A and apply to counts in all zones. General comment: In spring observations in 1999 and 2003, more than 40% of the migration occurs in headwinds. If the whole material for Cormorant is combined for all four spring seasons (5481 Cormorants) it is clear that 65% of them migrate in westerly winds and headwinds while 26% of the migration occurs in tailwinds.

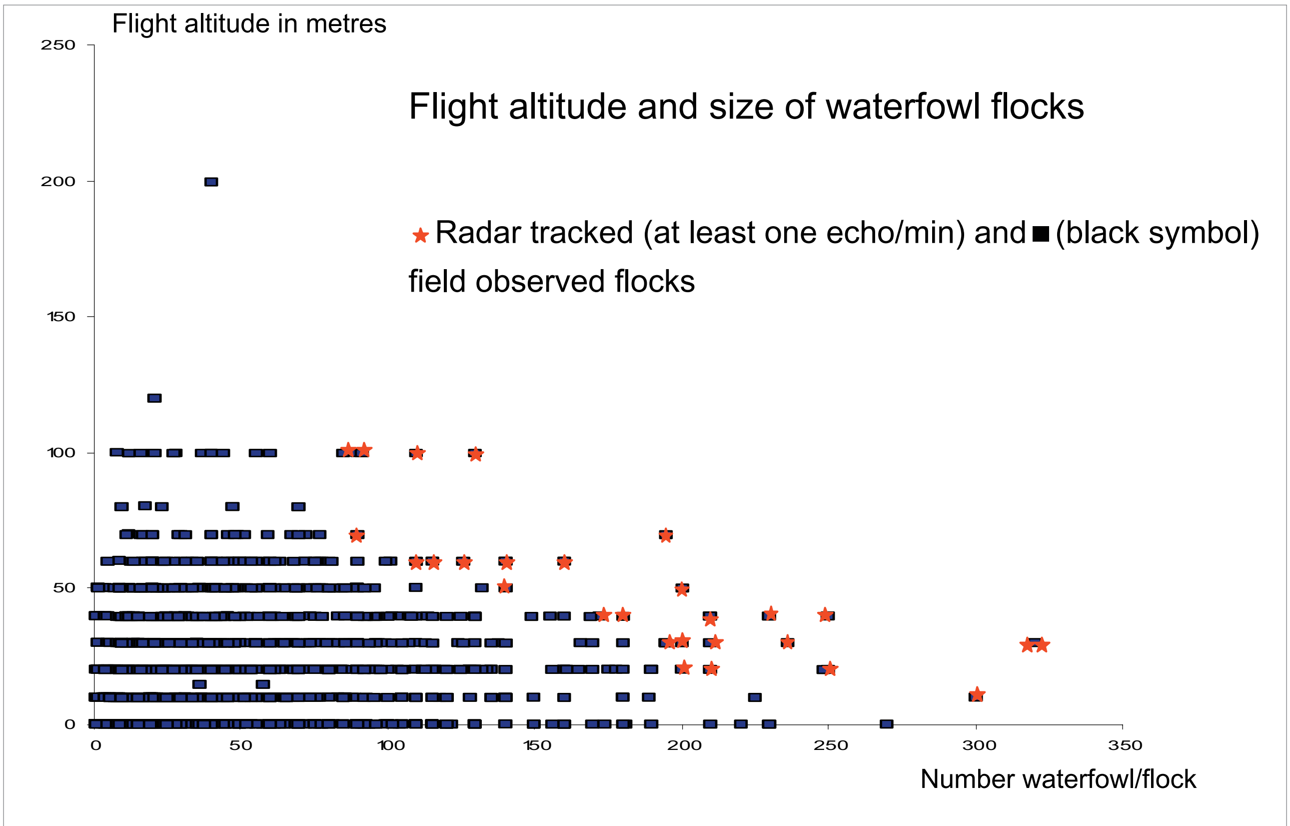


Figure 11 Comparison of simultaneously radar-tracked (at least one echo/minute) and field-observed waterfowl flocks with flock size and estimated flight altitude during the period 31/3–6/4 2001. During this period a total of 2045 flocks were observed, of which 28 could be radar-tracked for at least four kilometres with at least one radar echo per minute. The field-observed and radar-tracked flocks were compiled in the diagram and compared with flock size and estimated flight altitude. Only flocks of about 100 or more birds and with a lowest flight altitude of 50 metres give identifiable results, as shown in the diagram. Flocks of 200 or more birds were tracked by radar also at a lower flight altitude.

4.3 Radar observations of spring migration

The technique of tracking bird flocks with radar provides good opportunities of studying bird migration. Radar film analyses have given detailed information of waterfowl movements and behaviour during their migration through Kalmar Sound.

4.3.1 Radar recording of spring migration in Kalmar Sound

In the first partial report for the autumn and winter of 2000 (Pettersson 2001), a minor survey was carried out based on echoes recorded at the surveillance radar stations referred to above. This established that Eider flocks must consist of not less than 45–50 birds and must fly 20 metres above the water to give a reliable, identifiable echo. To enable longer flock tracking in the direction of the Sound, the flock should preferably consist of more than 100 birds. For larger birds such as geese, swans and cranes, a radar echo is obtained for most flocks with as few as 20 birds (Figure 11).

All trackings longer than four kilometres are represented as lines. During spring 2001, 28 of the 2045 flocks observed during daytime in good visibility were identified on radar (Figure 12). It is therefore only one per cent of the passing flocks that were recorded by observers as well as radar in this area. In order to show clearly by radar how these flocks fly, it is necessary to make long trackings of the flocks (at least one radar echo from the flock per minute for approximately 45 minutes). To be able to use radar observations to a greater extent for recording migration intensity, fewer echoes from flocks may be counted when they pass a line. One practicable method when there is poor radar coverage is described by Gudmundsson (1995). This method was used by locating a radar observation line in southern Kalmar Sound, where radar gives many clear indications of echoes. This line was located approximately 7 kilometres south of the observation line for field observations at Utgrunden (Figure 3, radar line). Using this method, individual echoes are registered as a flock if they are recorded at least once every four minutes and show a flight path crossing the radar observation line. These echoes are compared with data recorded by field observers and noted along the field observation line. Radar recordings of 462 waterfowl flocks in the Sound were obtained with this method during spring 2001, which is 23 per cent of the total number of field-recorded waterfowl flocks and 40 per cent of the number of flocks which had the necessary characteristics for producing radar echoes. (Figure 14 and Table 17). With this rather coarse method, the risk of confusing flocks obviously increases

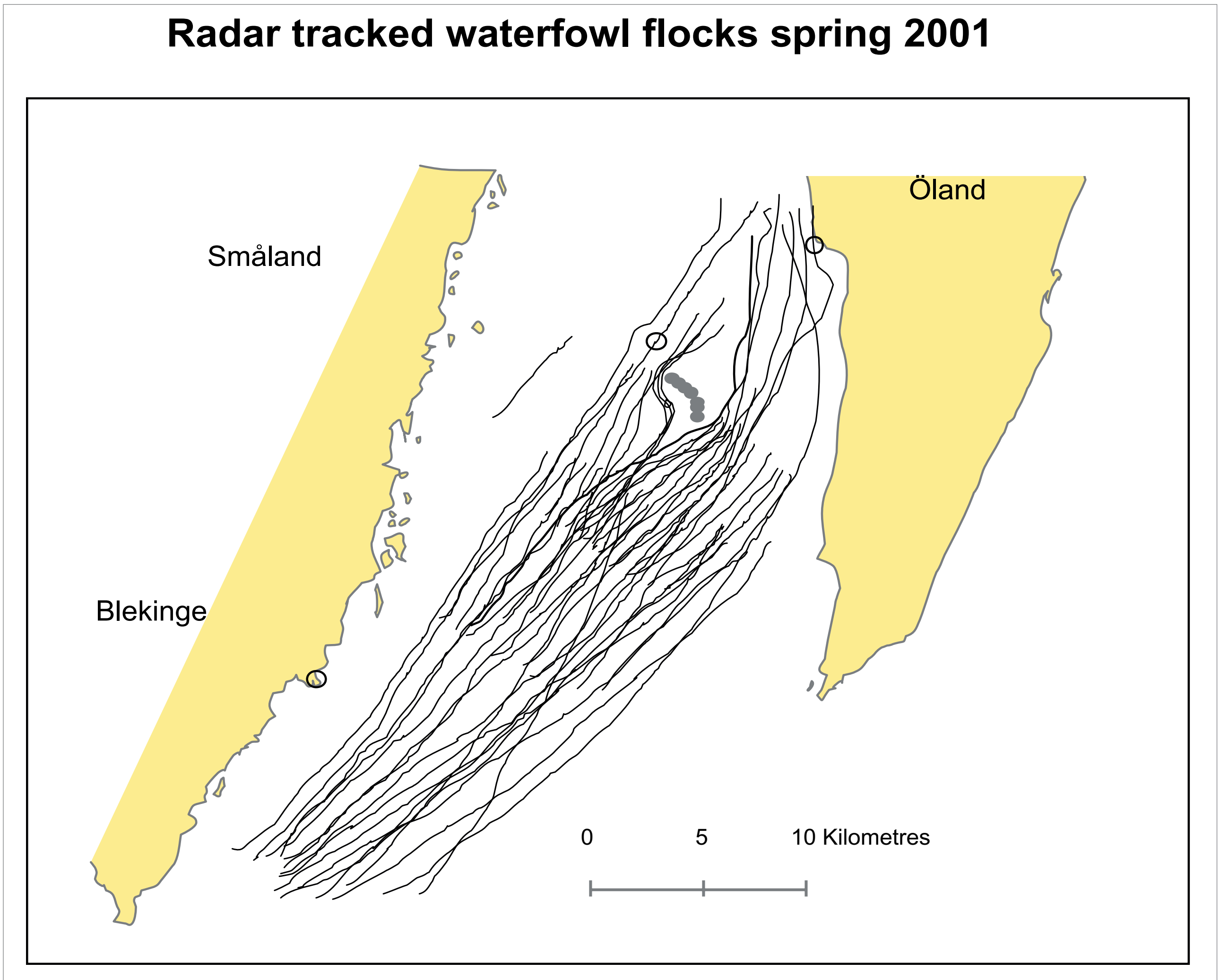


Figure 12 Radar-tracked waterfowl flocks (Eider predominant species) in spring 2001. Of a total of 29 flocks, 23 were tracked by radar past Utgrunden and 16 past Yttre Stengrund. All the flocks were observed in daytime in good visibility.

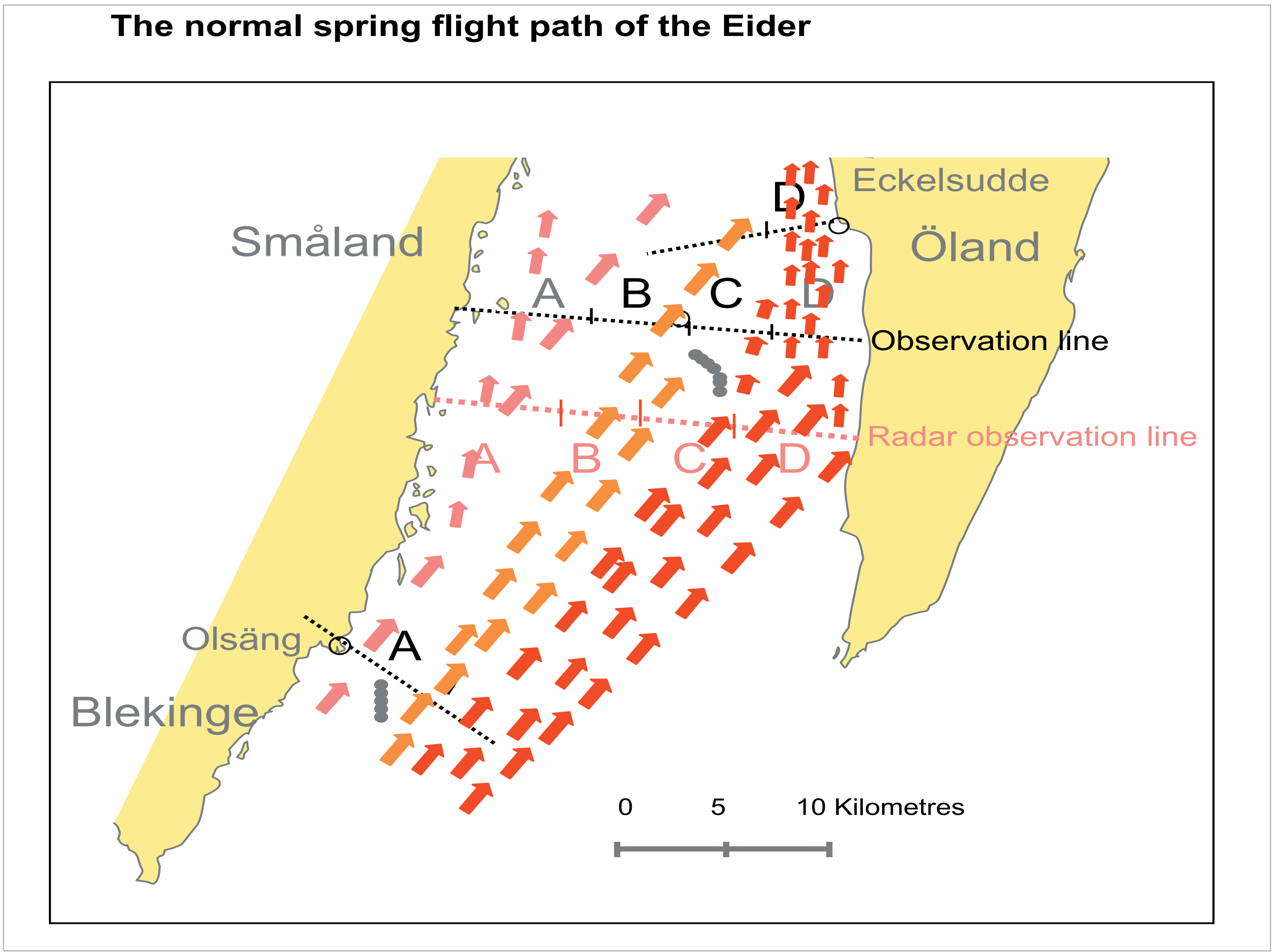


Figure 13 Normal migration path of Eider through southern Kalmar Sound during the observation period 1999–2003. This migration pattern shows the distribution of the migration in westerly winds, when the major part of Eider migration occurs.

Number of bird flocks with different echo result requirements

Spring	Radar observed flocks 1 one echo/ minute	2 one echo/ 2 minutes	3 one echo/ four minutes	4 Pot. radar obs. flocks, 45+	Field observed flocks 5 Total
2001	28	104	462	1169	2045
2002	15	30	121	586	1391
2003	80	115	860	1741	3586
Total	123	249	1443	3496	7022
% of	**2**	**4**	**21**	**50**	

Table 17 The number of waterfowl flocks observed by radar in different spring seasons with different criteria for radar echoes.
The columns in the table refer to:
1. Flocks clearly identified by radar over longer tracking with the criterion of at least one echo per minute.
2. Flocks considered to have crossed a marked radar observation line in southern Kalmar Sound (Figure 3) with the criterion of at least one echo every second minute.
3. Flocks considered to have crossed a marked radar observation line (Figure 3) with the criterion of at least one echo every fourth minute. Compare to frequency material of the report.
4. Flocks large enough to produce echoes on radar (Eider flocks of more than 45 individuals or waterfowl flocks of larger species with more than 20 individuals) = potentially radar-recorded flocks, >45.
5. Total number of observed flocks of all sizes down to one bird as smallest unit.

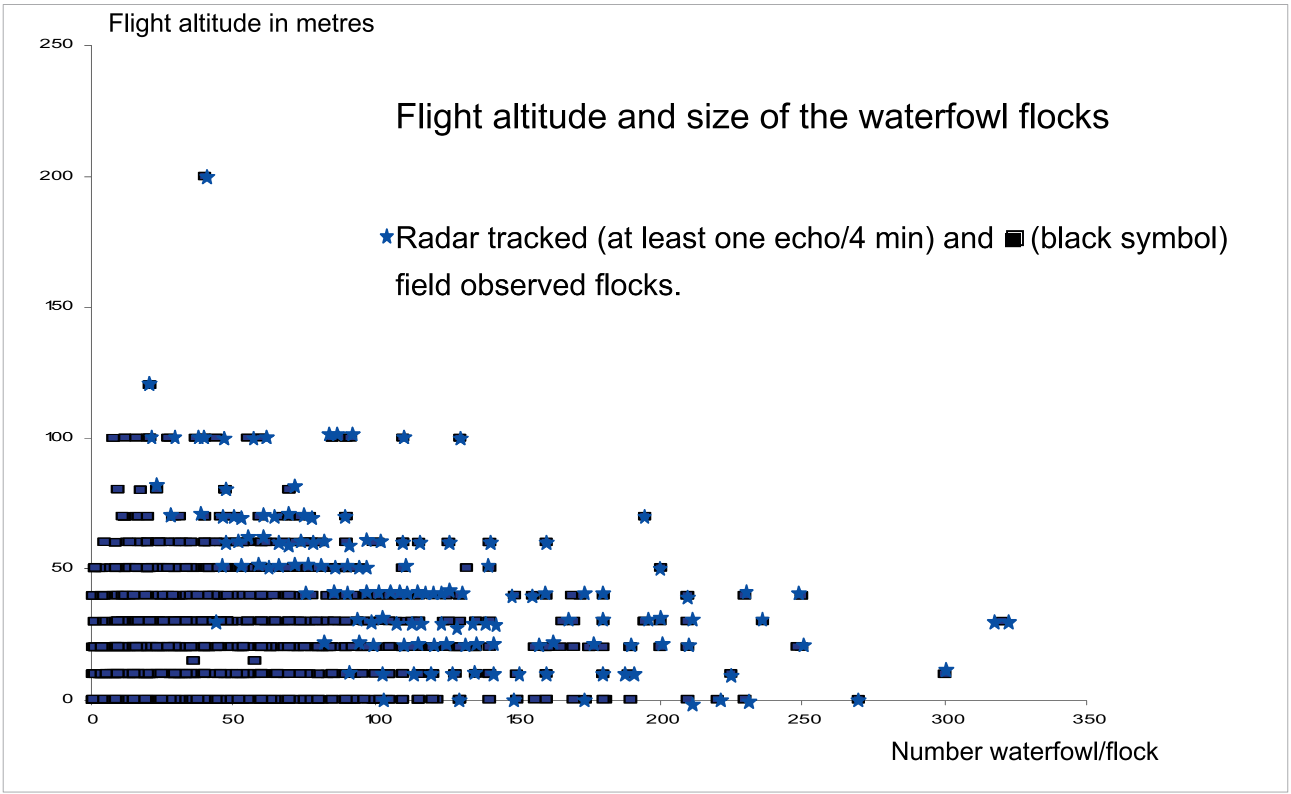


Figure 14 Comparison of simultaneous radar- tracked (at least one echo/minute) and field-observed waterfowl flocks with flock size and estimated flight altitude during the period 31/3–6/4 2001. Blue asterisks shows waterfowl flocks which were identified by radar with at least one echo every fourth minute and with at least one echo on each side of the marked radar observation line and therefore judged as migrating through the Sound. A total of 462 flocks of this kind were recorded by radar during the period. Of these, 142* (those shown in the diagram) could be correlated to the field observations which gave flight altitude and flock size. Note that in most cases it was fairly high-flying flocks and larger flocks that reflected echoes on radar.

*Only flocks classified with a high degree of certainty were linked to observed flocks.

when the ongoing migration is dense. The main intention of making an estimate of migration intensity in different conditions is clearly improved however, since it was possible to register 23 per cent of the overall migration in comparison with only one per cent previously. If we look at all data from all spring seasons, then the efficiency of radar observations becomes even higher (Table 17). This method is a better tool for gathering information about migration patterns at night and during mist.

4.3.2 Do waterfowl migrate in fog and at night?

If we want to compare the distribution of migrating birds during different times of the day and night in different light and weather conditions and want to see the distribution between day, night and foggy conditions when human beings cannot observe birds, it is important to choose the same technique for different conditions. Thus, in the account below, only times when recording could take place with the help of the radar are used in accordance with the norms described above (Figure 14 and Table 17) for recording along an arranged radar observation line which is also valid for diurnal flights in good visibility conditions. Figure 16 shows how 15-minute periods studied by radar are calculated as a percentage for different light and weather conditions over the whole project period. Furthermore, reports show how the flocks recorded by radar according to the "line method" during the period were distributed as a percentage of these different light and weather conditions.

When making estimates it is necessary to take into account the fact that radar registers approximately 40 per cent of diurnally migrating birds. It is reasonable to assume that radar registers neither more nor fewer birds at night or in fog unless the flock size or flight altitude during such conditions deviates from the diurnal pattern.

Of the time included in these studies, only 8 per cent is at night whereas up to 22 per cent of recorded flocks over the whole period migrate during the night (Figure 15). It is worth pointing out that most of the nocturnal migration takes place when there is a tailwind, while diurnal migration takes place in good visibility with more varied wind conditions. Waterfowl migration is shown in Table 18 in numbers of flocks per 15-minute intervals in daytime as well as at night. The table shows that more birds per quarter migrate during daytime in good visibility (spring 2001, 2.6 flocks per quarter) than during the night (spring 2001, 0.8 flocks per quarter). It can also be seen from the table that migration in fog, observed as the number of flocks per quarter (spring 2001, 0.7 flocks per quarter) is equal to night flights (Table 18). Pettersson & Lindell (1999) have previously shown that spring night migration probably accounts for approximately 20 per cent of the total migration in Kalmar Sound.

Radar observed flocks per quarter

	Daytime good visibility			Daytime mist			Daytime fog			Night		
Spring	n	m	sd	n	m	sd	n	m	sd	n	m	sd
2001	175	**2.6**	0.8	42	**(0.3)**		66	**0.7**	0.3	211	**0.8**	0.4
2002	245	**0.5**	0.2	7			17	**(0.3)**		193	**0.3**	0.1
2003	558	**1.1**	0.4	24	**(0.6)**		15	**(0.5)**		490	**0.3**	0.1

Table 18 Number of waterfowl flocks observed by radar in 15minute intervals in spring in different visibility conditions. Under "n". Numbers of quarters studied are shown and "M" shows the average number of flocks per quarter recorded by radar. Average values in brackets are values of great uncertainty. The only statistically significant differences are from spring 2001 when more flocks per quarter were recorded by radar during daytime than during nighttime (n=175/211 quarters, r=0.578, p<0.05, Wilcoxon twosided pair test). The choice of test was made with regard to the small number of recorded flocks and the data not being normally distributed.

4.3.3 Where and how do waterfowl flocks fly in the Sound in bad visibility and at night?

Unfortunately there are no radar data from spring 1999 before the wind turbines were erected at Utgrunden. To be able to compare waterfowl migration at night and by day in poor visibility before and after construction of the wind farms, data from spring 2001 (only the Utgrunden wind farm had been constructed) were compared with that of spring observations in both 2002 and 2003, when the two wind farms had been erected (Figures 16 and 17). The groups of waterfowl flocks (Eider 45+ and larger species 20+) which should be large enough to produce radar echoes were also separated and accounted for. As before, the Öland side dominates in spring 2001 (Figure 16). But in this case it is possible to establish that flocks consisting of a large number of birds (potentially radar-identifiable large flocks) and the radar-recorded Eider flocks show a tendency to fly out in the Sound more than the group of fully observed birds does. Those migrating diurnally and in fog show a tendency to migrate more centrally in the Sound, with an increased migration intensity in zone B, although most birds remain in zone D. Migration in daytime and mist shows hardly any reliable deviation in comparison with migration in daytime in good visibility.

The radar data show hardly any migration along the mainland side (zone A) during spring 2001 and a very small number of migrating flocks over Utgrunden (zone C) in good visibility as well as in mist and fog. Of the few flocks flying through zone C, more seem to migrate in fog than in other weather conditions. The radar-recorded night migration of spring 2001 (Figure 16) took place to a great extent in the middle of the Sound (zone B) in definitely smaller numbers along the Öland side, which is the main flight path during daytime. Hardly any flocks were recorded at night in the zones where the wind turbines were already situated (zone C, Utgrunden) or were later constructed (zone A, Yttre Stengrund). The fact that few flocks were recorded on radar flying along the western side of the Sound tallies with the migration pattern noted from observations. In the spring periods of 2002 and 2003, as in the previous spring (Figure 17) there were very few flocks migrating through zone A, the zone where the wind turbines at Yttre Stengrund had been in situ. The results also show that diurnal migration in good visibility, as well as in mist and fog, takes place on the Öland side to a greater extent than during spring 2001. Nocturnal migration is evenly distributed between zone B and zone D, while very little occurs in zone C. Thus waterfowl seem to avoid flying close to the wind turbines at Utgrunden in zone C at night as well as in poor visibility in daytime, but mainly during daytime in good visibility. This confirms that in all probability the birds detect the wind turbines even in the dark from a distance of some kilometres.

4.3.4 How much further do flocks fly when they avoid the wind turbines?

Waterfowl migration in Kalmar Sound occurs during the spring mostly in relatively small flocks and near the surface of the sea, which limits the possibilities of radar recording. In spite of these restrictions it was possible to make longer radar trackings of a number of flocks. In total during all the spring periods 123 waterfowl flocks (mainly Eider) were tracked during daytime in good visibility at Utgrunden (Figure 18). It was possible at night to make 48 radar trackings (Figure 20) but only during nights with good visibility. During foggy days, with visibility less than 300 metres, in total 38 waterfowl flocks were tracked for a slightly longer distance at Utgrunden (Figure 19). As the spring migration is at its most intense in westerly winds and tailwinds, almost all long trackings are in this type of wind conditions. Waterfowl migration in Kalmar Sound in spring 2002 and 2003, when both wind farms had been extended, shows clearly that most flocks only fly close to the Blekinge coast and after that cross over to the Öland side, which is most obvious in daytime in good visibility (see outlines of how the flights generally occur in the Sound

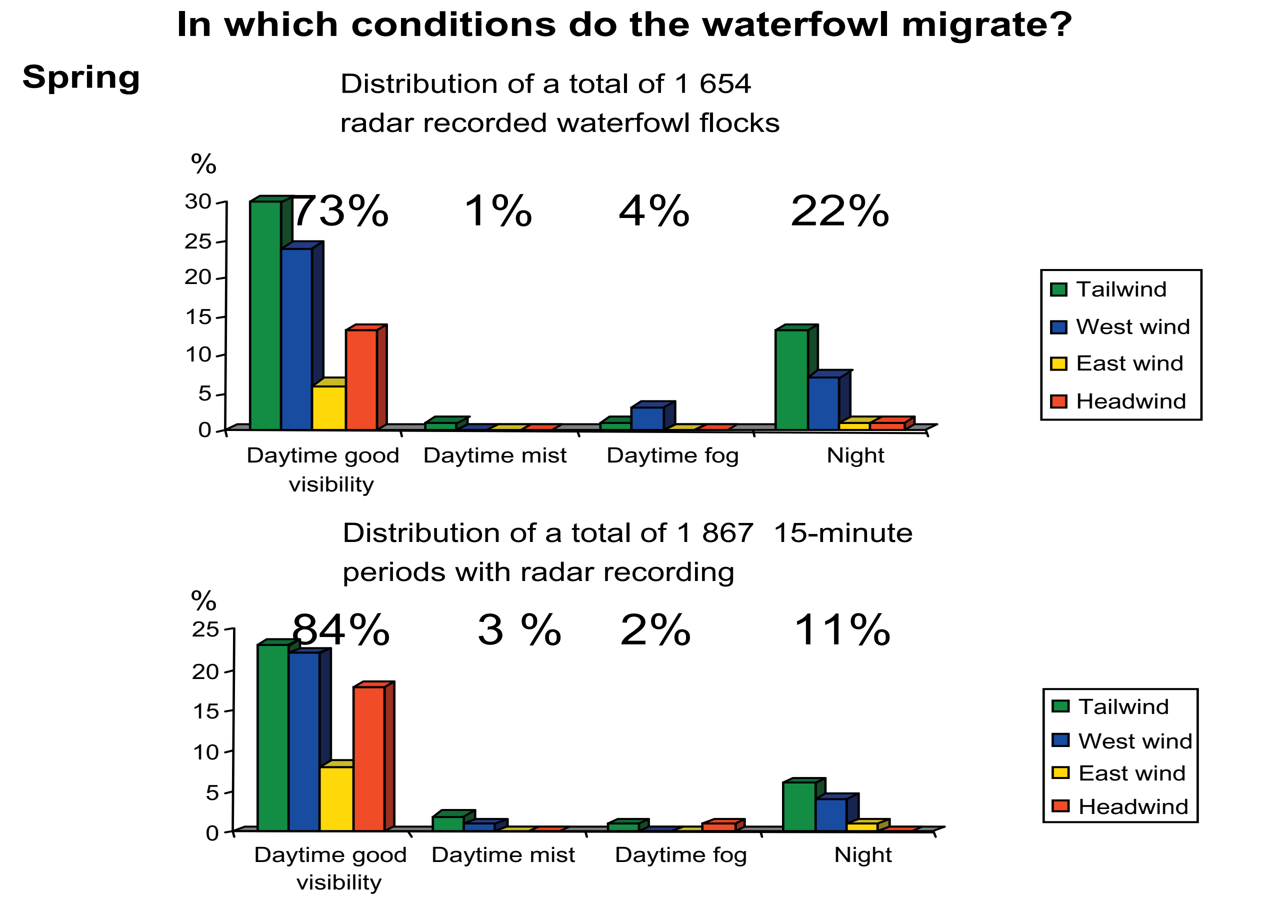


Figure 15 Radar-recorded waterfowl flocks and time recorded by radar divided into separate light and weather conditions. The top figure shows distribution as percentage of the number of waterfowl flocks recorded by radar ("the linear method") as having passed the marked radar observation line in southern Kalmar Sound (Figure 3). The bottom figure shows the number of 15minute periods of radar monitoring distributed over different conditions. The material is based on spring studies in 2001–2003.

during springtime Figure 13).

Flocks flying directly towards the Utgrunden wind farm show a clear tendency to veer off approximately 1–2 kilometres before the turbines (Figure 18). This curve in the migration path was drawn as an average curve chosen by these flocks in comparison to the projected possible path above or between the turbines. This migration path curve involves an extension of the flight path of 1.2 km. Out of the 123 radar-tracked flocks that passed the Utgrunden area there were, at a rough estimate, about 22 flocks (18 per cent) that made this or a similar detour (see detailed study in Figure 18). Some flocks choose a curve westward of the turbines and then often along two alternative paths, of which one narrower curve results in an approximately 2.2 km longer flight path and the slightly wider curve causes an approximately 2.9 km longer flight path than a straight path through the wind farm (Figure 18). Radar trackings showed about 7 flocks flying in this or a similar curve for each of the alternative flight curves. Of the radar-tracked flocks, about 36 (or 30 per cent) took this detour at Utgrunden and therefore extended their flight path a little through the Sound to avoid the wind turbines. Most flocks making a slight detour start it early, flying approximately 2 km east of the wind turbines and therefore have a slightly longer flight path.

Of the waterfowl flocks recorded by radar at Yttre Stengrund (a total of 56 flocks during these years) only 3 flocks (5 per cent) flew in some kind of curve, which resulted in an approximately 1.9 kilometre longer flight path than if they had flown in a straight line (Figure 18). From spring 2001 there were 2 - 3 radar-tracked flocks (see Figure 18) which flew over Yttre Stengrund above the future wind turbine construction area. In fog and mist (Figure 19) 4 out of 31 radar-tracked flocks at Utgrunden showed a detour involving an approximately 1.2 kilometre longer flight path, in the same way as certain flocks do when migrating in good visibility during the day. In fog, one out of every 9 flocks at Yttre Stengrund can also be seen veering away from the wind turbines (Figure 19). In spring 2001 four flocks were identified crossing the Sound from west to east in fog. These flocks were most likely barnacle geese as the observer at Utgrunden heard barnacle geese in the thick fog at that time. During nocturnal migration (Figure 20) 4 flocks of 45 (9 per cent) show a detour causing an approximately 2 kilometre longer flight. If this extra flight distance is converted into time, it means that the detour of the flocks around the wind farms leads to a 2–3 minute longer flight time. This slightly longer flight time is also caused by the flocks choose a slightly higher altitude at the same time as they make the detour (see next section). Radar tracking also shows that some flocks fly between or over the turbines during daytime in good visibility. The frequency of this flight path is dealt with in the next section.

4.3.5 Flocks that fly close to the wind turbines

An optical rangefinder borrowed from the Department of Animal Ecology at Lund University was an important step in estimating the risk of collisions (see section 3.2.5). This device made it possible to measure flight altitude and positions of a large number of flocks flying in the vicinity of the wind turbines. For a total of 8 days (24 March–8 April) in spring 2002 and 15 days (period 25 March–8 April) in spring 2003, bird migration around the wind turbines was monitored from the Utgrunden lighthouse throughout the hours of daylight. During these periods the majority of waterfowl flocks passing in the vicinity of the wind turbines (approximately 500–100 metres) was measured for position and altitude using the optical rangefinder. In some cases there was time to make short trackings of flocks, mostly in spring 2003 when skills in using the instrument and recording data had been developed.

For half of the flocks measured (156) with this instrument during the two spring seasons (see Figure 23), it was only possible to measure the flight altitude of separate flocks from four stationary sites. These sites were chosen to record the flocks approximately one kilometre away from the wind turbines, 300 metres before the wind turbines, at a passage level with the wind turbines and approximately one kilometre after passage (Figure 21).

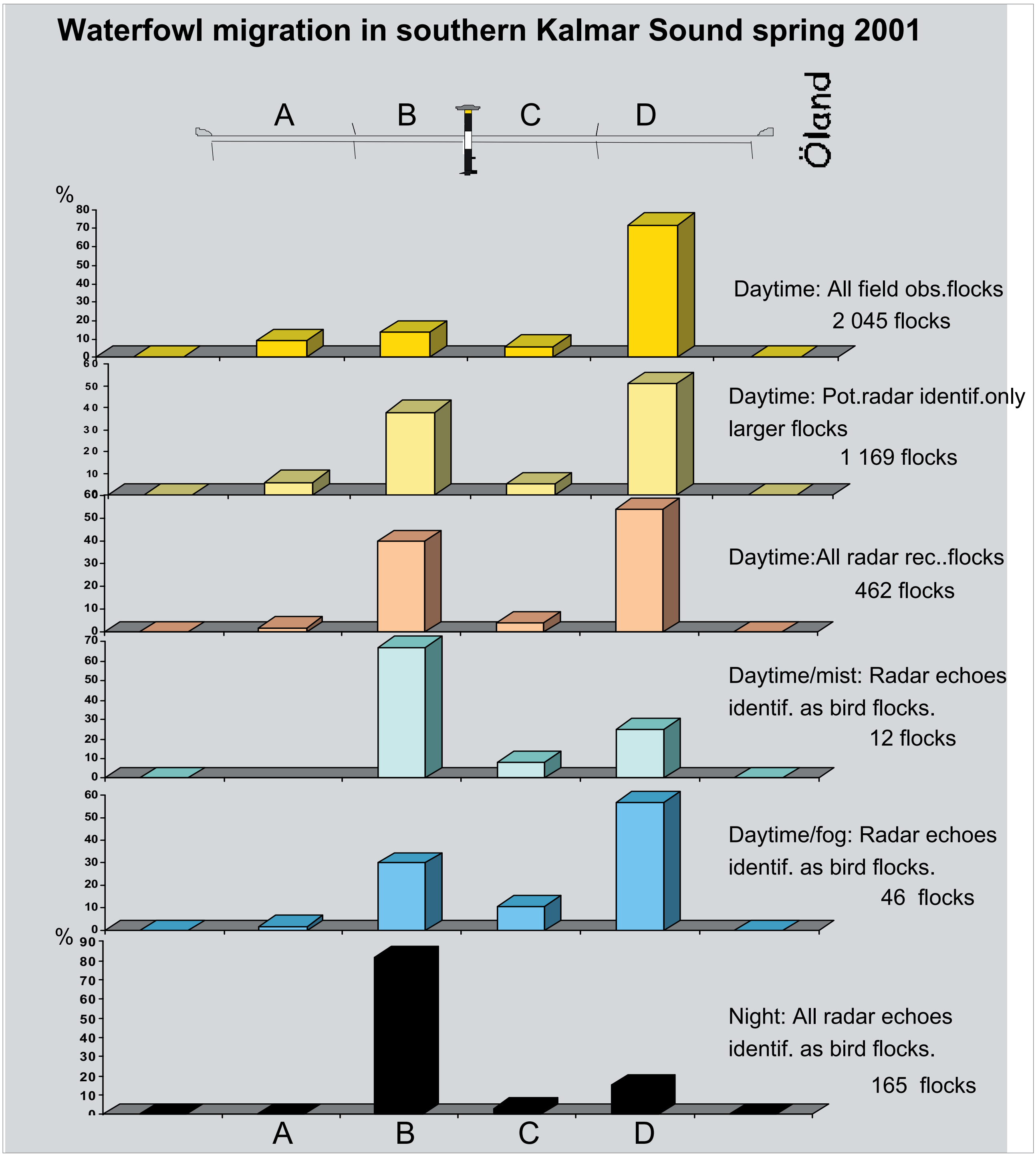


Figure 16 All observed and radar-recorded waterfowl flocks divided into migration zones and weather conditions during the period 31/3–6/4 2001. The total observation time was 135 hours, of which 494 quarters (15minute periods) are radar monitored.

During these two spring periods it was possible to visually track considerably more waterfowl flocks (in total 331) in the vicinity of the wind farm area. Of these, 12 flocks of species other than Eider (Mute Swan, Cormorant, Goosander, Red-breasted Merganser and Barnacle Goose) were recorded. None of these species showed any greater deviations in behaviour in the vicinity of the wind turbines compared with the Eider, and at least one flock of each species was also observed flying between the turbines.

The previously reported radar study showed that most of the Eider flocks (Figure 16) which come in towards the wind turbines alter their course slightly about 1–2 km before the turbines so that they usually pass at a distance greater than 500 metres. The instrument trackings of the flocks that flew closer to the wind turbines (Figure 21) during the two spring periods showed that all waterfowl flocks seem to climb a little on passage of the wind farm when they fly between, as well as alongside, the turbines. These observations correspond with those from the whole of zone C, i.e. the wind farm zone, where all flocks of different waterfowl groups had a higher average flight altitude than in the other zones. Flocks flying between the turbines show an increase in flight altitude when they pass between the turbines in headwinds as well as tailwinds. They increase flight altitude in a headwind by approximately 30 metres on average when they fly between the wind turbines compared with flights 1000 metres from the turbines, but the accuracy of these instrument measurements at a distance of 3000 to

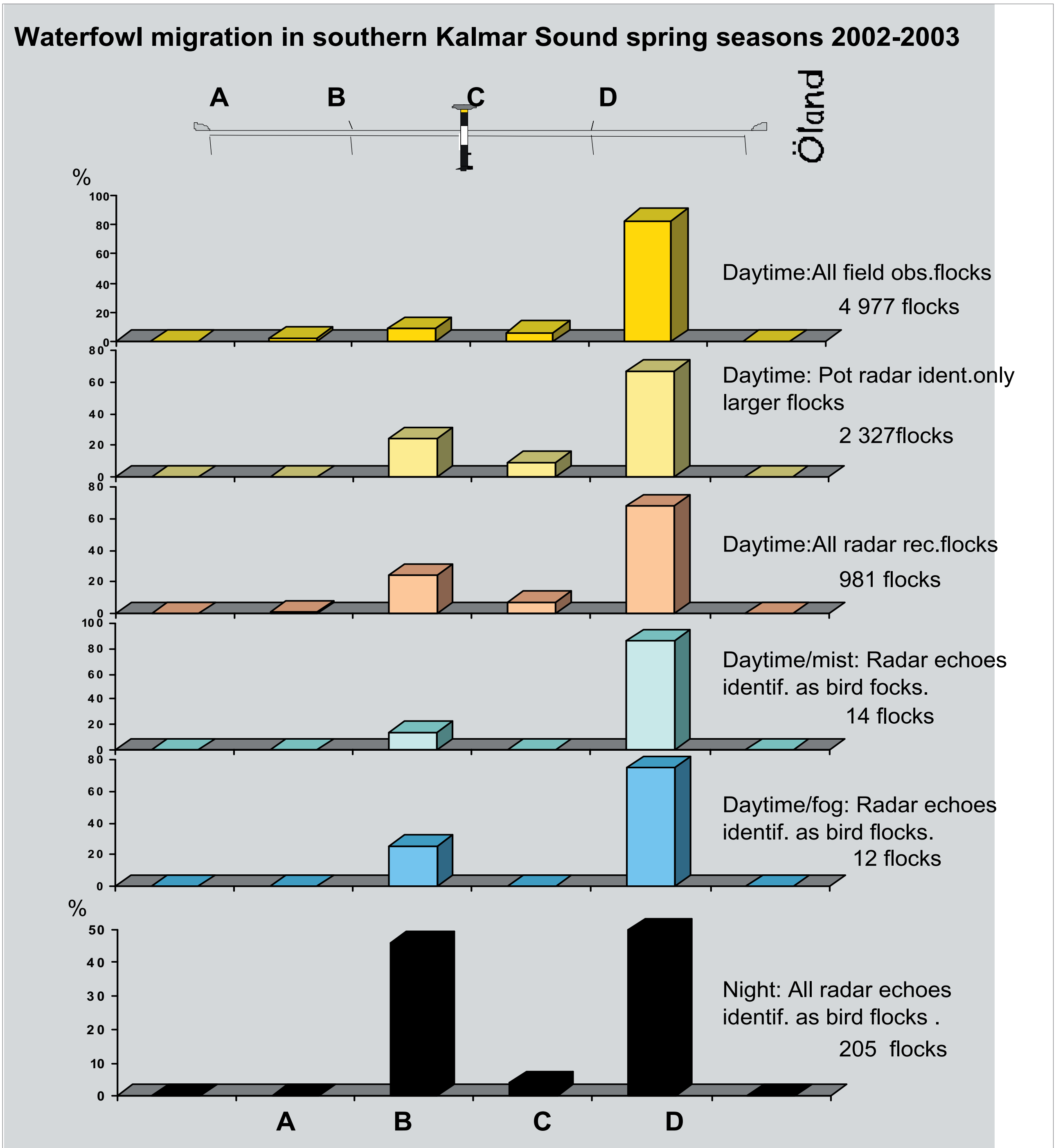


Figure 17 All observed and radar-recorded waterfowl flocks from the observation periods 3/4–8/4 2002 and 25/3–8/4 2003 divided into migration zones and light and weather conditions. Radar monitoring was carried out in 464 quarters in 2002 and as many as 909 quarters in 2003. There was a total of 71 hours during these periods without radar monitoring.

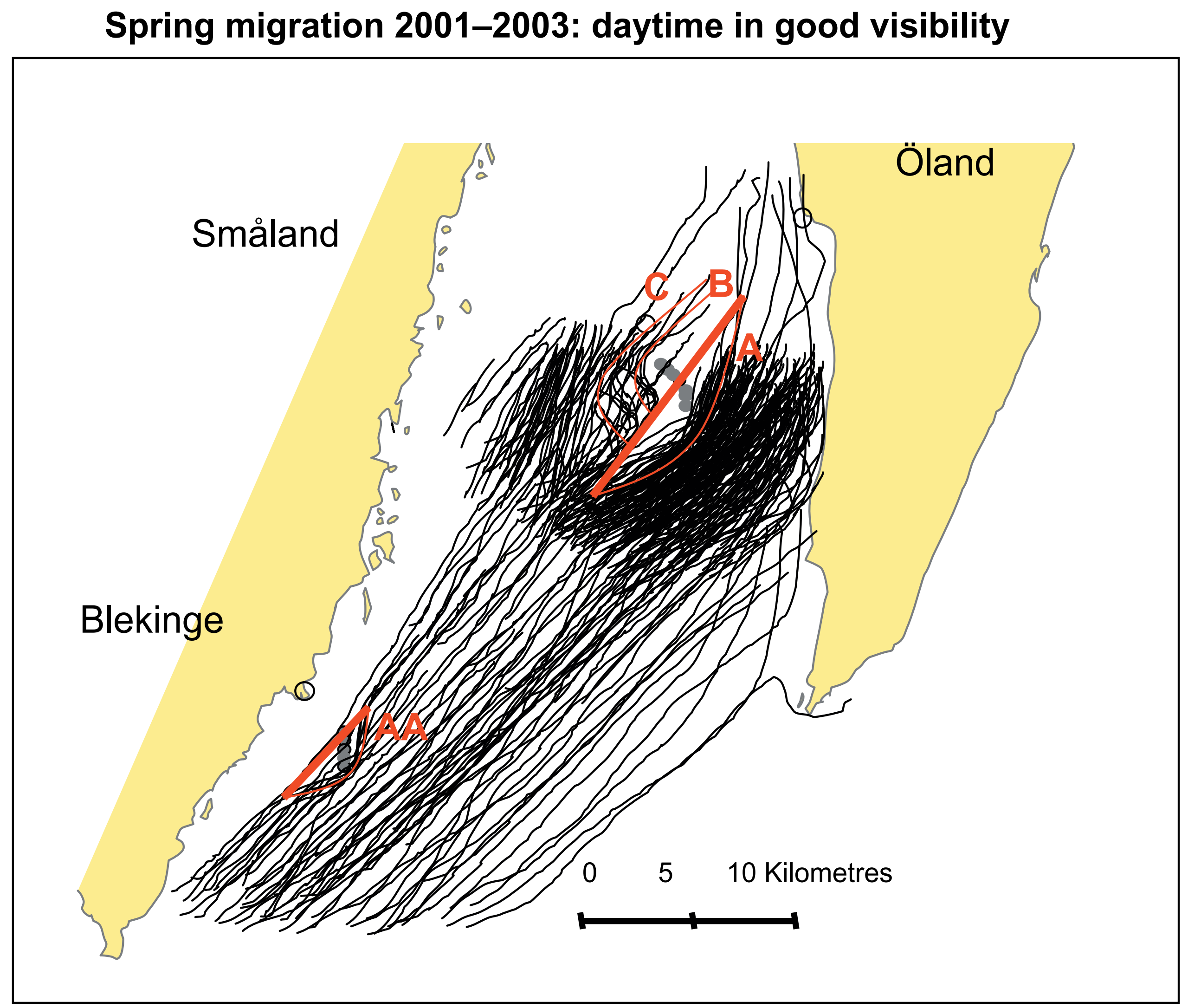


Figure 18 Radar trackings of 123 waterfowl flocks (Eider) during spring migration 2001–2003. The figure shows flock trackings in daytime and good visibility. xx Red lines A, B, C and AA are examples of evasive migration manoeuvres past the wind turbines. The broad red line shows a possible straight flight path without taking the wind turbines into consideration.

4000 metres cannot produce reliable enough values to be statistically guaranteed.

The Eider flocks which fly highest in this zone are naturally those that fly over the turbines. Of the 331 flocks measured for altitude and flying close to the wind turbines, 35 flocks (11 per cent) flew over the turbines (Figure 22). It may seem surprising that the Eider flocks flying above the turbines do not fly especially high - on average only 166 metres. The tips of the rotor blades reach up to approximately 100 metres. The method of measurement cannot show the flight altitude with sufficient accuracy, but the birds seem to fly barely 100 metres above the turbines.

During the whole project period a total of 10654 migrating flocks were observed during spring migration in the whole of southern Kalmar Sound. Of these, approximately 335 flocks (3 per cent of the total number of flocks) flew closer than 500 metres. It should be pointed out then that when a flock flies at a distance of 500 metres from the wind turbines, there is no risk of collision. For 256 of the observed flocks, the shortest distance to the wind turbines was measured (Figure 23). These ”close-to-turbine flights” were also divided into flights in different wind directions, showing that most of these “close” flights occur in westerly winds and tailwinds, and fewer in easterly winds (Figure 23). For flocks flying between the turbines, the distance to the nearest turbine was approximately 200 metres. Only four recorded flocks flew as close as approximately 100 metres to the nearest turbine and this occurred in tailwinds and westerly winds. As is evident from the material, wind direction affects the readiness to fly closer to the wind turbines. In spite of all these factors, there were only four flocks, together with approximately half of the 35 flocks which flew over the turbines, that flew at a distance of approximately 100 metres or slightly less from the nearest turbine. This means that only approximately 29 (4+25) flocks of the observed total of 10654 (or 0.3 per cent) in the Sound flew as near as approximately 100 metres from the turbines during daytime in good visibility.

The flock trackings from spring 2003 are presented in Figures 24–27, and show in more detail how the Eider flocks pass the Utgrunden wind farm. In Figure 24 there is a presentation of how 27 Eider flocks in strong WSW winds on 30 March 2003 flew past Utgrunden wind farm. Four flocks flew between the turbines; two of these split

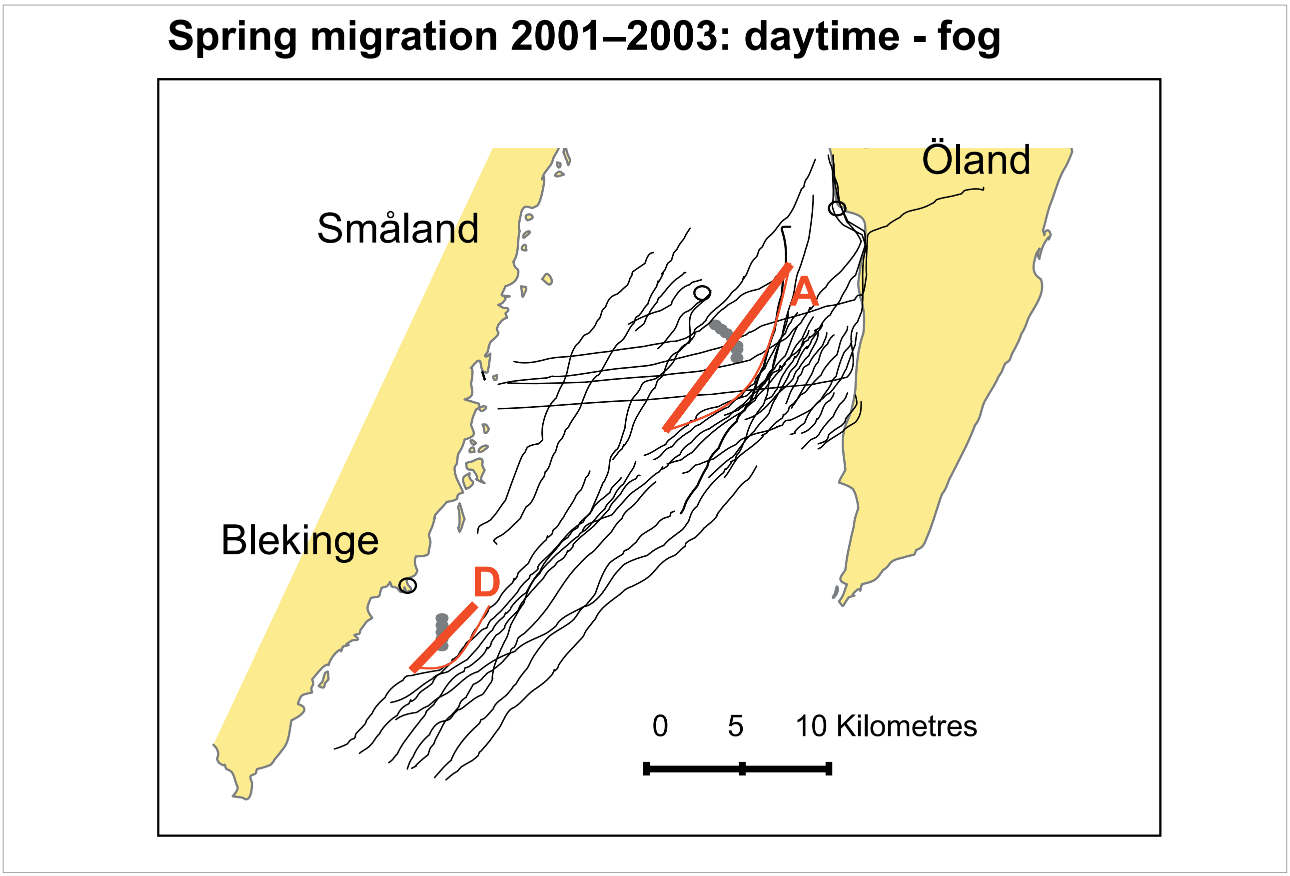


Figure 19 Radar trackings of waterfowl flocks during spring migration 2001–2003 on occasions when they were recorded in daytime at the Utgrunden lighthouse. A total of 38 trackings are shown here, of which 28 passed the Utgrunden area and 9 passed Yttre Stengrund. The red straight line shows a possible flight path directly through the wind farm compared with the curved line which shows the usual evasive manoeuvre before and around the wind turbines.

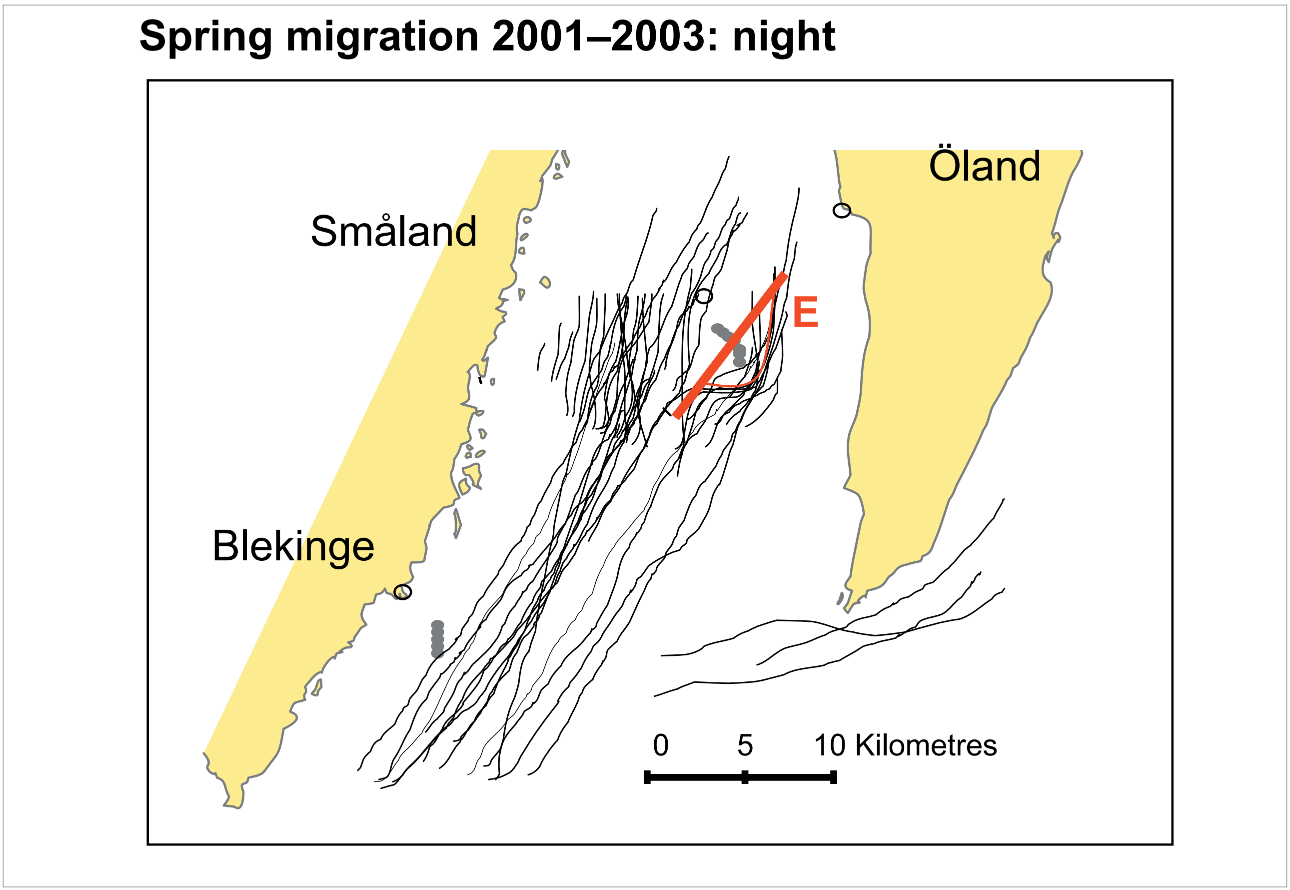


Figure 20 Radar trackings of waterfowl flocks in spring migration 2001–2003, without fog or mist. A total of 51 flocks are shown here, of which 48 pass Utgrunden and 14 over or through Yttre Stengrund. The red straight line shows a possible flight path straight over or through the wind farm compared with a curved line, E, which shows the migration path which the bird flocks usually show in an evasive manoeuvre around the wind turbines.

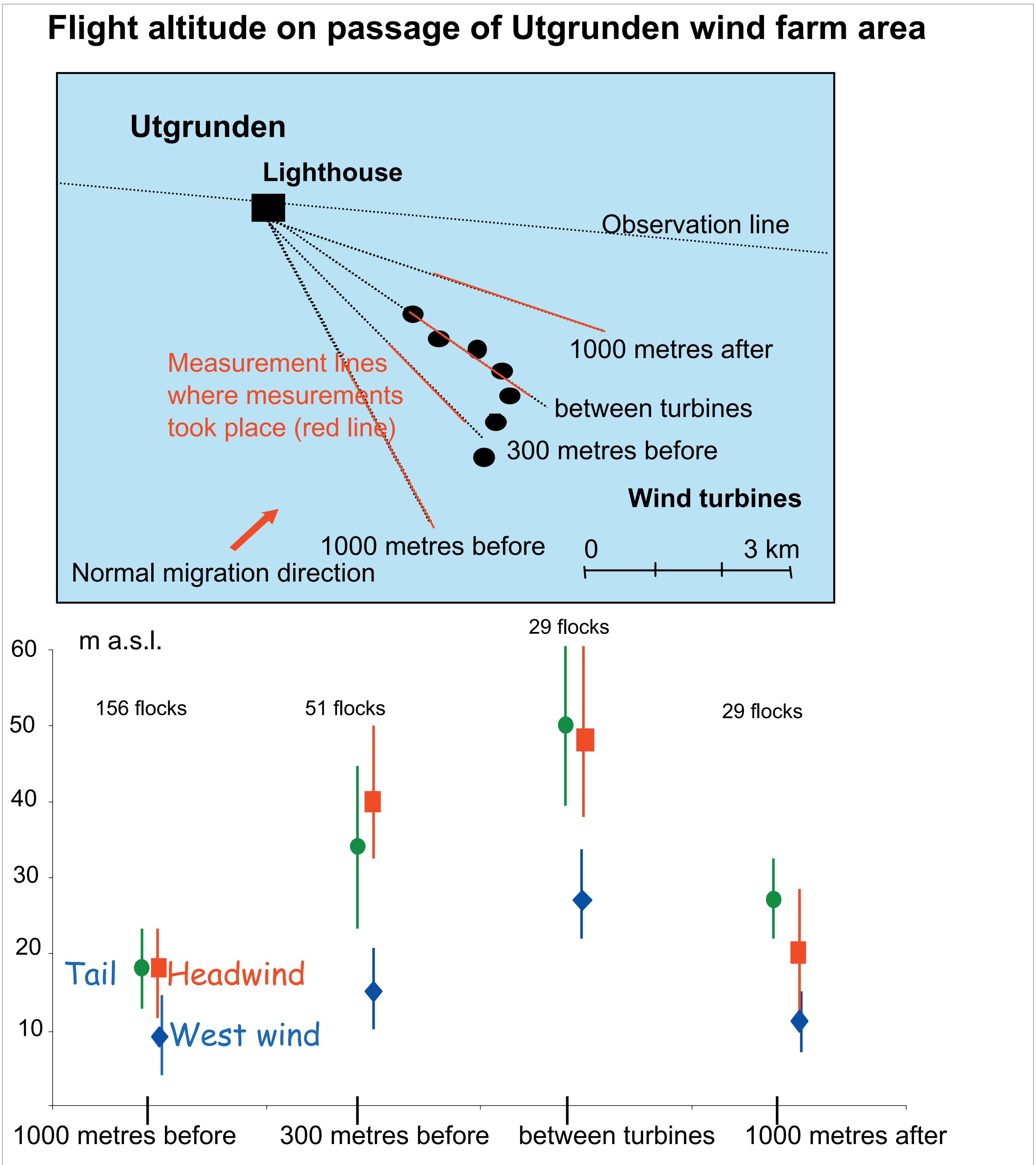


Figure 21 The small map shows where measurements were made (the red part of the line): measured flight altitudes at four selected lines for Eider flocks which fly towards the wind turbines when passing the wind farm at Utgrunden. The measurements were made during spring migration 2002 and 2003. Measurements of altitude and position were made using an optical rangefinder with an accuracy of 10–20 metres. The average figures for flight altitude and the standard deviation in different winds are shown in the diagram.

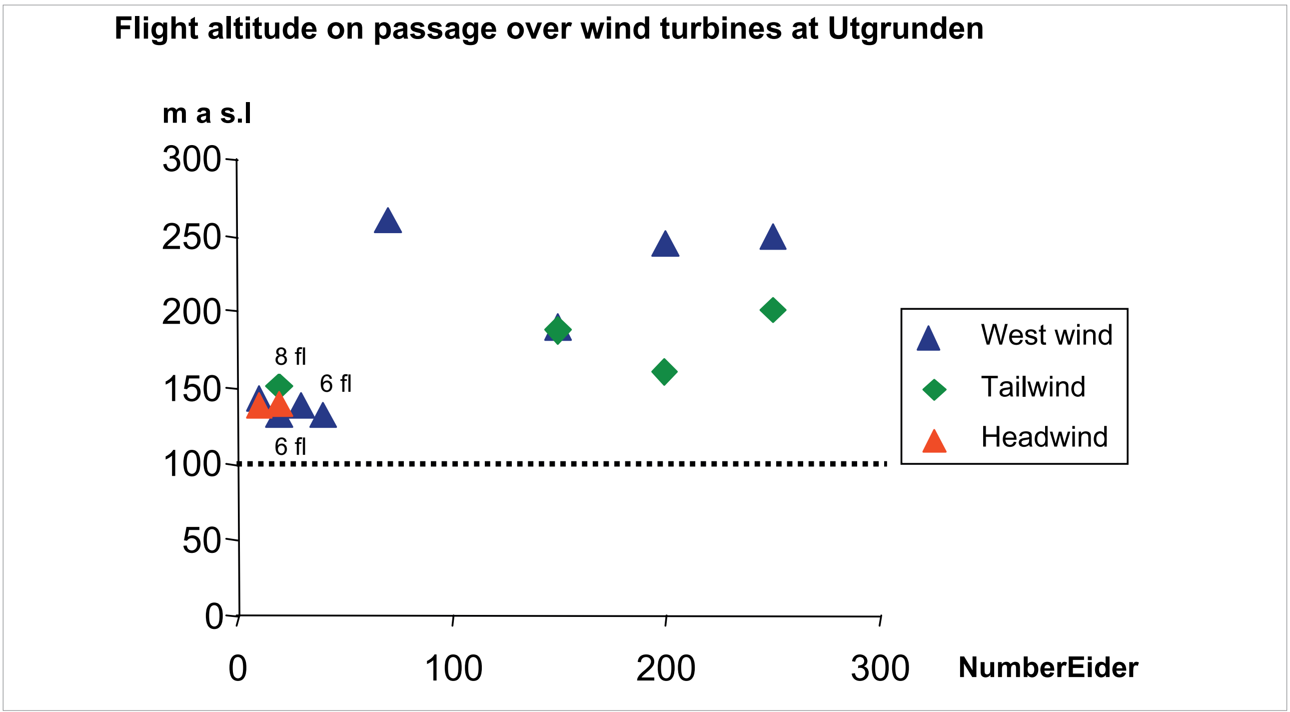


Figure 22 Flight altitude for 35 Eider flocks which flew over the wind turbines at Utgrunden during spring migration 2002 and 2003. Measurements of position and altitude were made with an optical rangefinder. The average altitude for all 35 flocks is 170m, i.e. only 70m above the highest point of the rotor blades. Note that it is only small flocks which pass over the wind turbines in headwind, whereas larger flocks also passed in tailwind and in westerly winds. The accuracy of the instrument used to measure these distances is shown in the method section above. The dotted line shows the highest point of the rotor blade at the Utgrunden wind turbines.

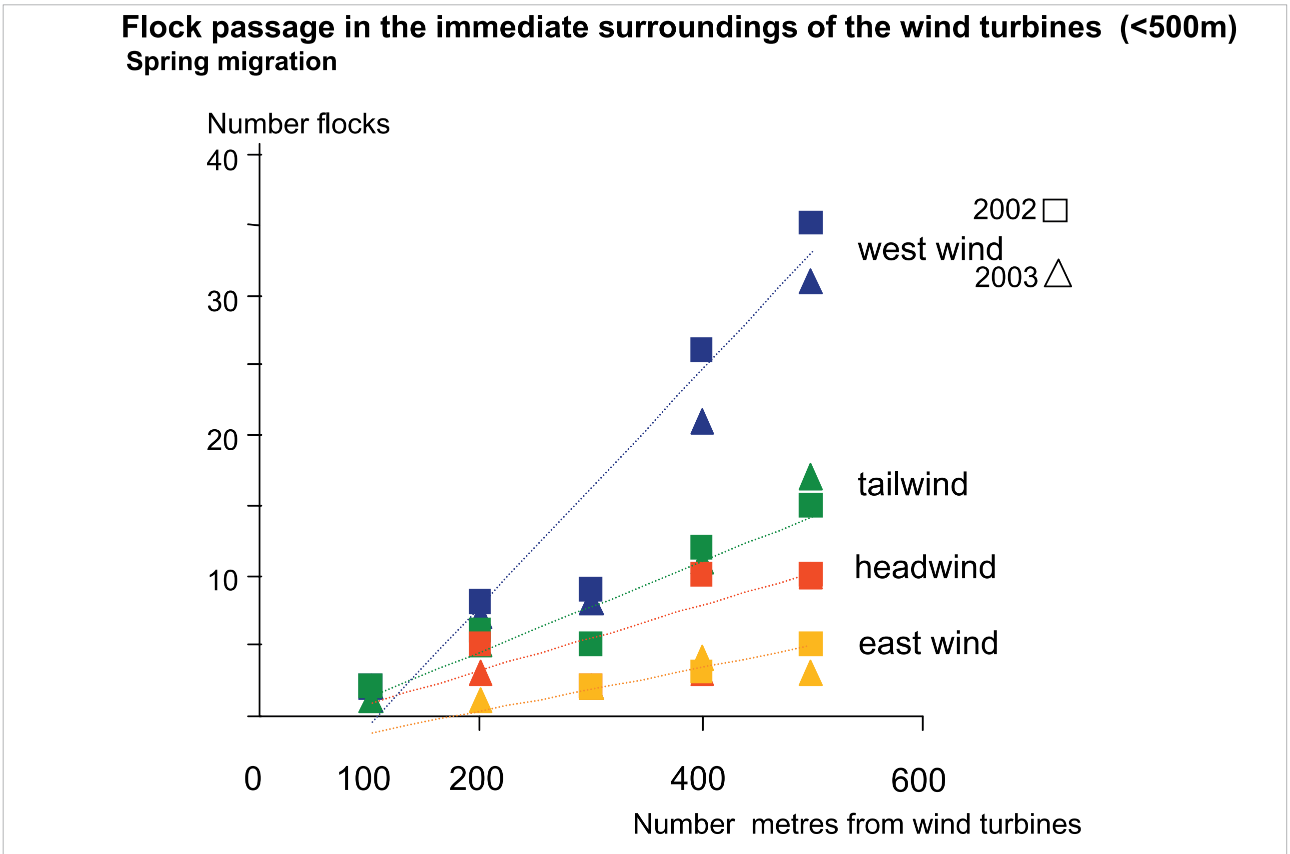


Figure 23 Number of waterfowl flocks which flew closer than 500m from the nearest wind turbine at Utgrunden during spring migration 2002 and 2003. The distance of all 256 flocks was measured as close as 100m and they were grouped into prevailing wind direction. Only four flocks, of which 3 in tailwind and 1 in headwind, flew as close as 100m from the nearest wind turbine. The instruments have an accuracy of about 100m at a distance of 4000m (the longest distance included) and this resolution was also used for flocks measured with a higher accuracy at a distance of slightly more than 2000m.

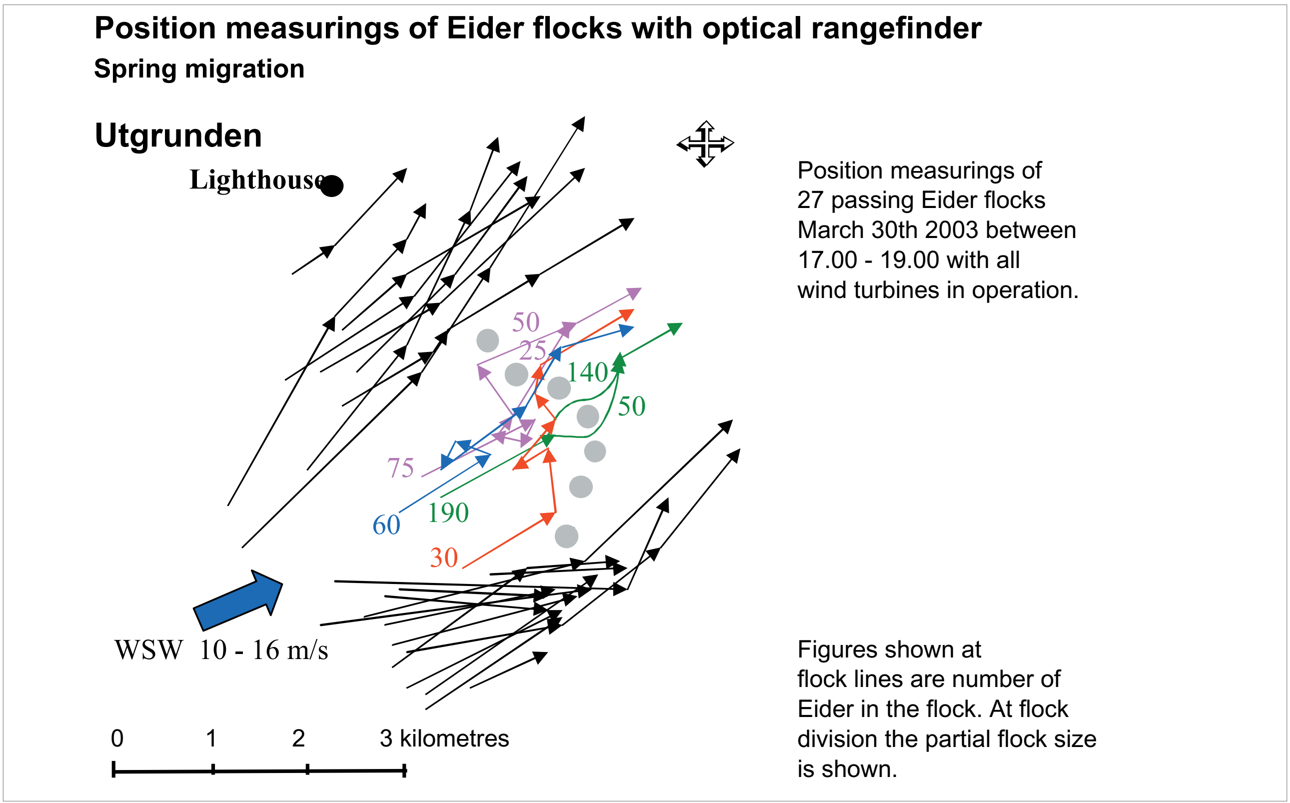


Figure 24 Measurements of position and tracking of Eider flocks from the Utgrunden lighthouse using an optical rangefinder. The time between each measurement of position is usually 1 minute, sometimes at shorter intervals down to 20 seconds. The flock paths copied onto the map are measured for position at the beginning and at the end of the line, and at the arrow markings. Each wind turbine is marked in grey. The different colours of certain flock trackings were made to distinguish their flight paths between the turbines.

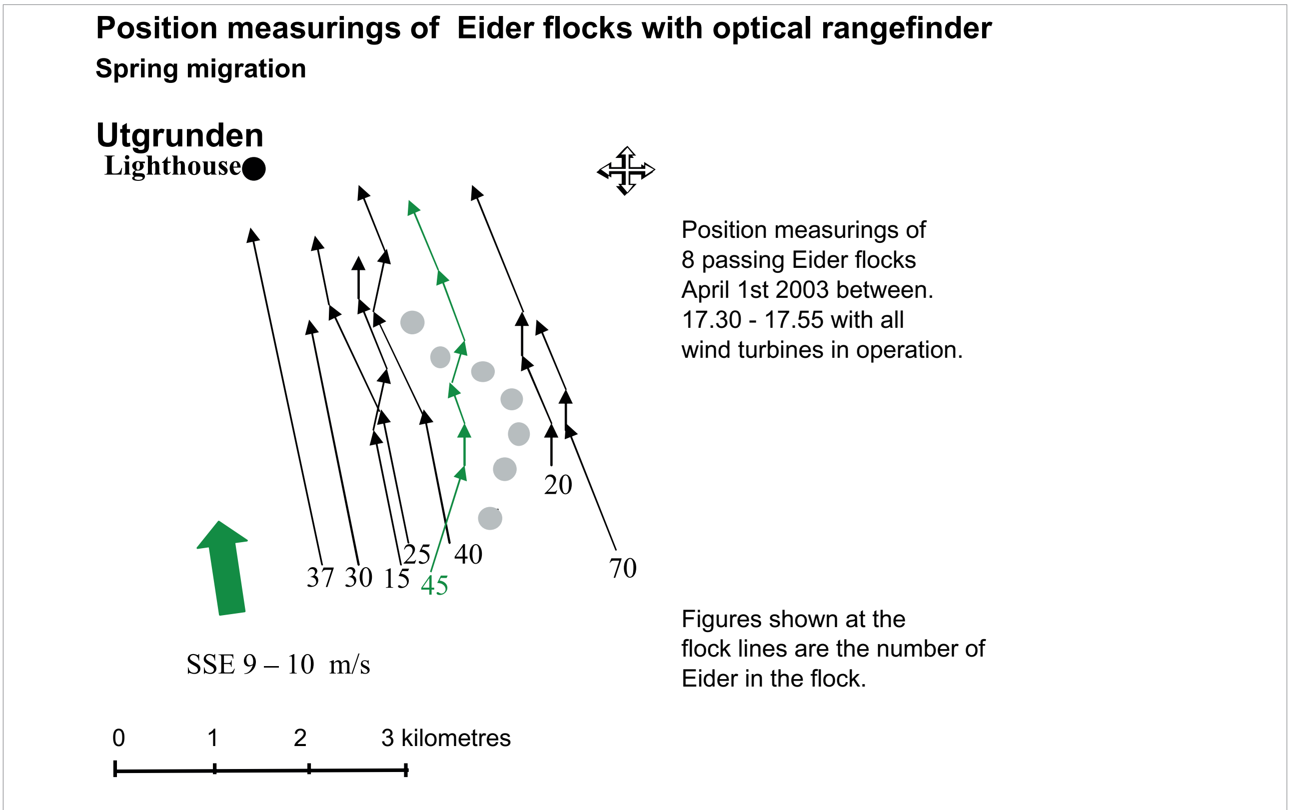


Figure 25 Measurements of position and tracking of Eider flocks from the Utgrunden lighthouse using an optical rangefinder. The time between each measurement of position is usually 1 minute, sometimes at shorter intervals down to 20 seconds. The flock paths copied onto the map are measured for position at the beginning and at the end of the line, and at the arrow markings. Each wind turbine is marked in grey. The flock marked in green was the only one to fly between the turbines.

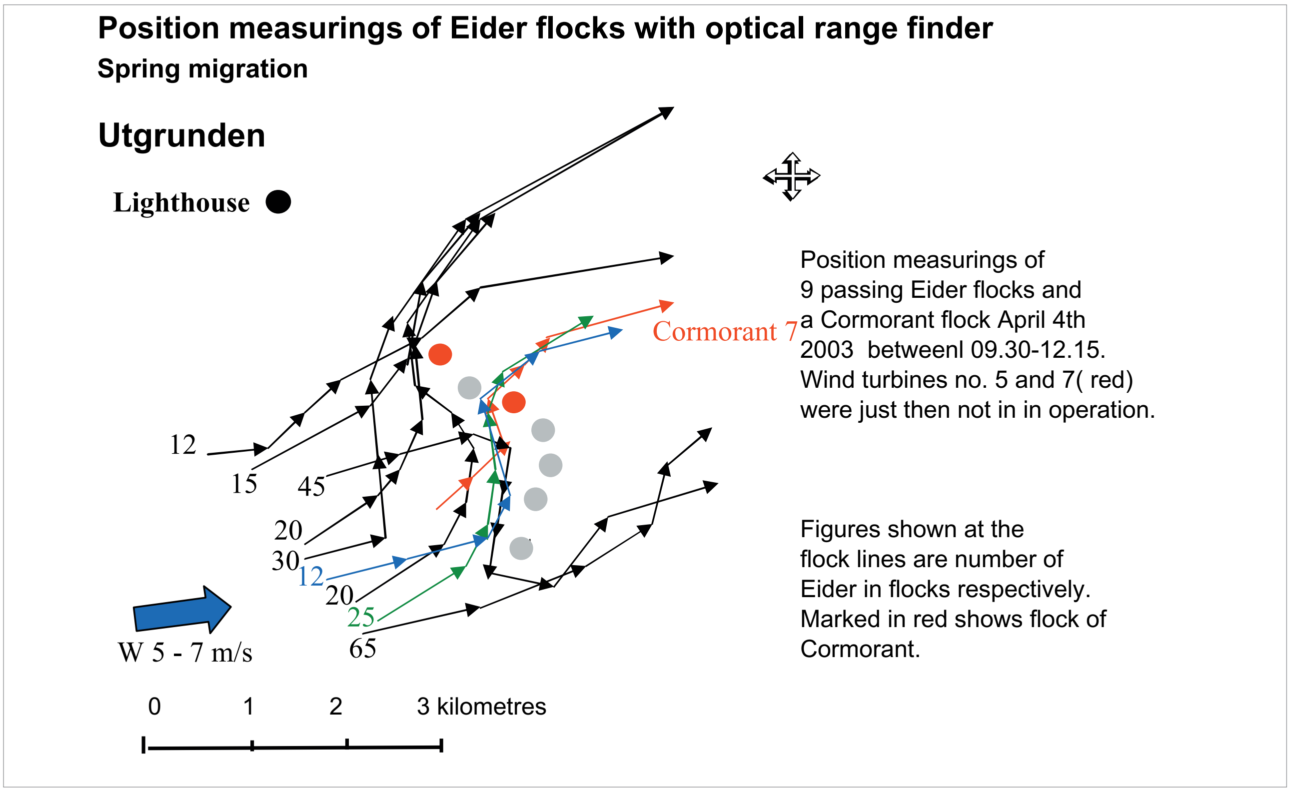


Figure 26 Measurements of position and tracking of Eider flocks from the Utgrunden lighthouse using an optical rangefinder. The time between every measurement of position is usually 1 minute, sometimes at shorter intervals down to 20 seconds. The flock paths copied onto the map are measured for position at the beginning and at the end of the line, and at the arrow markings. Each wind turbine is marked in grey. The different colours of certain flock trackings have been made just to distinguish their path between the turbines. The accuracy of the instrument on these occasions is approximately 100m at a distance of just over 3000m.

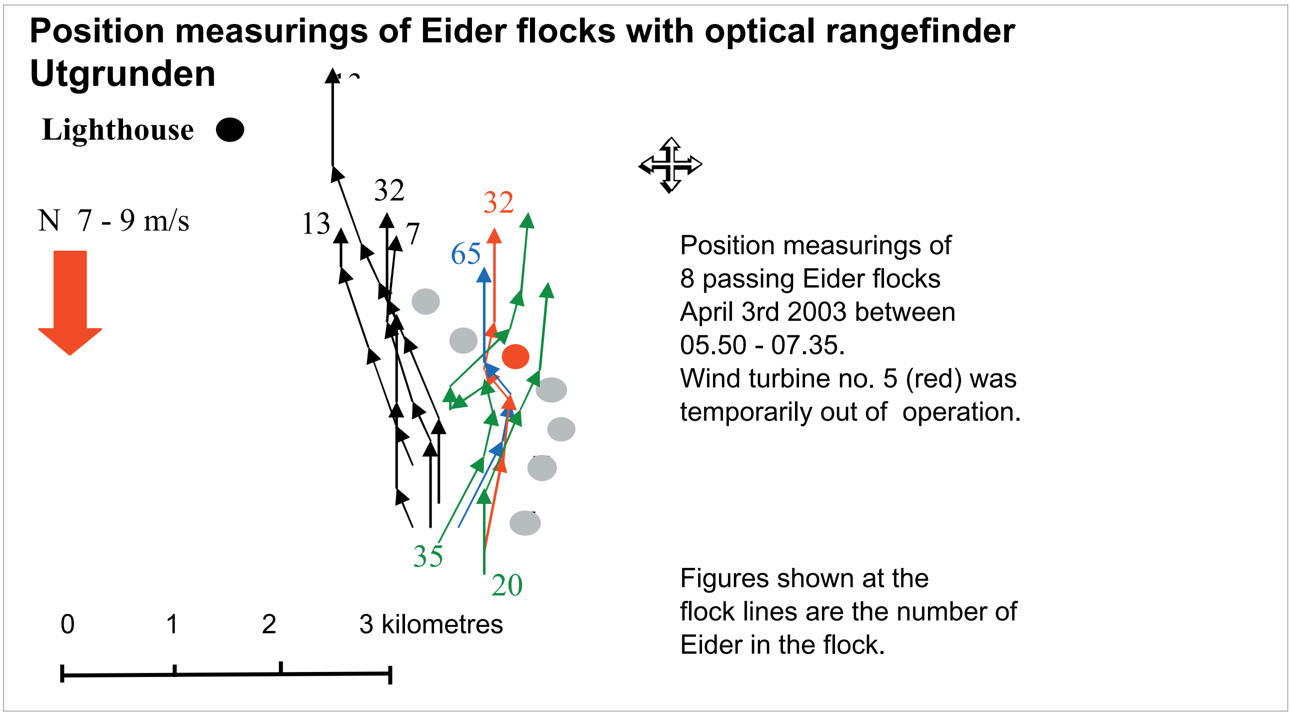


Figure 27 Measurement of position and tracking of Eider flocks from the Utgrunden lighthouse using an optical rangefinder. The time between every measurement of position is usually 1 minute, sometimes at shorter intervals down to 20 seconds. The flock paths copied onto the map are measured for position at the beginning and at the end of the line, and at the arrow markings. Each wind turbine is marked in grey. The different colours of certain flock trackings have been made to distinguish their flight path between the turbines.

up and flew in different areas between the turbines to rejoin directly after passage. Eight Eider flocks passed in the vicinity of the turbines in one hour in the evening of 1 April 2003 in a strong SSE wind. Only one of these flocks was large enough to be recorded by radar. Of these eight flocks, only one chose to fly between the turbines without any significant hesitation (Figure 25).

There was some confirmation of waterfowl daring to fly closer or more often between non-rotating turbines when some of the turbines were not in use and most of the flights were heading for the Utgrunden wind turbines (see Figures 26 and 27). On the morning of 3 April 2003, turbine five (counted from the south) was out of order and there was a moderate northerly wind when eight Eider flocks passed near the wind turbines (Figure 27). Four chose to fly between the turbines, around turbine five, while the other four flew west of the turbines. In the middle of the day on 4 April 2003 there were moderate westerly winds and both turbines five and seven were out of order. Nine Eider flocks and a Cormorant flock came in close to the turbines and could be measured (Figure 26). The flocks heading directly towards the turbines showed great hesitation. Four of the Eider flocks and the Cormorant flock chose to fly between the turbines five and six, but several of the flocks flew around turbine seven at a shorter distance than the radius of a rotating rotor. It seems that waterfowl dare to fly closer to the turbines when they are not rotating. However, it was not possible to make a thorough test by stopping the turbines during heavy migration to compare flocks' readiness to fly between and closer to the turbines. No measurements were made with the optical rangefinder of flocks in spring migration at Yttre Stengrund wind farm.

Number and percentage of different groups of waterfowl

Autumn	2000		2001		2002		Total	
Species/groups of sp.	Number	Perc. %	Number	Perc. %	Number	Perc. %	Number	Perc. %
Diver, Grebe and Auk	432	1	220		328		**980**	
Cormorant	1 979	1	1 958	1	2 525	4	**6 462**	**2**
Swan and Goose	11 869	15	70 499	39	5 341	8	**87 709**	**27**
Heavy diving Duck	414	1	1 265	1	343		**2 022**	
Eider	49 838	62	85 354	47	49 559	74	**184 751**	**56**
Long-tailed Duck	2 457	3	272		405		**3 134**	**1**
Dabbling Duck	8 146	10	6 334	3	3 907	7	**18 387**	**6**
Light diving Duck and Merganser	3 596	5	5 349	3	2 666	4	**11 611**	**4**
Crane	1 025	1	10 351	6	2 223	3	**13 599**	**4**
Wader	249	1	341		14		**604**	
Total	**80 005**		**181 943**		**67 311**		**329 259**	

Table 19 The number of observed waterfowl divided into different species or groups of species. The compilation includes periods when it was possible to observe the whole Sound. See table 21 for the composition of species in the different groups of birds.

4.4 Field observations of autumn migration

How has the erection of wind farms in southern Kalmar Sound influenced waterfowl flight paths in their autumn migration through the Sound? To obtain a satisfactory answer to this question, it is necessary to conduct simultaneous observations over the whole width of the Sound. Simultaneous observations from the three observation sites in good visibility enabled full coverage of the whole migration corridor. Most of these observations were made in the early morning and late morning, when migration intensity was greatest. In order to gain an overall picture

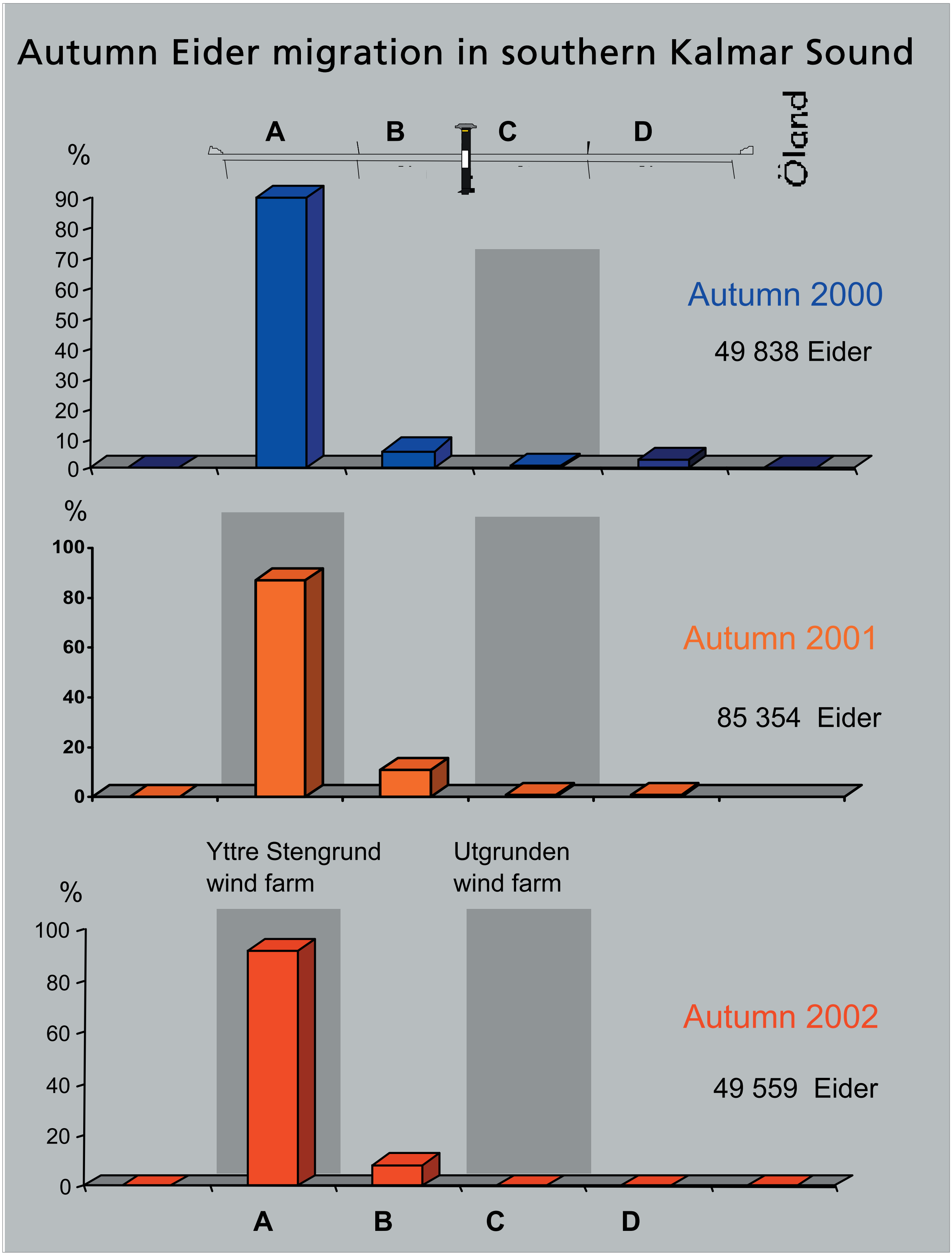


Figure 28 Eider migration in southern Kalmar Sound with distribution as a percentage in the four zones A–D and on the two mainland sides. Markings in grey are zones with wind turbines.

of waterfowl flight paths in the Sound, data from certain days that fulfilled all criteria for full observation coverage were selected. With these criteria in mind, 12 observation days in autumn 2000, 13 days in 2001 and 14 days in 2002 were selected to show flight patterns for autumn migration in Kalmar Sound (Table 2).

4.4.1 Eider migration in daytime in the whole of the Sound

Eider are not as predominant in the autumn when compared with the spring, and only 56 per cent of the recorded migrating birds were Eider (Table 19). The group of swans, geese and Cormorants accounted for up to 30 per cent of the total in the autumn. The autumn migration is not concentrated to a three-week period as is the spring migration. It is more

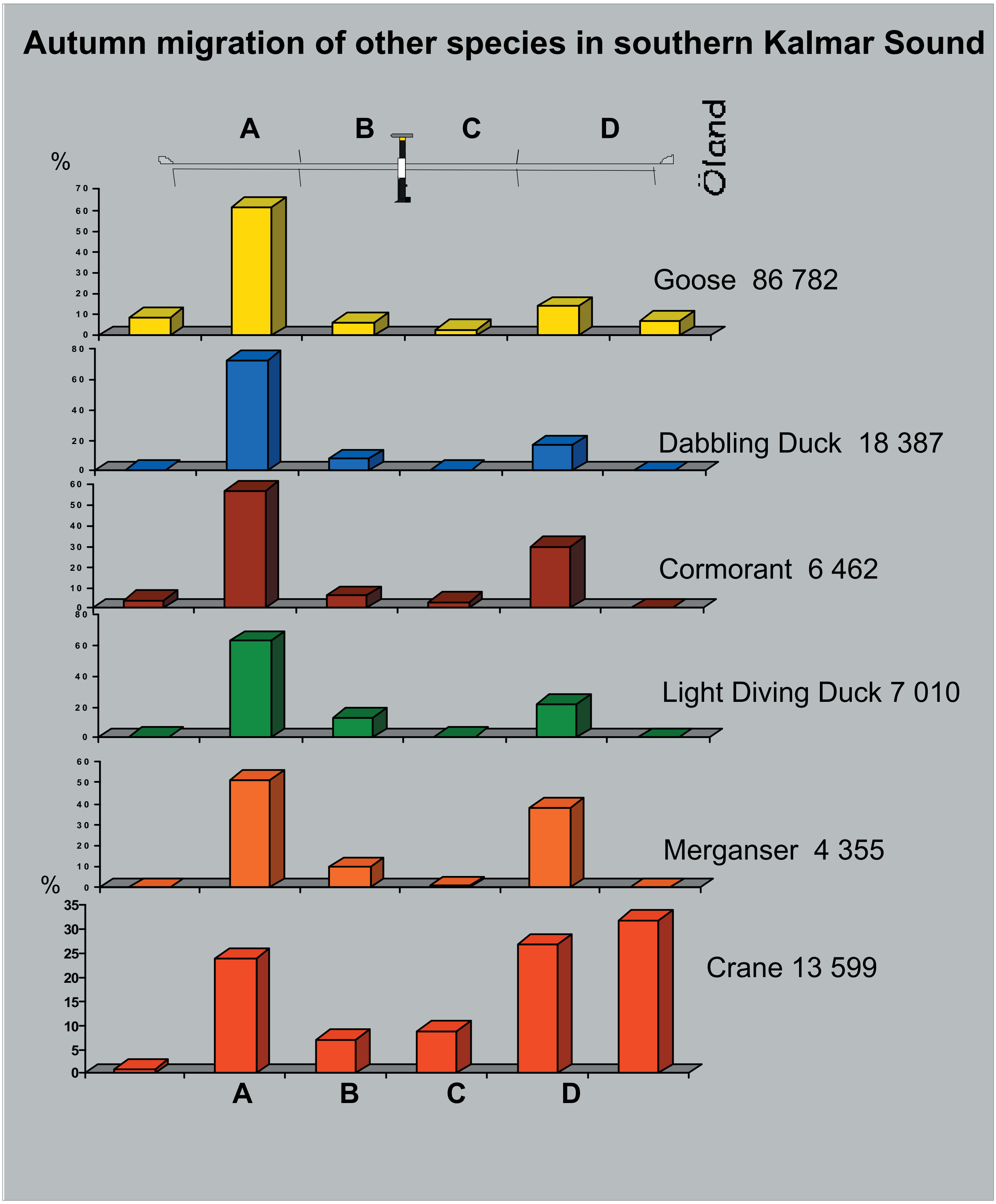


Figure 29 Choice of path and distribution as a percentage in the different zones in southern Kalmar Sound for species or group species from the collective group of other waterfowl, including Cranes. The presentation includes the aggregated autumn material from three autumn periods 2000–2002. These groups, except for Crane, show a similar choice of path as the Eider (compare figure 30) but not as concentrated on the mainland side.

common in times when the right weather conditions occur, producing variations in the times of peak migration.

As there is no data on Eider autumn migration before the wind turbines were constructed at Utgrunden, the distribution of Eider in Kalmar Sound is shown for three autumn periods in each case (Figure 28). The results clearly show that Eider mainly follow the western side of southern Kalmar Sound. In autumn 2000 the wind turbines at Yttre Stengrund had not been erected. They were in place in after 2001, this being the reason for presenting autumn migration data separately for 2000 and compiled for 2001 and 2002. It must however be clearly stated that in all probability it is not the construction of the wind turbines at Utgrunden that has caused the Eiders to fly more along the mainland side. Even before the wind turbines were erected, autumn flight paths in usual migration conditions were along the western side of the Sound. The presentation of the number of Eider and other waterfowl species per quarter in the different zones during the different autumn periods (Table 20) shows that Eider are predominant with an average of approximately 275 birds per quarter in zone A along the mainland side of Kalmar Sound.

It is clear in all three autumn periods that very few Eider fly in zone C by the Utgrunden wind farm. In zone B, which includes the section just outside the Yttre Stengrund wind farm, this species showed a larger number per quarter in the autumns of 2001 and 2002 when the turbines had been erected than during autumn 2000 before the wind turbines. This is hardly due to the erection of the wind turbines as this zone was not affected by the Yttre Stengrund wind turbines and bird migration in the zone was recorded at Utgrunden, before the birds reach the area outside Yttre Stengrund.

The reduction in number of Eider per quarter shown in zone D (the Öland side) from autumn 2000 compared to the later autumn periods cannot be explained by the construction of turbines in the Sound either. In autumn 2000 construction of the Utgrunden wind turbines was in full swing, but in the following two years when the turbines were in place there was not much human activity in the area. The decrease in migration intensity in zone D is not statistically significant, while the increase in number of Eider per quarter in zone B is a statistically significant change (Table 20 for n-values, d=0.534, p<0.01, Kolmogrov-Smirnov Test).

In zone C with the Utgrunden turbines, the number of Eider per quarter shows no great variation in the three autumn periods. But if we look at the total number of waterfowl per quarter in zone C, an increase from 3 to 12 is indicated over the last two years. This increase is not on a statistically significant level however, χ^2=6.3, 1, p<0.08 (Table 20).

Number of waterfowl per 15-minute periods in southern Kalmar Sound

The different zones in southern Kalmar Sound

Autumn		Land		A		B		C		D		Öl		Total		
Species/groups of sp.		m	sd	m	sd	m	sd	m	sd	m	sd	m	sd	m	sd	n
Diver, Grebe and Auk etc.	F			3	2	2	1	0		16	9			20	7	3303
	e			1	2	4	2	0		1	1			7	3	2833
Cormorant	F			8	3	1	2	0		3	2			12	3	1979
	e	1	2	6	4	1	1	0		3	3			11	5	4483
Goose	F			41	12	5	6	1	2	21	6	4	2	72	15	11775
	e	19	9	108	21	11	9	6	8	20	3	13	7	176	27	75007
Eider	F			275	78	18	12	2	4	8	3			304	77	49838
	e			282	70	31	14	3	4	4	4			317	72	134913
Light diving Duck and Merganser	F			12	2	0		0		10	4			22	6	3596
	e			11	2	3	3	0		4	2			18	4	7769
Dabbling Duck	F			38	12	0	6			12	3			50	14	8146
	e	1	4	17	8	4	5	0		3	2			24	8	10241
Crane	F			1	6	0				3	4	3	2	6	4	1025
	e	1	3	7	6	2	2	3	4	7	6	9	7	30	9	12574
Other waterfowl with wader	F			1	2	0				1	2			2	2	343
	e	0		1	2	0		0		2	2	0		3	2	1088
Total all waterfowl	F			379		26		3		84		7		488	87	80005
	e	22		433		56		12		44		22		584	91	248908

Table 20 Number of birds per quarter divided into different zones. "F" refers to autumn 2000, i.e. wind turbines at Yttre Stengrund; "e" refers to the autumn seasons 2001–2002 when the wind farms in the Sound were built; "m" represents the average; "sd" is the standard deviation and "n" is the number of birds. Other species groups are presented in table 21. The numbers of quarters are 164 for F (autumn 2000) and 426 for e (autumn seasons 2001–2002).

4.4.2 Distribution of other species of waterfowl in the Sound in daytime

As other waterfowl species (i.e. species other than the predominant Eider) are so common in the autumn these are presented in groups, either as separate species or in groups of species (Tables 19 and 20). Gulls and terns are not shown since only some of the flights of these birds have been monitored and recording of these species has not been wholly covered in the Sound. A report corresponding to those for other species and groups of species would not therefore give a correct picture of the distribution of flight paths in the Sound. The occurrence of these species is shown in tables with short comments at the end of the report (see tables in appendices A1 and A2) where raptors

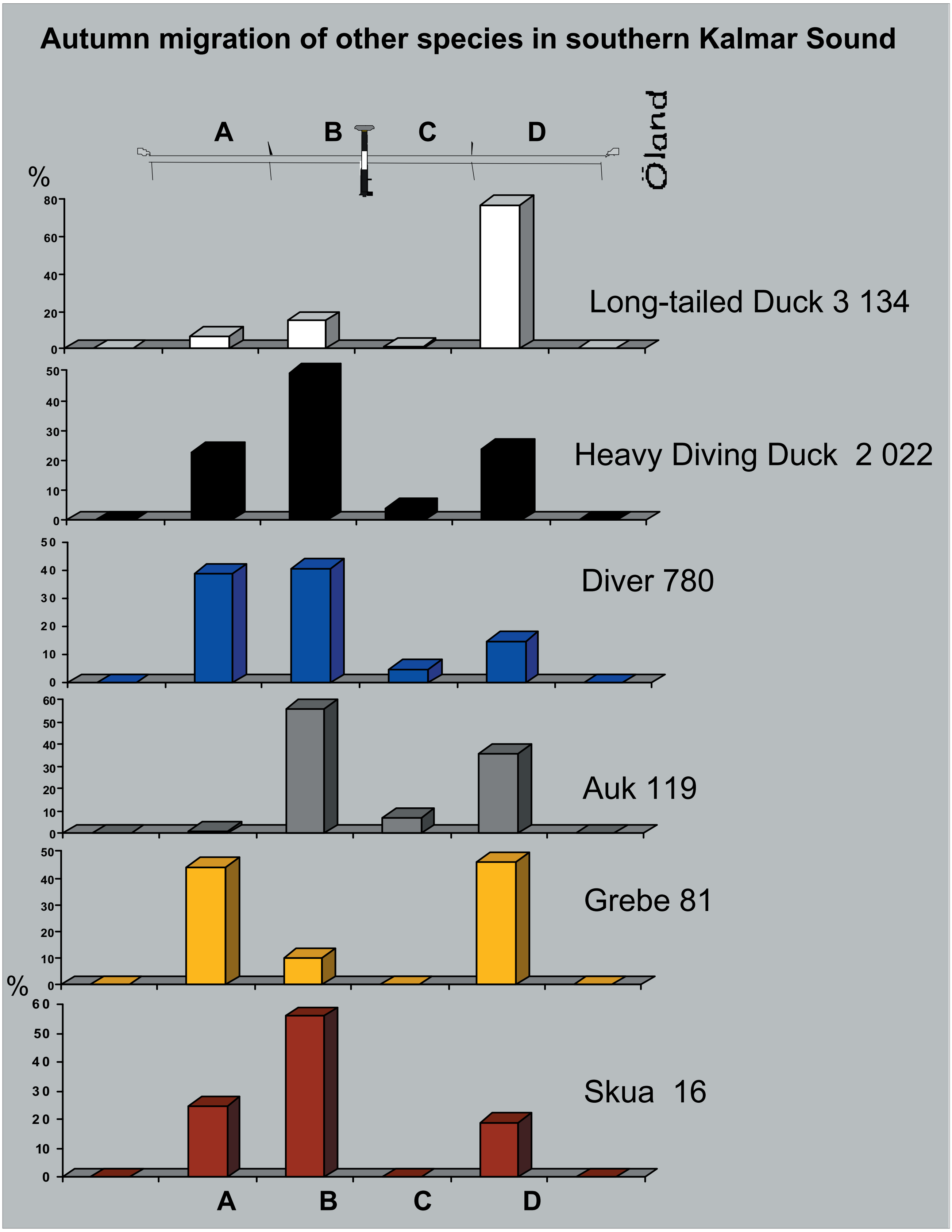


Figure 30 Choice of flight paths and distribution as a percentage in the different zones in southern Kalmar Sound for species or groups of species. The aggregated autumn material from autumn periods 2002–2003 shows a slightly different distribution for these groupings of species in the Sound than that of Eider. These groups also seem to avoid the wind farm zone C however.

and passerines recorded in the area are also shown. The distribution of migratory birds in the Sound is shown in Table 20, reported as the number of birds per quarter in the different zones for the time before construction at Yttre Stengrund (autumn 2000) and after construction (autumn 2001 and 2002 respectively).

The number of Eider per quarter (Table 19) as well as the distribution of the autumn flight paths as a percentage in the Sound (Figure 28) shows very clearly how autumn Eider migration is generally located to the mainland side. From Table 20 it is also possible to see that other waterfowl species show a similar distribution in the Sound. However, there are great differences in the number of birds of different species and groups of species. To give an integrated picture of other waterfowl species' flight paths in the Sound, Figure 29 presents their distribution as a percentage of the species/groups of species showing a similar choice of path to the Eider in Figure 29. In Figure 30, distribution in the Sound is shown as a percentage of the different zones for the species/groups of species which have a slightly different distribution compared to the Eider's choice of flight path through the Sound. The distribution of the 16 observed Arctic Skua was been included here. These latter groups show a slightly greater tendency to fly further out in the Sound than other species. These species do not seem to want to fly through the wind farm zone at Utgrunden either, in any case to a much smaller extent than through adjacent zones.

4.4.3 Daytime waterfowl migration at Yttre Stengrund

A study was made at Yttre Stengrund in autumn 2000 before construction of the five wind turbines (2001). Eider migration through the local zones at Yttre Stengrund is shown here for autumn 2000 compared with the two following autumn periods after the wind turbines were erected (Table 22, Figure 31). Since construction of the wind turbines there have been great displacements in the passage of Eider flocks through the area (Figure 31). These displacements between the different zones are statistically significant, as shown in Table 23. Even before the wind farm was constructed relatively few Eider flew through local zone 3, but the change after construction is very clear. After construction, the number of Eider passing through local zone 1 (nearest the shore) also decreased in the last two autumn periods. This

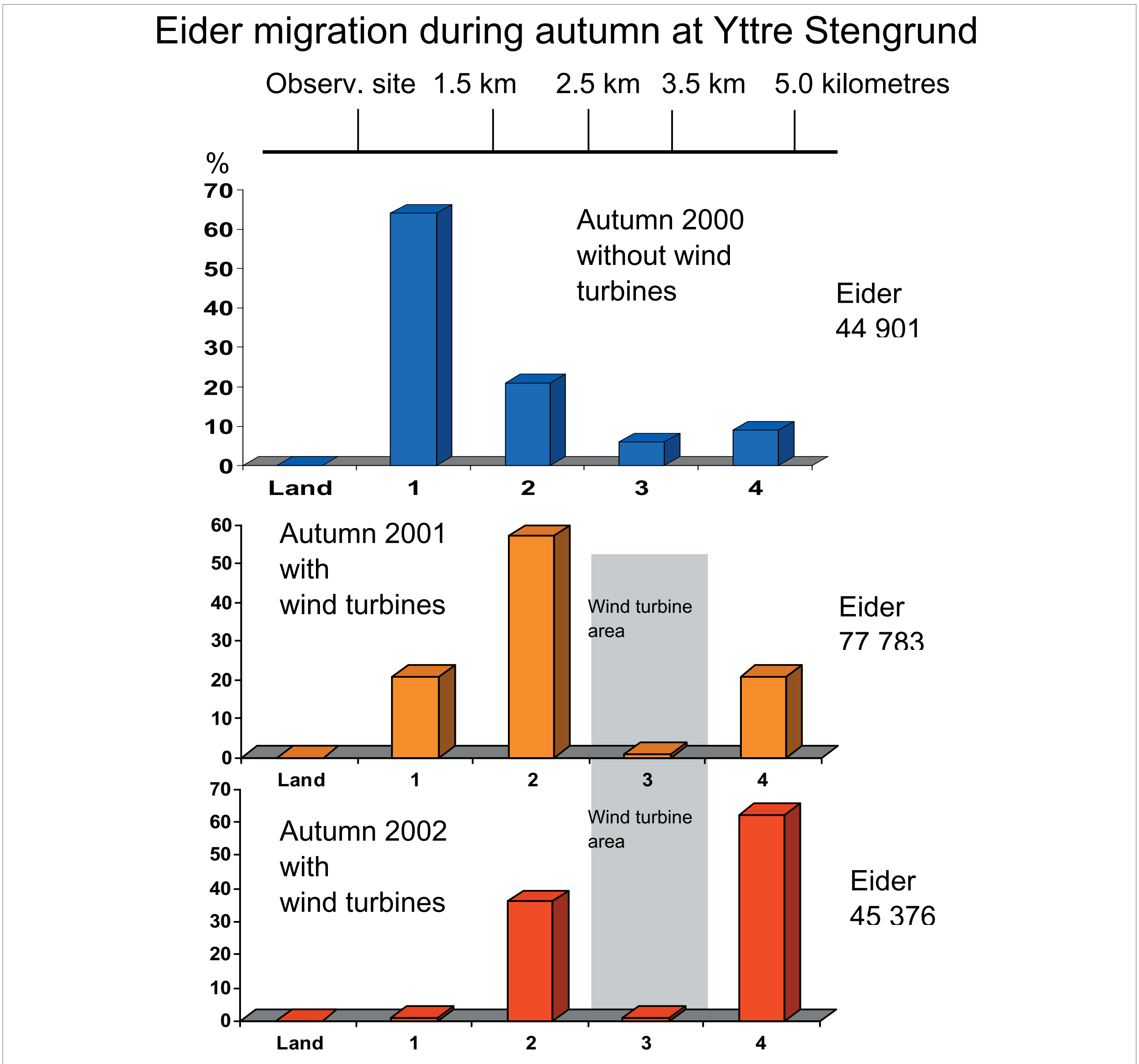


Figure 31 Distribution as a percentage of Eider migration at Yttre Stengrund in autumn 2000 before the wind turbines were built and autumn seasons 2001 and 2002 with wind turbines in zone 3.

change is statistically significant. The reasons for choosing to fly inside or just outside the turbines seem to differ between the two autumn periods after construction. One reason could be dependency on the winds. Similar changes in behaviour in the different local zones were noted for other species (Table 24).

Geese flew each autumn, both before and after construction, mainly through zone 1 (nearest the coast) but their numbers in zone 3 (the wind farm zone) increased after construction, as shown in Table 24. The number of geese migrating through zone 4 (outside the wind turbines) decreased markedly after the construction. Dabbling Ducks choose fly inside the turbines, a tendency also showed by Cormorants (Table 24). The spring data (Table 9 and Section 4.1.3) for Eider through the wind farm zone, zone A, show small differences in both flock size and flight altitude

List of all bird species and species groups

Species		Speciesgroups		Groups	
Red-throated Diver	*Gavia stellata*	**Diver**	*Gaviidae*	**Diver Grebe and Auk.**	**Diver, Grebe and Auk etc.**
Black-throated Diver	*Gavia arctica*				
Great Northern Diver	*Gavia immer*				
Great Crested Grebe	*Podiceps cristatus*	**Grebe**	*Podicipedidae*		
Red-necked Grebe	*Podiceps grisegena*				
Slavonian Grebe	*Podiceps auritus*				
Guillemot	*Uria aalge*	**Auk**	*Alcidae*		
Razorbill	*Alca torda*				
Black Guillemot	*Cepphus grylle*				
Puffin	*Fratercula arctica*				
Common Scoter	*Melanitta nigra*	**Heavy Diving Duck**			
Velvet Scoter	*Melanitta fusca*				
Long-tailed Duck	*Clangula hyemalis*	**Long-tailed Duck**			
Cormorant	*Phalacrocorax carbo*	**Cormorant**	*Phalac.*	**Cormorant**	
Mute Swan	*Cygnus olor*	**Swan**	*Cygnus*	**Swan and Goose**	
Bewick´s Swan	*Cygnus columbianus*				
Whooper Swan	*Cygnus cygnus*				
Bean Goose	*Anser fabalis*	**Goose**	*Anser and Branta*		
Pink-footed Goose	*Anser brachyrhynchus*				
White-fronted Goose	*Anser albifrons*				
Graylag Goose	*Anser anser*				
Canada Goose	*Branta canadensis*				
Barnacle Goose	*Branta leucopsis*				
Brent Goose	*Branta bernicla*				
Red-breasted Goose	*Branta ruficollis*				
Shelduck	*Tordorna tadorna*				
Wigeon	*Anas penelope*	**Dabbling Duck**	*Anas*	**Dabbling Duck**	
Gadwall	*Anas strepera*				
Teal	*Anas crecca*				
Mallard	*Anas platyrhynchos*				
Pintail	*Anas acuta*				
Garganey	*Anas querquedula*				
Shoveler	*Anas clypeata*				
Pochard	*Aythya ferina*	**Light Diving Duck**		**L.D.Duck and Mergus**	
Tufted Duck	*Aythya fuligula*				
Scaup	*Aythya marila*				
Goldeneye	*Bucephala clangula*				
Smew	*Mergus albellus*	**Mergus**	*Mergus*		
Red-breasted Merga	*Mergus serrator*				
Goosander	*Mergus merganser*				
Eider	*Somateria mollissima*	**Eider**		**Eider**	
King Eider	*Somateria spectabilis*				
Steller´s Eider	*Polysticta stelleri*				
Crane	*Grus grus*	**Crane**	*Gruidae*	**Crane**	
Heron	*Ardea cinerea*	**Wader**	*Charadriiformes*	**Wader**	
Oystercatcher	*Haematopus ostralegus*				
Ringed Plover	*Charadrius hiaticula*				
Golden Plover	*Pluvialis apricaria*				
Lapwing	*Vanellus vanellus*				
Purple Sandpiper	*Calidris maritima*				
Dunlin	*Calidris alpina*				
Curlew	*Numenius arquata*				

Table 21 List of the species of waterfowl observed and the groupings used in the report. Some waders occur in addition to this report.

Autumn migration of Eider per quarter at Yttre Stengrund

		Partial zones Yttre Stengrund								Total		
		1		2		3		4				
Autumn	n	m	sd	m	sd	m	sd	m	sd	m	sd	Number
2000	164	**175**	71	**57**	23	**16**	8	**30**	12	**274**	74	44 901
2001	226	**73**	28	**195**	92	**2**	6	**75**	27	**331**	109	77 783
2002	200	**1**	3	**84**	27	**1**	7	**141**	65	**227**	57	45 376

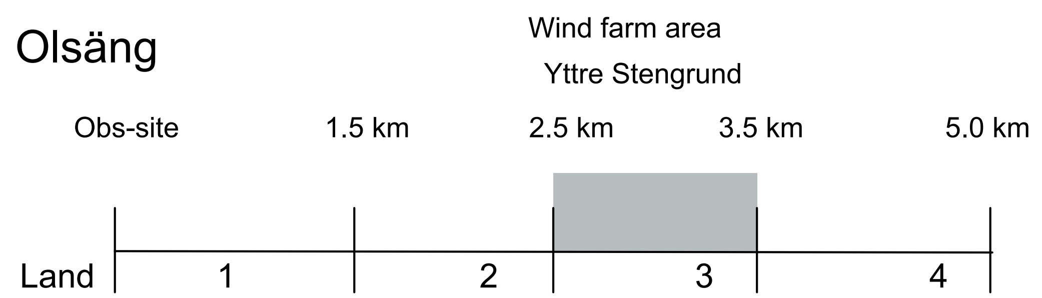
Table 22 The average number of Eider per quarter in the different autumn seasons distributed in the local zones 1–4 at Yttre Stengrund where local zone 1 is situated nearest the mainland and zone 3 contains wind turbines. This division into local zones is shown more in detail in table 23 and in figure 7. Number of quarters is shown under "n".

before and after construction of the wind turbines. But no such differences are seen in the autumn data (Table 25) even though differences in the spring are within the margin of error for estimates of flight altitude.

4.4.4 Influence of wind on daytime Eider migration in the whole of the Sound

Headwinds were prevailing in autumn 2000. Easterly winds and tailwinds were predominant in autumn 2002, while in autumn 2001 there was an almost equal distribution of different types of wind (Figure 32). The southbound Eider migration generally follows the mainland shore in all winds (Figure 33). Westerly winds may increase the numbers of flocks both in zone B and zone D. Easterly winds in all three autumn periods correlate with large numbers of Eider along the mainland side. In Table 26 the numbers of Eider per quarter are shown for different winds and wind forces in the various zones. Most Eider fly along the mainland side with an average of between 227 and 331 Eider per quarter as compared with only 2–8 per quarter along the Öland side. One surprising finding in this report is that very intensive Eider migration also occurs in strong winds of more than 9 m/s from all directions, even in strong headwind (see Table 26). In strong winds almost all flight paths are along the mainland side but strong tailwinds may give relatively

Statistical test of number of Eider per quarter at Yttre Stengrund



	1	2	3	4
2000 2001	d= 0.569 **	0.611**	0.588**	0.333
2000 2002	0.765***	0.288	0.432**	0.645***
2001 2002	0.543**	0.561**	0.023	0.821***

Table 23 Statistical test of the number of Eider per quarter in the different local zones1–4 at Yttre Stengrund before and after construction of the wind turbines. Compare table 22 or see the distribution as a percentage in figure 31. Grey marking in zone 3 shows location of wind turbines. Statistical test using Kolmogrov Smirnov test ((**=P<0.01 and ***=P<0.001). The values of the individual quarters were tested in comparison with each other and not average values as in table 22. All of the 164 quarters in autumn 2000 in comparison with the 226 quarters in autumn 2001 and the 200 quarters in autumn 2002 were tested in comparison with each other according to the specified test. It is therefore the 164 quarters from autumn 2000, the 226 quarters from autumn 2001 and the 200 quarters from autumn 2002 which were tested and compared with each other.

higher values per quarter out in the Sound. Strong tailwinds in autumn 2001, for example, resulted in 187 Eider per quarter in zone B.

The choice of flight paths for other waterfowl groups in different winds is a little more varied (Figure 34) but the tendency is the same as Eider, i.e. that waterfowl flight paths in westerly winds are located slightly further out in the Sound and along the Öland side while easterly winds and tailwinds push the flight paths towards the mainland side. Geese and Dabbling Ducks tend to leave the Sound in easterly winds and fly a little distance in over the mainland (Figure 34). See next section for a more detailed discussion of wind dependency of these other waterfowl species.

4.4.5 Influence of wind on daytime waterfowl migration at Yttre Stengrund

The wind obviously affects the choice of Eider flight paths at Yttre Stengrund (Figure 35). In autumn 2000 Eider flocks were only seen in the outer zone in tailwinds whereas flocks in headwinds, westerly winds and even more in easterly winds passed mainly in the two zones nearest land. Results from the following two autumn periods with wind turbines at Yttre Stengrund show that in easterly winds flight paths are inside the turbines while in tailwinds the Eider choose to fly outside the turbines.

Other waterfowl groups show more varied behaviour (Figures 35 and 36). In easterly winds and tailwinds goose migration is intense in all zones while in westerly winds and headwinds the flight paths of other waterfowl species is concentrated to the area inside the wind turbines. The flight paths of Dabbling Ducks in all wind directions are concentrated to the two zones nearest land. Note too that hardly any flocks of Cormorants or waterfowl fly in zone 3 where the wind turbines are located, or in the zone outside.

4.5 Observations of autumn migration

The general picture for most waterfowl migration during the autumn is well illustrated by the pattern of the Eider (Figure 37) whose main migration corridors occur along the mainland side. Autumn conditions allowed many more radar trackings than in the spring. This is probably because waterfowl flocks in the autumn consist on average of a greater number of birds (Tables 27 and 28) than during spring migration (Tables 9 and 10). Comparative studies have shown that radar can record Eider flocks of more than 45 birds (but only records really well those of 100 birds or more) and as the size of the average flock during the autumn

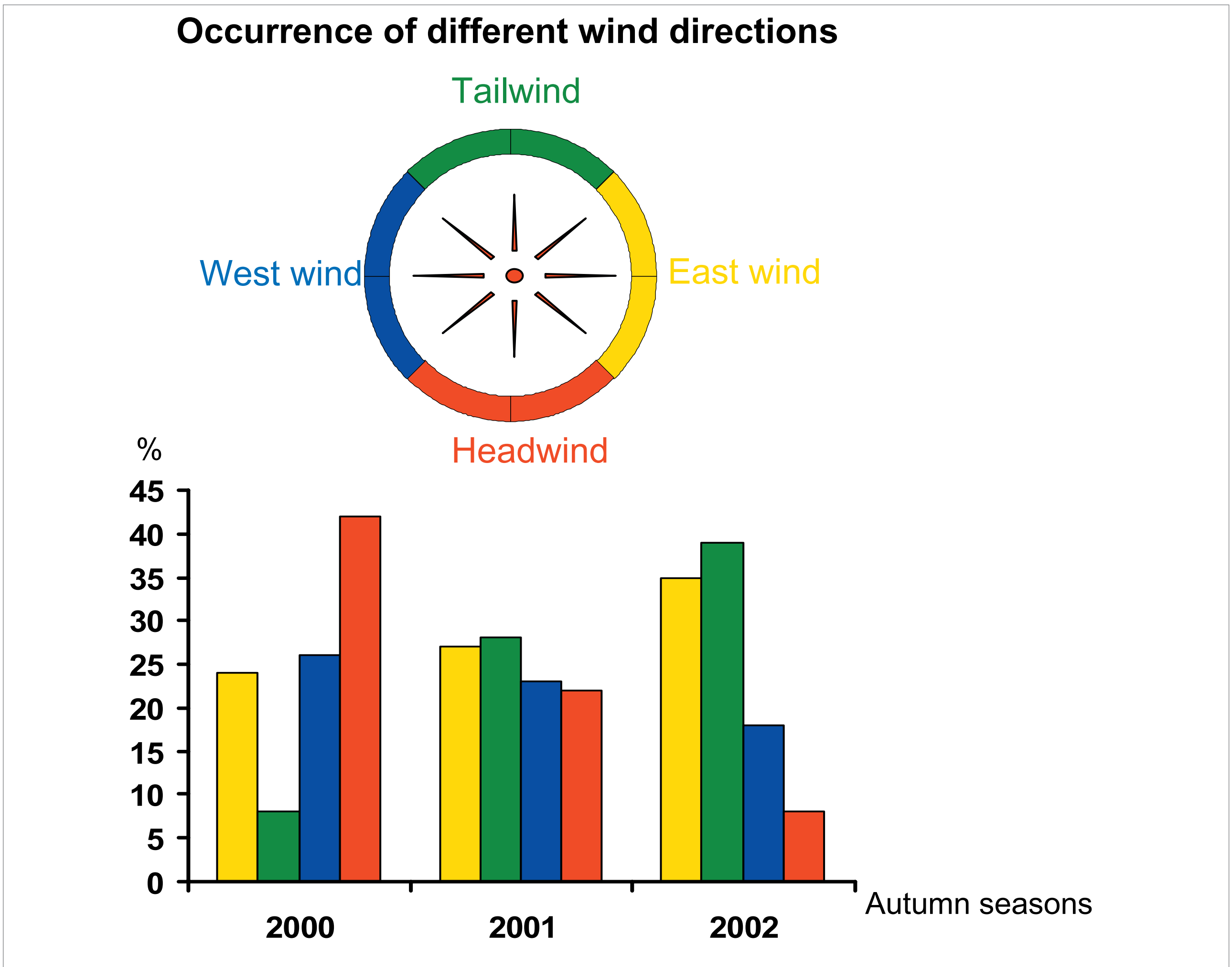


Figure 32 Distribution as a percentage of wind directions during the periods with full coverage observation (Table 3) during the four autumn seasons 2000–2003. There are large differences in prevailing wind directions for different years. This is shown in the figure of predominant headwinds for autumn 2000, with a corresponding lack of headwind in 2002. The opposite is valid for tailwinds in autumn 2000 and 2002.

The most frequent waterfowl at Yttre Stengrund

Autumn migration		Zones at Yttre Stengrund										
		Land		1		2		3		4		Total
Species/groups	P	%	n	%	n	%	n	%	n	%	n	n
Cormorant	F			78	1 103	11	149	2	35	9	131	1 418
	e	11	389	67	2 484	13	497		11	8	309	3 690
Goose	F			54	3561	10	676	6	422	30	1993	6 652
	e	15	7 966	55	29 343	14	7 802	13	7 224	3	1 642	53 977
Eider	F			63	28 708	21	9 219	6	2 611	10	4 363	44 901
	e			14	16 661	49	60 757	1	647	36	45 094	123 159
Dabbling Duck	F			51	3 180	21	1 312	27	1 666	1	79	6 237
	e	4	267	69	5 203	26	1 935	1	80		34	7 519

Table 24 The distribution as a percentage and the number of waterfowl migrating through local zones 1–4 during the autumn migration at Yttre Stengrund. "**F**" shows the situation for autumn 2000 before the wind turbines were built and "**e**" shows the situation in the autumn seasons 2001–2002 with the wind turbines in situ in zone 3. It is therefore the 164 quarters from the autumn 2000, the 226 quarters from autumn 2001 and the 200 quarters from autumn 2002 which were tested and compared with each other.

migration consists of 76 birds (Table 27) most flocks have the requisite size for radar recording. The median size of autumn migrating Eider flocks is 90 birds for all autumn data. Flocks of bird species that exceed the number of Eider per flock by at least 20 birds are also recorded. As the average flock of swans, geese and Cormorants consists of 11–57 individuals (Table 27) several of these flocks were probably recorded by radar. In autumn radar studies so-called long trackings (i.e. at least one echo per minute) were made of a reasonably large number of flocks, so it was possible with these trackings to estimate the extent of the migration (Figure 38). Figure 38 also shows 1476 waterfowl flocks tracked by radar from all autumn periods, and their distribution in daytime and nighttime under different visibility conditions. This compilation of all trackings shows that 68 per cent of all waterfowl migration takes place in daytime in good visibility and that migration takes place in all wind directions with the highest intensities in easterly winds and in tailwinds. Only 2–3 per cent of all birds pass during daytime in poor visibility, which is slightly below the time period of 4–5 per cent in poor visibility (Table 26). The data collected also indicates that 27 per cent of all migration takes place during the night. This is an unexpectedly high value as studies during separate autumn periods previously indicated that 16–20 per cent of total migration takes place during the night. The largest proportion of night migration seems to take place in tailwinds. Some migration takes place in mist during the night in autumn, but only to

Eider migration, flock size and flight altitude

Autumn migration	Utgrunden				Yttre Stengrund			
Flock size	Autumn	m	sd	Number flocks	Autumn	m	sd	Number flocks
Before construct.					2000	79	7	568
After construct.	2000	20	2	20	2001	108	9	694
After construct.	2001	23	3	28	2002	58	5	782
After construct.	2002	21	2	9				
Estimated flight altitude shown as metres above sea level								
Before construct.					2000	10	2	568
After construct.	2000	10	2	20	2001	20	3	694
After construct.	2001	10	2	28	2002	20	3	782
After construct.	2002	10	1	9				

Table 25 Comparison of the flock size and flight altitude of migrating Eider before and after construction of wind turbines at Utgrunden (zone C) and at Yttre Stengrund (zone A). "m" shows the average value and "sd" the standard deviation. None of the changes was tested, as the uncertainty of estimate is greater than the observed differences of altitude. The flock size seems to vary but not sufficiently for any statistically significant differences to be shown.

Number of Eider per quarter through Kalmar Sound

Autumn Zone in Sound	East 1-3 m/s	East 4-8 m/s	East 9- m/s	Tail 1-3 m/s	Tail 4-8 m/s	Tail 9- m/s	West 1-3 m/s	West 4-8 m/s	West 9- m/s	Head 1-3 m/s	Head 4-8 m/s	Head 9- m/s	Total
A 2000 n	2	17	21	2	7	4	4	27	12	1	54	13	164
A m	**0**	**142**	**291**	**0**	**73**	**1015**	**908**	**357**	**227**	**43**	**179**	**487**	**275**
A 2001 n	26	34		20	29	14		33	21		26	23	226
A m	**1059**	**389**		**220**	**328**	**156**		**476**	**62**		**30**	**19**	**331**
A 2002 n		22	47	20	24	34	7	4	26			16	200
A m		**371**	**203**	**82**	**41**	**713**	**0**	**14**	**0**			**48**	**227**
B 2000 m	**0**	**0**	**0**	**0**	**0**	**0**	**110**	**64**	**0**	**42**	**6**	**3**	**17**
B 2001 m	**1**	**3**		**3**	**78**	**187**		**150**	**10**		**0**	**3**	**46**
B 2002 m		**9**	**14**	**59**	**47**	**23**	**0**	**4**	**0**			**0**	**20**
C 2000 m	**0**	**0**	**0**	**0**	**0**	**0**	**31**	**4**	**0**	**6**	**2**	**0**	**2**
C 2001 m	**0**	**0**		**0**	**0**	**0**		**14**	**5**		**1**	**1**	**3**
C 2002 m		**0**	**0**	**0**	**2**	**4**	**0**	**0**	**0**			**0**	**1**
D 2000 m	**0**	**0**	**0**	**0**	**0**	**0**	**13**	**37**	**18**	**5**	**0**	**0**	**8**
D 2001 m	**1**	**0**		**0**	**1**	**13**		**8**	**1**		**0**	**0**	**5**
D 2002 m		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**			**0**	**0**
										Total number Eider			184772

Table 26 Number of Eider per quarter, on average, through the zones A–D in different wind directions and speeds. Number of Eider in each group is shown under zone A, but is also valid for the other zones.

a small extent and only in tailwinds: see Figure 38.

4.5.1 Radar-recorded migration in the Sound in different conditions

Radar trackings showed that waterfowl migration through the wind farm zone C at Utgrunden was low intensity during the day as well as at night during all the autumn periods (Figure 39). The flight paths were mainly concentrated to the western side of the Sound even in poor visibility during the day. The number of migrating birds in zone B was a little higher during misty and foggy conditions than in good visibility. At night the waterfowl migration had a similar distribution as during the day in good visibility but with a higher number through zone B, i.e. a tendency to shift the flight paths during the night a little further out in the Sound. At Yttre Stengrund (Table 29) it was noted that night migration took place mainly outside the wind turbines. During nights with poor visibility the migration pattern in the Sound deviates and a higher percentage of the flight paths are located in the zones B and D but also wind farm zone C is avoided (Figure 39). This indicates that the waterfowl somehow can register the wind turbines even at night with poor visibility. It should be pointed out that judging from the radar observations there is relatively little waterfowl migration in such conditions.

At Yttre Stengrund (Table 29) at night, the flocks also seem to avoid the wind farm zone, local zone 3, in good as well as in poor visibility. But it is more uncertain how the flocks react to the existence of turbines at Yttre Stengrund during the day in fog and mist as there seems to be a relatively small number of flocks recorded flying in such conditions. This indicates that there are probably very few waterfowl flocks that migrate in poor visibility.

4.5.2 How is the flight distance affected by avoiding the wind turbines?

There are very few waterfowl flocks that fly near the wind turbines at Utgrunden during the autumn. The few flocks that were observed via radar echoes to be flying towards the wind turbines usually deviated towards the west long before the turbines. The deviation in flight path shown by some flocks is only a few hundred metres longer than a straight flight path. The choice of path seems to be made at a distance of 1–2 kilometres or even further from the wind turbines. It is only tailwinds and to some extent westerly winds during the autumn that cause some waterfowl migration close to the Utgrunden wind farm. Figure 40, in which all radar tracking of waterfowl flocks is illustrated for autumn 2001 in a tailwind, shows that the flocks either fly west or east of the turbines and that a few deviate from the straight flight path in a detour movement. Three of these flocks deviated towards the west and two towards the east. These flocks have a slightly extended flight path of approximately one kilometre, no matter which flight path they take, which means approximately one minute longer flying time. A total of 205 passing flocks were recorded by radar here. At Yttre Stengrund the migration corridor heads more directly towards the wind turbines. Observations there before construction of the wind turbines showed that most of the flocks flew either outside or inside the projected wind farm area and relatively few flocks flew through this area. From radar trackings here it can be seen that flocks flying outside the turbines have an extended flight distance while those that fly inside hardly extend their flight path at all (Figure 40). The flocks bypass the wind turbines at Yttre Stengrund along two main paths: alternative D (Figure 40) which is approximately 3 kilometres longer, and a somewhat narrower path C, which is approximately 1.2 kilometres longer. These flight paths were taken by 11 and 15 flocks respectively. Of the 178 flocks which flew through the Olsäng area, 15 per cent took a longer flight path and therefore an extended migration time of 1–4 minutes compared with a straight path.

Radar trackings in poor visibility daytime conditions have generally been registered in tailwinds, which seem to be the only type of wind acceptable for migration under such conditions. For example, 15 flocks were tracked in autumn 2002 (Figure 41) on their passage through Yttre

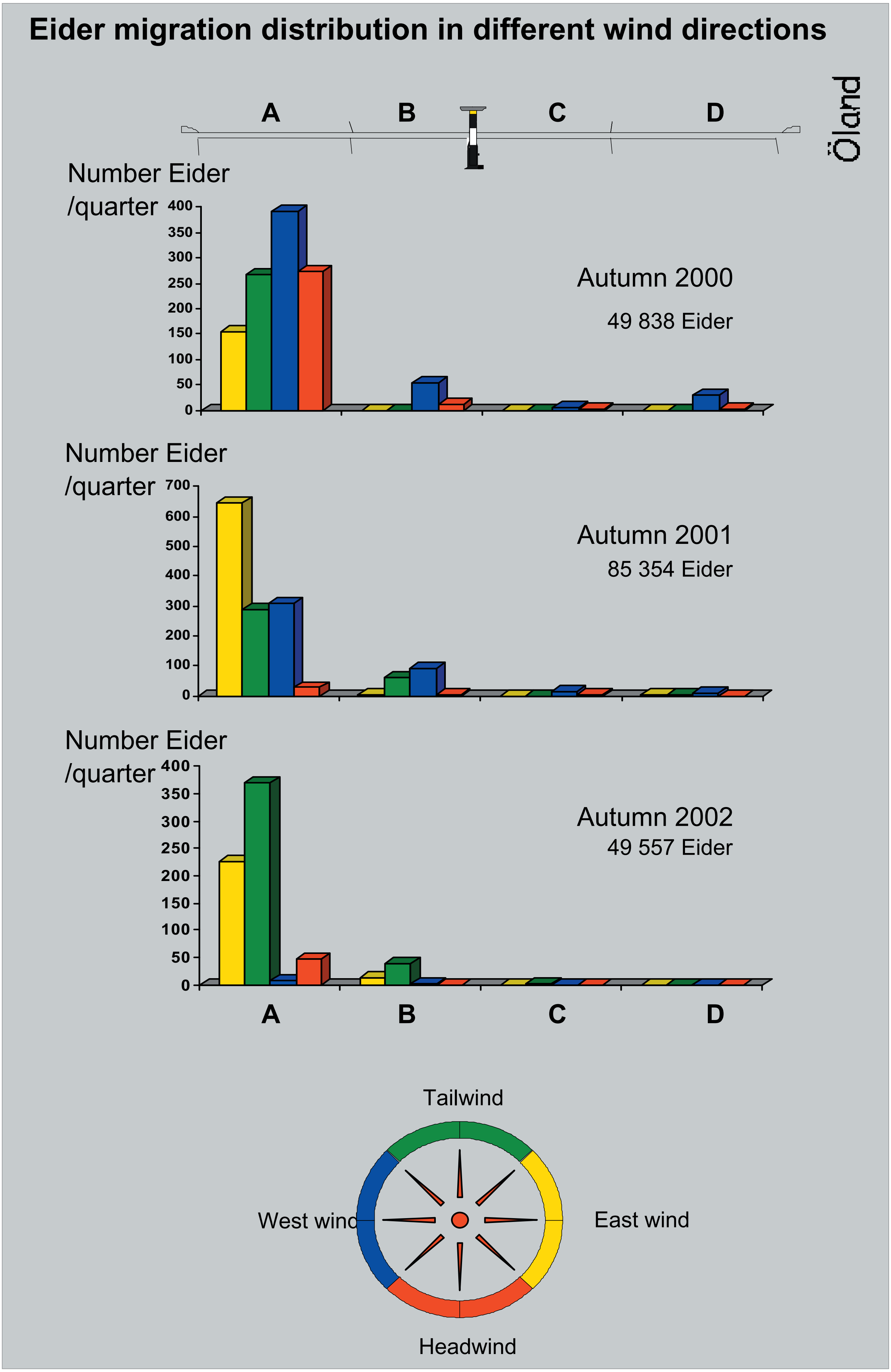


Figure 33 Number of Eider per quarter in different winds, divided into zones A–D.

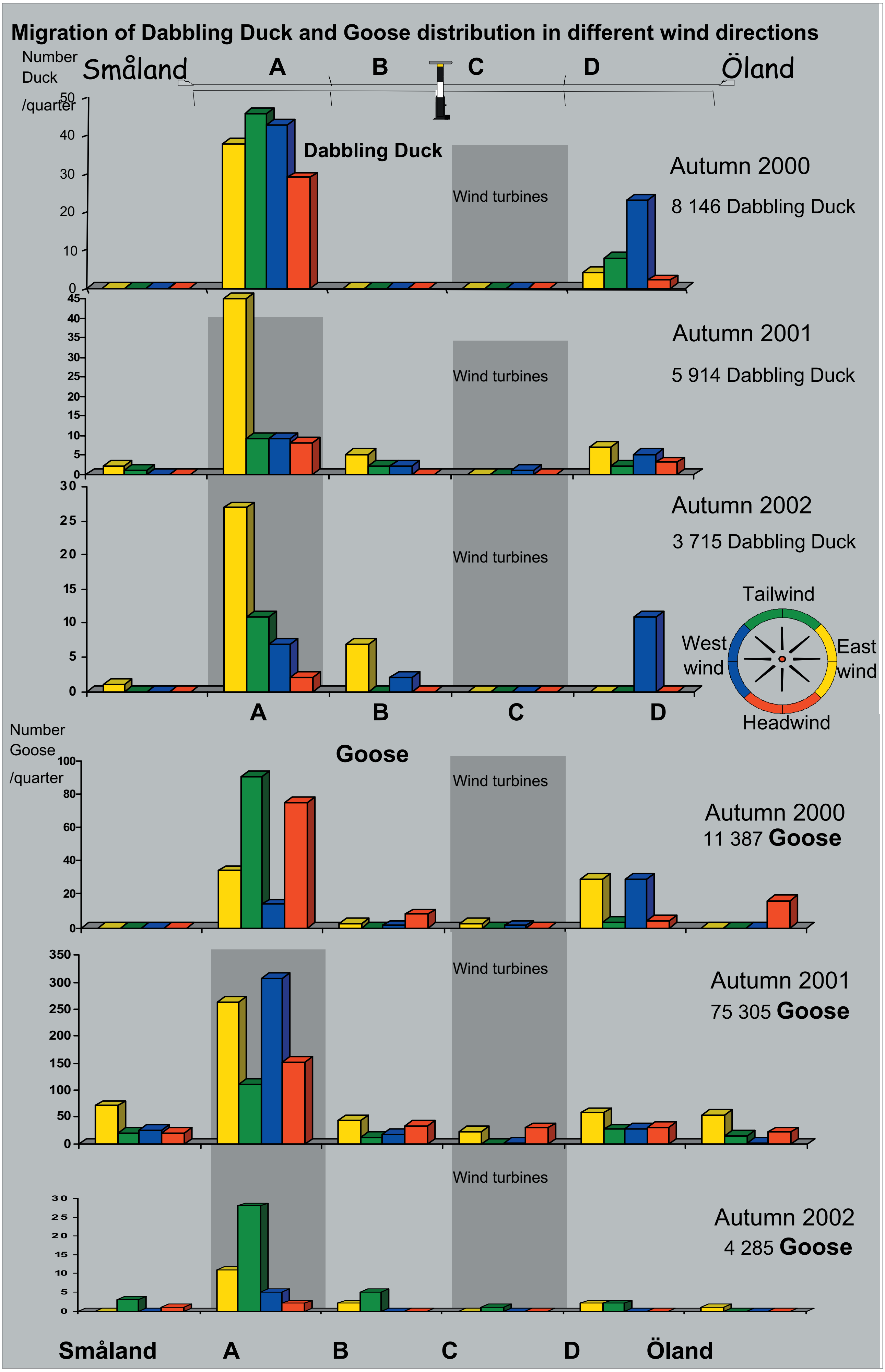


Figure 34 Number of Dabbling Ducks and Geese per quarter in different winds divided into zones A–D.

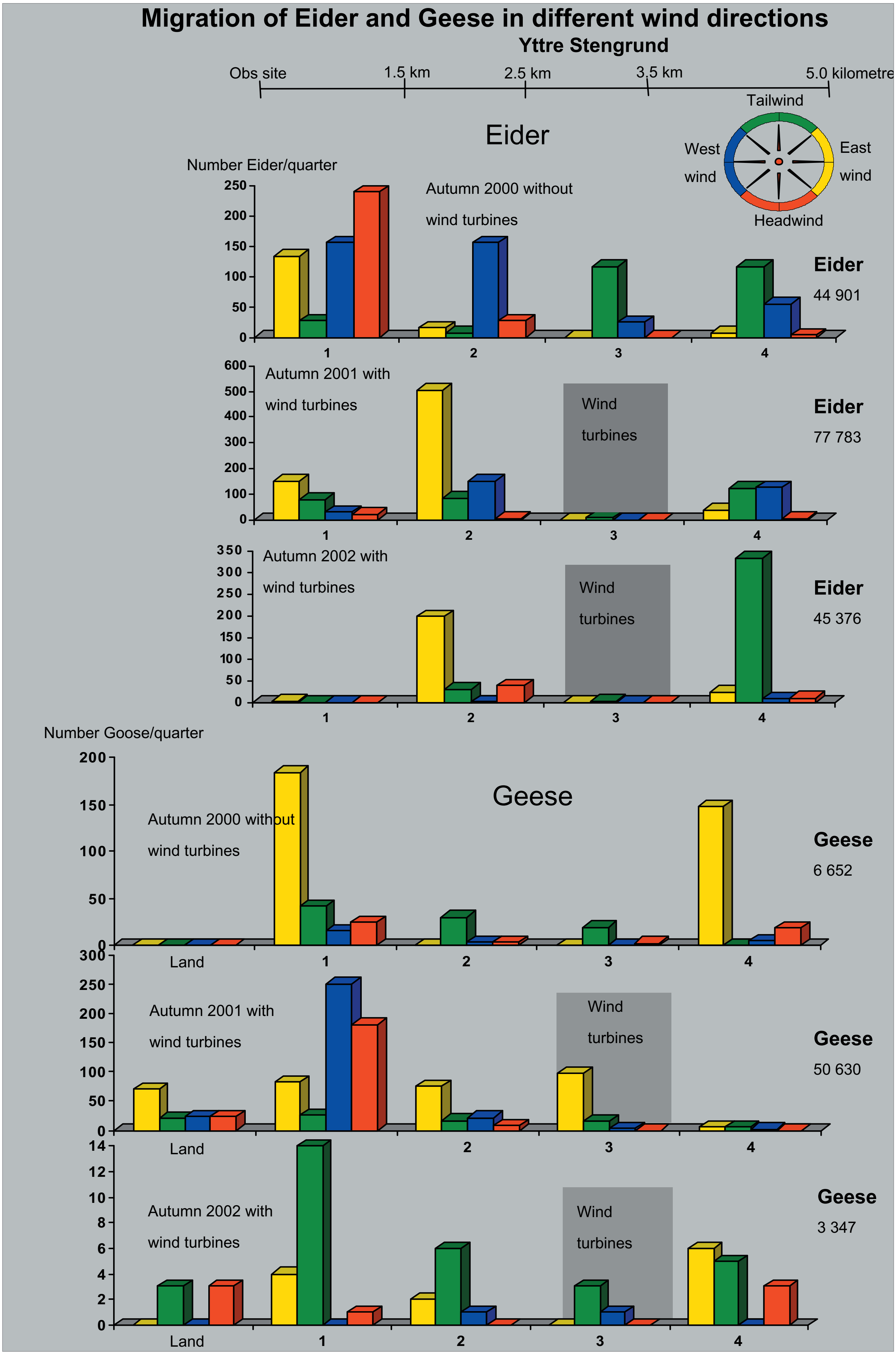


Figure 35 Number of observed Eider and Geese per quarter in different winds divided into four local zones 1–4 including the shore at Yttre Stengrund.

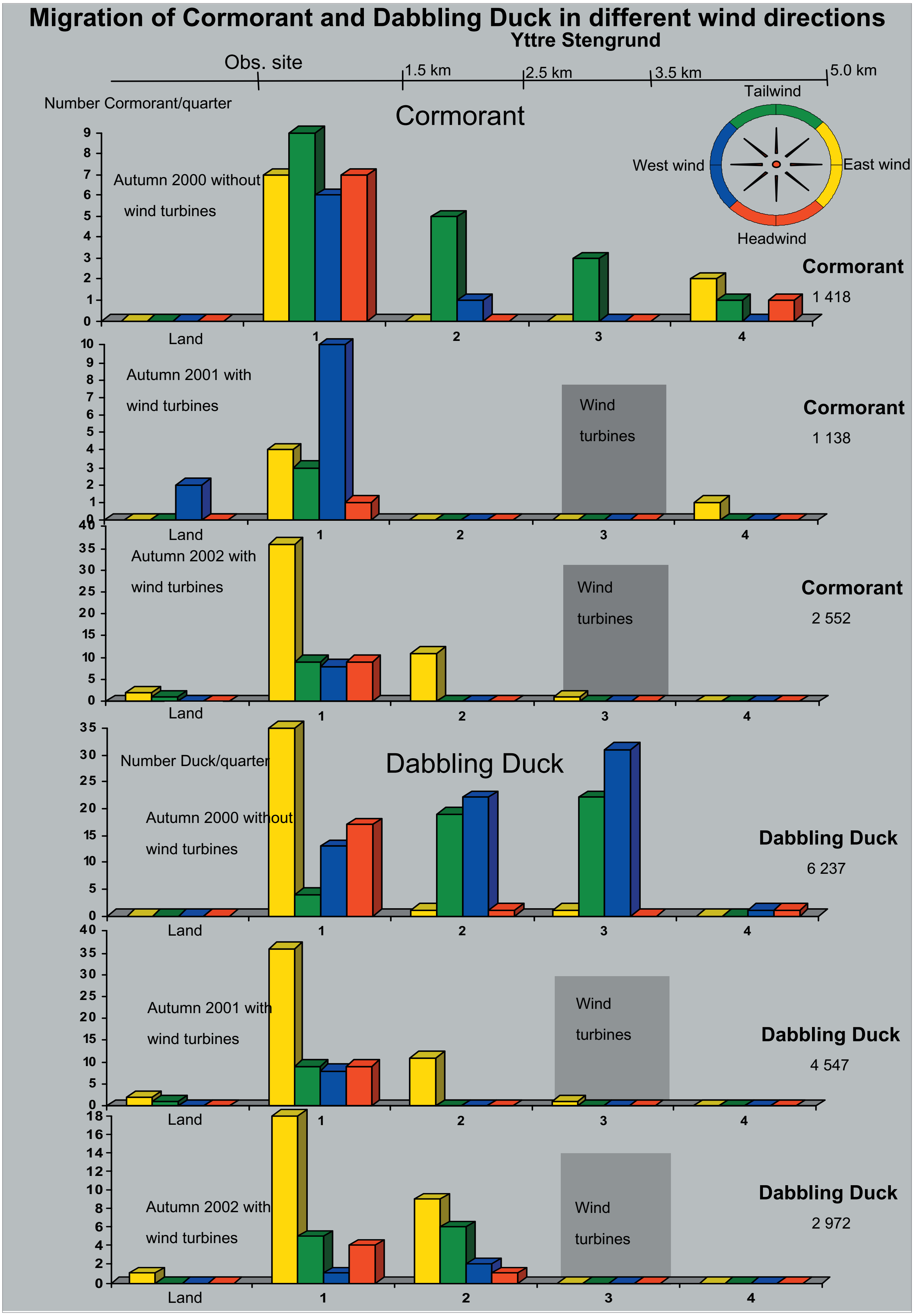


Figure 36 Number of observed Cormorants and Dabbling Ducks per quarter in different winds, divided into local zones 1–4 including the shore at Yttre Stengrund.

Eider migration normal autumn migration path

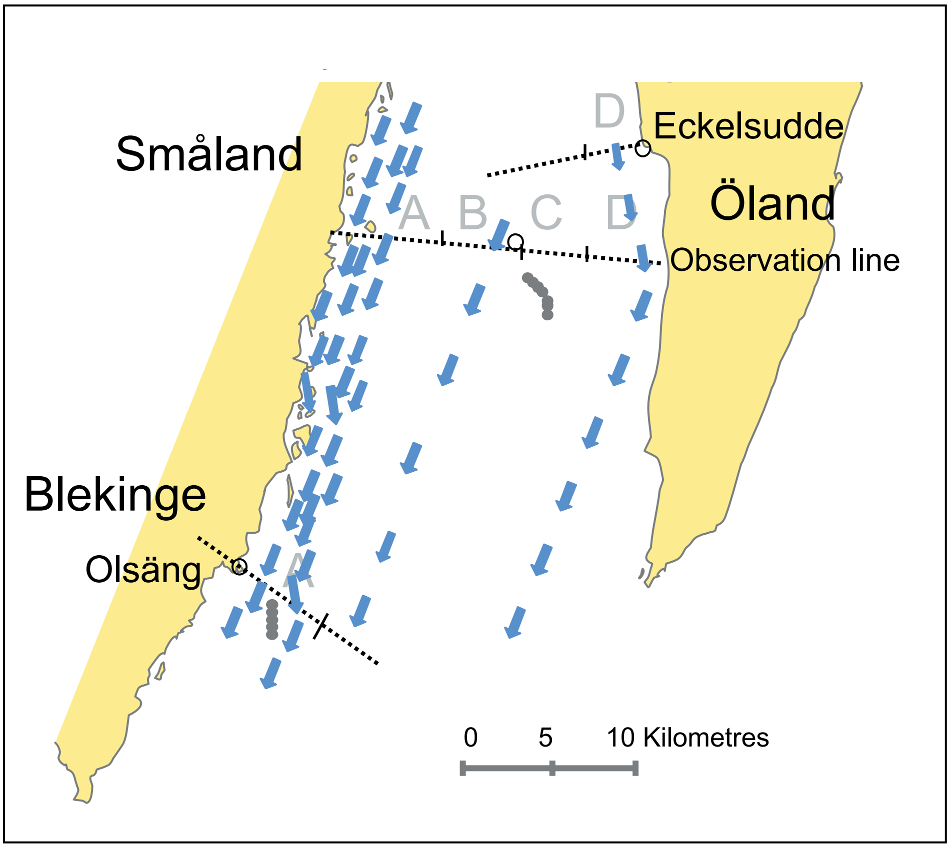


Figure 37 The figure shows a normal picture of the autumn migration of Eider flocks through southern Kalmar Sound in tailwind. On passage through the Sound the flocks retain their chosen positions in the different observation zones.

Average flock size during autumn migration

Autumn	The different zones in southern Kalmar Sound													
	Land		**A**		**B**		**C**		**D**		**Öland**		**Total**	
Species/groups of sp.	m	fl	m	fl	m	fl	m	fl	m	fl	m	fl	m	fl
Diver, Grebe and Auk			**3**	117	**3**	159	**3**	17	**1**	145			**2**	438
Cormorant	**36**	8	**11**	337	**13**	32	**11**	15	**9**	222	**6**	1	**11**	615
Swan and Goose	**100**	80	**55**	957	**53**	106	**53**	50	**43**	283	**99**	63	**57**	1 539
Heavy diving Duck			**11**	43	**12**	83	**7**	11	**17**	29			**12**	166
Eider			**81**	2044	**58**	281	**22**	57	**33**	55			**76**	2 437
Long-tailed Duck			**10**	23	**12**	38	**5**	3	**31**	79			**22**	143
Dabbling Duck	**27**	10	**20**	658	**18**	89	**13**	7	**7**	439			**15**	1 203
Light diving Duck and Merganser	**36**	3	**13**	523	**11**	127	**8**	10	**6**	548			**10**	1 211
Crane	**9**	5	**56**	58	**58**	16	**69**	17	**54**	67	**54**	82	**55**	245
Wader			**5**	14	**2**	4	**1**	1	**24**	22			**15**	41
Total	**84**	106	**52**	4774	**30**	935	**30**	188	**16**	1889	**73**	146	**41**	8 038

Table 27 The average size of flock for the different species/groups of species during autumn migration, divided into different zones. See table 21 for division of species into groups. The number of flocks is shown in column "fl".

Flock size of Eider in different zones during autumn migration

Autumn	Zone A m	Zone A sd	Zone A fl	Zone B m	Zone B sd	Zone B fl	Zone C m	Zone C sd	Zone C fl	Zone D m	Zone D sd	Zone D fl	Total in whole of Sound m	Total in whole of Sound sd	Total in whole of Sound fl
2000	**79**	7	568	**67**	8	45	**20**	3	20	**41**	5	33	**75**	7	666
2001	**108**	9	694	**63**	7	149	**23**	3	28	**25**	3	18	**96**	7	889
2002	**58**	6	782	**46**	5	87	**21**	3	9	**2**	1	4	**56**	5	882
Total	**81**	7	2 044	**58**	6	281	**22**	3	57	**33**	4	55	**76**	6	2437

Table 28 Eider flock size in the different zones in different autumn seasons. "m" shows the average size of flock;"sd" shows the standard deviation of the average; "fl" shows the number of flocks.

Stengrund in mist and fog, and 4 flocks at Utgrunden. The latter did not show any tendency to deviate around the wind turbines but flew at a safe distance west of the turbines, while at Yttre Stengrund at least two flocks deviated east of the turbines but then choose the shorter alternative with a detour of approximately 1.2 kilometres. Here one flock was also recorded flying in fog, either between or above the turbines. There are some radar trackings from foggy and misty nights but migration in such conditions only seems to occur when there are tailwinds or easterly winds.

Figure 41 (bottom half) shows all radar trackings of waterfowl flocks which took place during the night in autumn 2001 in easterly winds. Of the 42 flocks in total that flew through the Utgrunden area during radar tracking, three flocks showed a tendency to deviate around the turbines. Two flocks detoured west of the turbines while one flew to the east of the turbines. Both deviations extend the flight path by 1.2–1.5 kilometres, which gives a two-minute longer migration time. At Yttre Stengrund the flocks are too concentrated to distinguish individual flocks, but 58 flocks flew through the area of which six flew inside the turbines and the rest outside. In some cases it is doubtful whether they flew between or over the turbines. All the flocks which flew around the turbines on the outside chose the shortest alternative of curve (C) around the turbines, resulting in a 1.2 kilometre longer flight path. In all, 8 flocks or 14 per cent of the total passing through the whole area chose this detour.

According to the radar trackings it is obvious that flocks which fly close to the wind turbines at night and in fog and mist detect the turbines and deviate one way or the other (Figure 41). These evasive actions which some flocks take are slightly narrower than the curves around the turbines which flocks take during daytime. Radar trackings from all types of visibility conditions and winds in different autumn periods are shown in Figures 42–44 and 45–48. The first

Waterfowl migration at Yttre Stengrund

Autumn Light and visibility		Land %	Land fl	1 %	1 fl	2 %	2 fl	3 %	3 fl	4 %	4 fl	Total fl
		The diffrent zones at Yttre Stengrund										
Visual observ.flocks daytime, good visibility	F			48	517	26	278	22	238	4	36	1069
	e	4	112	36	901	33	854	2	59	25	658	2584
Radar recorded flocks daytime, good visibility	F			53	41	26	20	4	3	17	13	77
	e	9	41	26	113	34	153	4	16	27	120	443
Radar recorded flocks daytime, fog/mist	F			57	8	29	4			14	2	14
	e			26	8	39	12	6	2	29	9	31
Radar recorded flocks night, good visibility	F					20	8	17	7	63	26	41
	e					10	9	3	3	87	79	91
Radar recorded flocks night, mist	F					3	1	20	7	77	27	35
	e			14	2	57	8			29	4	14

Table 29 Number and distribution of percentage of waterfowl flocks tracked by radar in autumn in local zones 1–4 and the shore at Yttre Stengrund. "F" shows autumn 2000 without wind turbines; "e" shows autumn 2001 and 2002 with wind turbines. The table includes all flocks observed visually in daytime in good visibility and flocks identified by radar in different conditions.

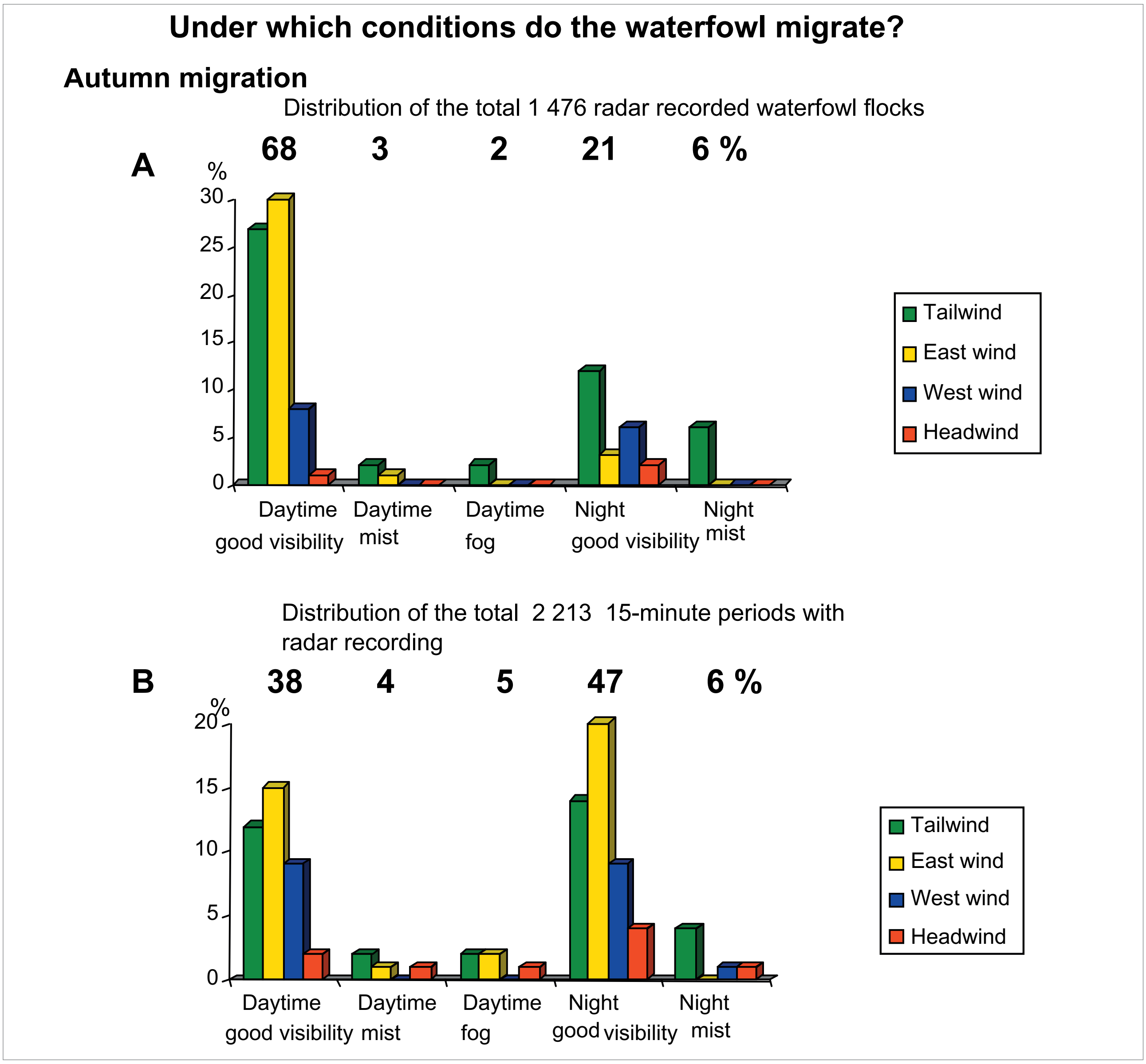


Figure 38 A: Radar-tracked waterfowl flocks during the autumn in southern Kalmar Sound, with distribution as a percentage of different wind and visibility conditions. Radar-tracked flocks fulfil the criteria that they must have been identified on radar with at least one echo per minute and that the tracking must have lasted 4–5 minutes, which normally corresponds to a flight distance of 4–5 kilometres.
B: Number of quarters (15minute periods) with radar tracking in autumn seasons 2000–2002 and with distribution as a percentage of different wind and visibility conditions. This corresponds to the time of flock tracking in A.

group of figures refers to only radar-tracked flocks while the second group refers to radar-tracked flocks that were also observed visually and the species named. In this second group, trackings are shown of Eider and the four most frequent species from the group other waterfowl. The variation in flocks' flight paths in the Sound does not appear to be very great, with the exception of some waterfowl flocks that cross the Sound from east to west in easterly winds. Cranes differ, as do geese, quite clearly from the predominant waterfowl pattern and migrate slightly more across the Sound. In the reported trackings of each species, Cormorants show very similar flight paths to Eider while Dabbling Ducks generally fly close to and along the mainland side.

4.6 Trackings of autumn migrant waterfowl flocks near the wind turbines

During the autumn periods few flocks passed within a distance of 500 metres from the wind turbines at Utgrunden. In autumn 2002 when operation of the optical rangefinder was sufficiently skilled, 17 longer trackings of flocks which passed in the vicinity of the wind turbines could be carried out (Figure 49). Shorter and more occasional trackings from autumn 2001 were not reported. It was only in northerly and northwesterly winds that migrant flocks during the autumn were seen flying near the wind turbines at Utgrunden. All

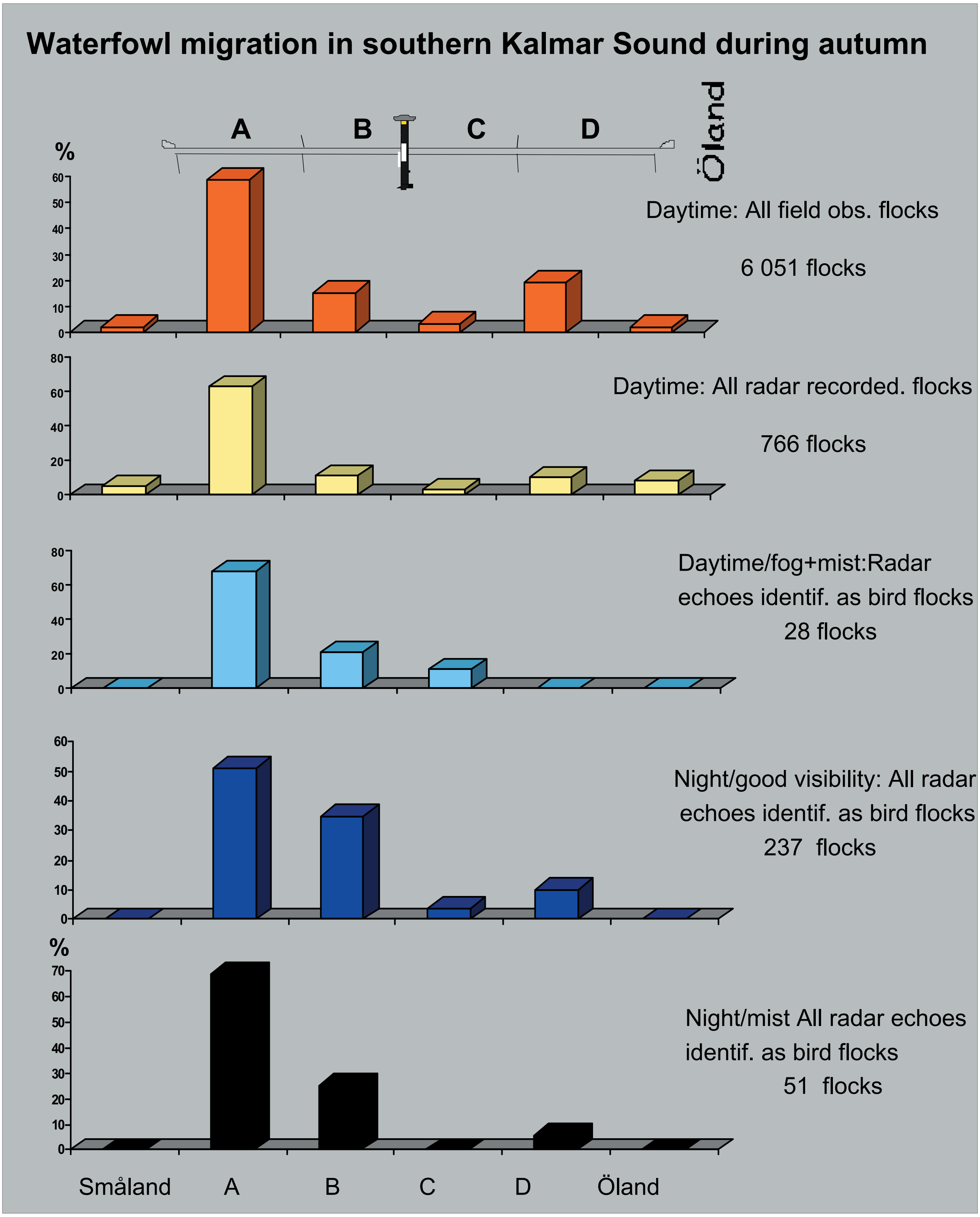


Figure 39 Radar-recorded waterfowl flocks in southern Kalmar Sound during autumn migration 2000–2002 divided into different zones in varying visibility conditions. The partial top figure shows flocks observed visually in daytime in good visibility with simultaneous radar observations.

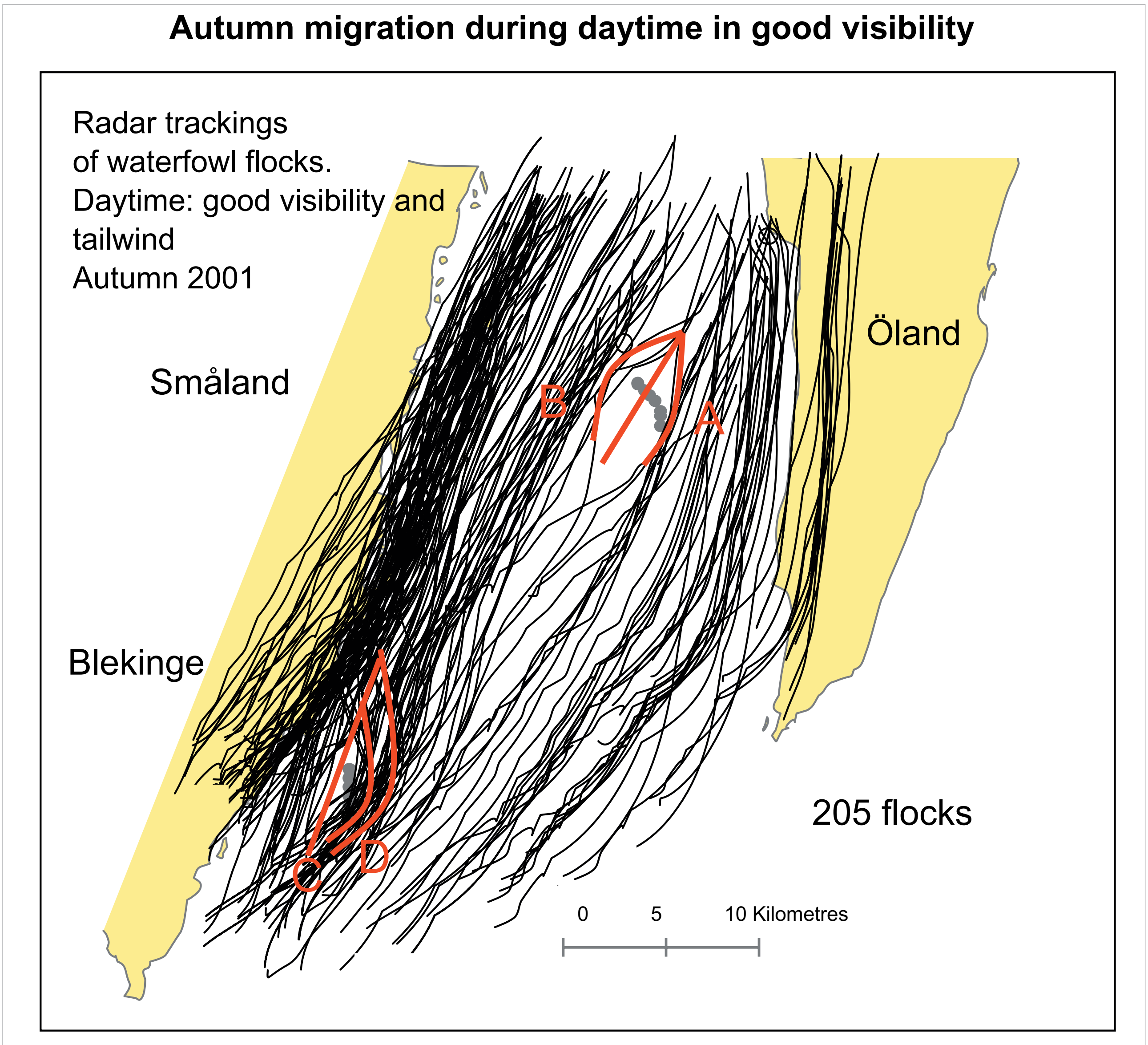


Figure 40 All radar-tracked waterfowl flocks in autumn 2001 in tailwinds and good visibility showing their paths around the wind turbines. "A" shows flocks which veer off to the east around the Utgrunden wind turbines. These flocks are less frequent and their flight distance is extended by about one kilometre. "B" shows the somewhat larger numbers of flocks which choose to pass the Utgrunden wind turbines in a curve to the west, also resulting in an extended flight distance. At Yttre Stengrund most flocks which veer off before the turbines seem to do so in a curve "C", which results in an extended flight distance of 1.2 kilometres, or in many cases even less. "D" shows that certain flocks veer off to the east at a distance of 2 kilometres from Yttre Stengrund and pass the wind turbines in a curve resulting in a 3 kilometre extension of their flight paths.

waterfowl flocks recorded in 2002 as passing the turbines closer than approximately 500 metres reacted by deviating from the turbines with greater or smaller changes in course. The two crane flocks recorded flying over the turbines passed at an altitude of 150 and 250 metres respectively (measured by instrument).

In Figure 50 flock measurements are shown for different wind directions and a total of 603 flocks at the measuring point before the Yttre Stengrund wind turbines. Of these, 93 flocks could be tracked past all three measuring points. All flocks measured for altitude increased their flight altitude markedly on passage of the wind turbines and then resumed the same altitude as before the turbines (Figure 50). The flight altitude on passing the turbines was about at the same level or just under the centre of the rotor (boss altitude = 65 metres). Those flocks flying in a headwind and in westerly winds flew at a higher altitude when passing the wind turbines than they did one kilometre earlier. In a headwind, the difference in altitude is on average 38 metres but these differences are within the margin of error for altitude measurements using these instruments. It may be stated that flocks fly higher than the turbines, but how much higher could not be accurately determined.

At Yttre Stengrund there was a linear decrease in the number of flocks at a distance of 500 metres or less to the wind turbines (Figure 51). In the different directions the number of flocks decreased from between 30 and 60 at a distance of 500 metres and from between 2 and 30 flocks at a distance of approximately 200 metres. Only two to four flocks flew in tailwinds and westerly winds as near as 100 metres from the nearest wind turbine. During the whole study time a total of 1944 flocks were recorded passing the wind farm at Yttre Stengrund. Of these there were at least 552 flocks, or 28 per cent of the total number, which flew

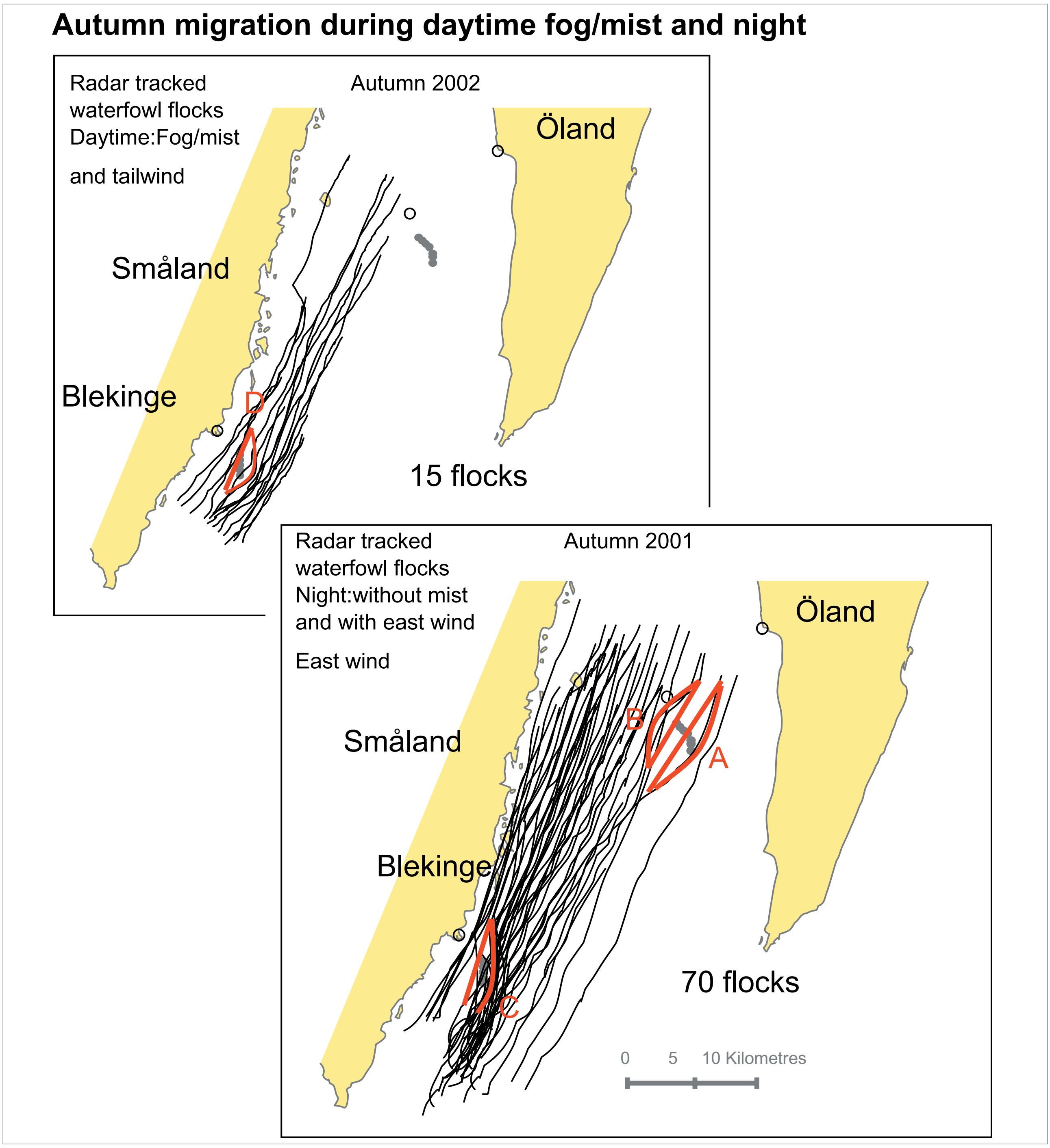


Figure 41 The top map shows all radar-tracked waterfowl flocks tracked in autumn 2002 in the daytime in poor visibility (mist or fog) in tailwinds. The bottom map shows radar-tracked waterfowl flocks in autumn 2001 at night in fog or mist in easterly winds. To show how much further the flocks fly on average in an evasive manoeuvre, the "average path" for this curve has been drawn in red and compared with a straight line through the wind farm area. At Utgrunden, the curve "A" marks how some flocks fly east of the turbines and extend their flight path by 1.2–1.5 kilometres. The curve "B" shows how some flocks fly west of the wind turbines and extend their flight path by 1.2 kilometres. The radar trackings at Yttre Stengrund show that flocks flying in clear night conditions seem to fly relatively close to the turbines where the evasive manoeuvre "C" results in an extended flight path of just over 1 kilometre. The top map shows how flocks at Yttre Stengrund in autumn 2002 in daytime in mist and fog follow a curve "D", which extends the flight path by 1.2–1.5 kilometres.

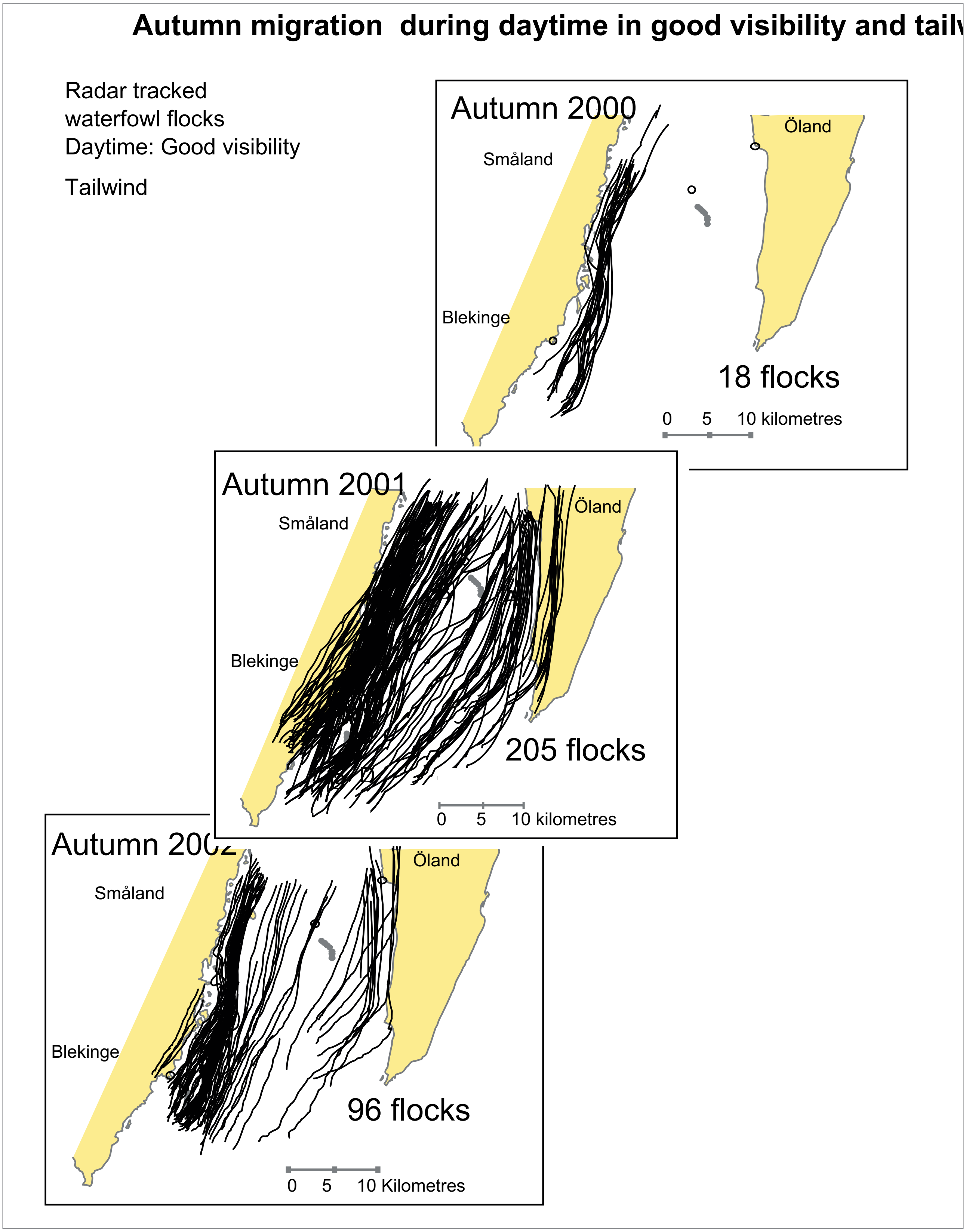


Figure 42 Radar-tracked waterfowl flocks in daytime, good visibility and tailwind during the three autumn seasons.

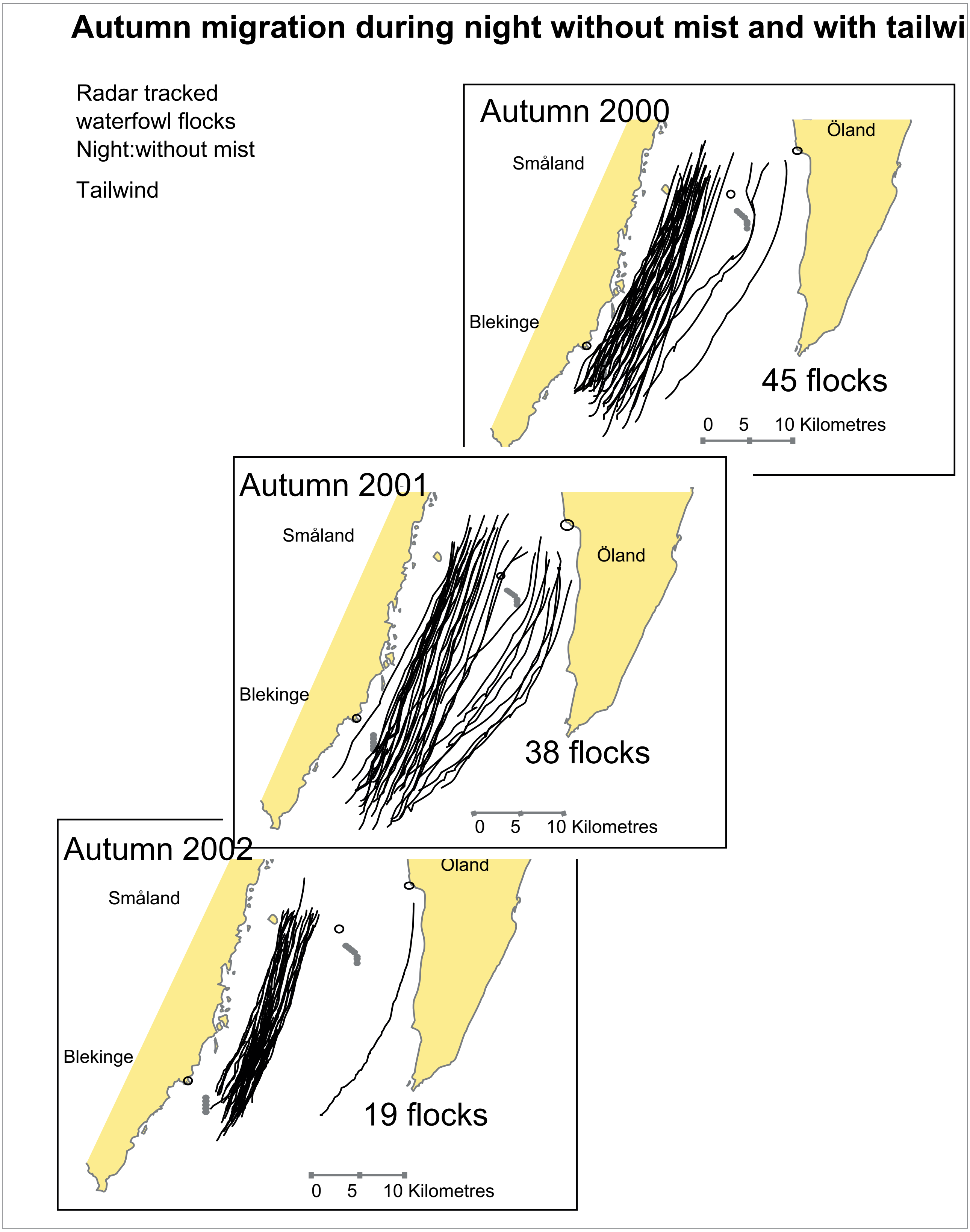


Figure 43 Radar-tracked waterfowl flocks at night in clear conditions and tailwind during the three autumn seasons.

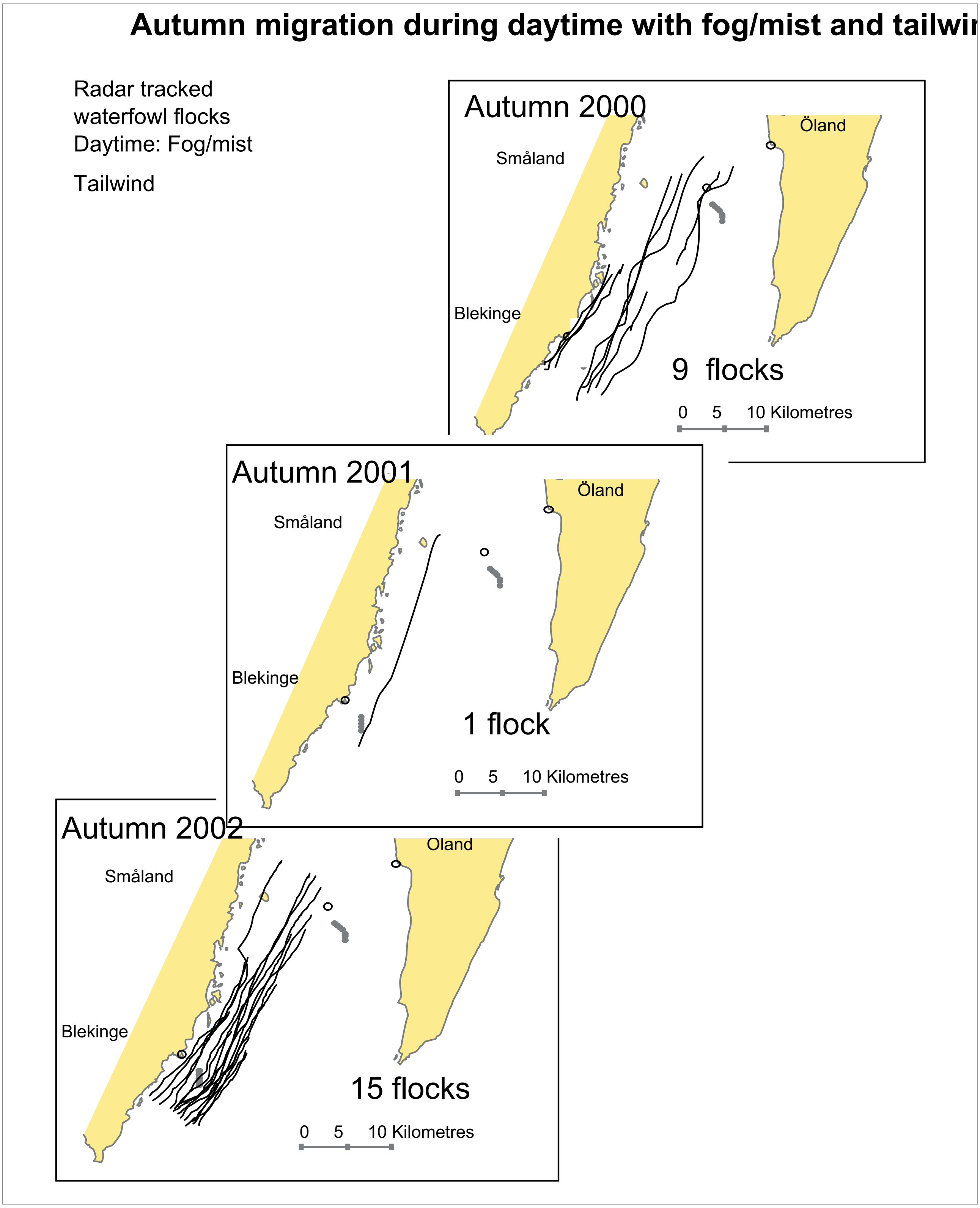


Figure 44 Radar-tracked waterfowl flocks in daytime in reduced visibility (mist or fog) in a tailwind during the three autumn seasons.

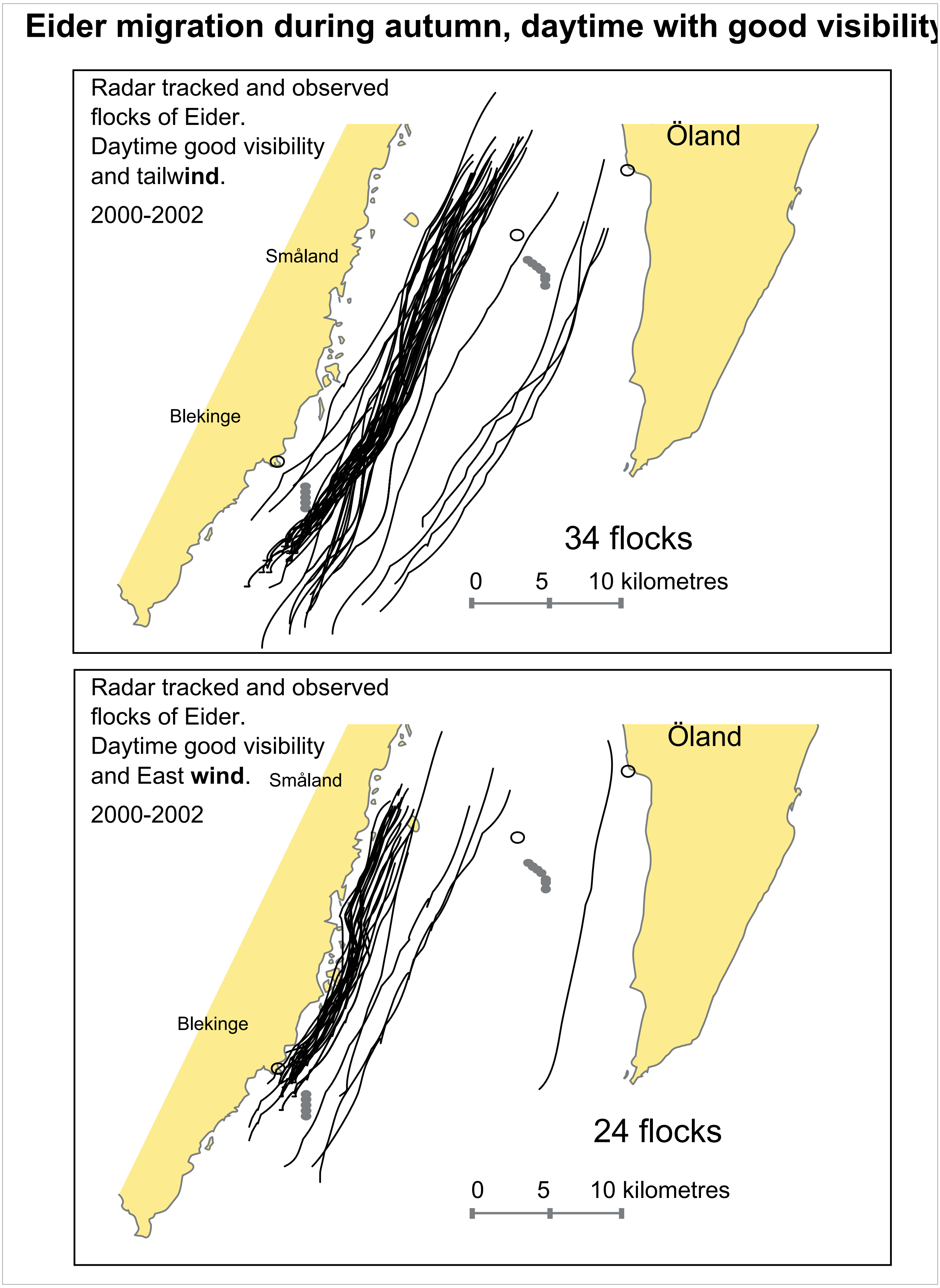


Figure 45 Radar-tracked flocks of Eider were recorded using a time comparison of identified radar echoes and field observations. Long trackings of flocks in tailwinds and headwinds are shown here.

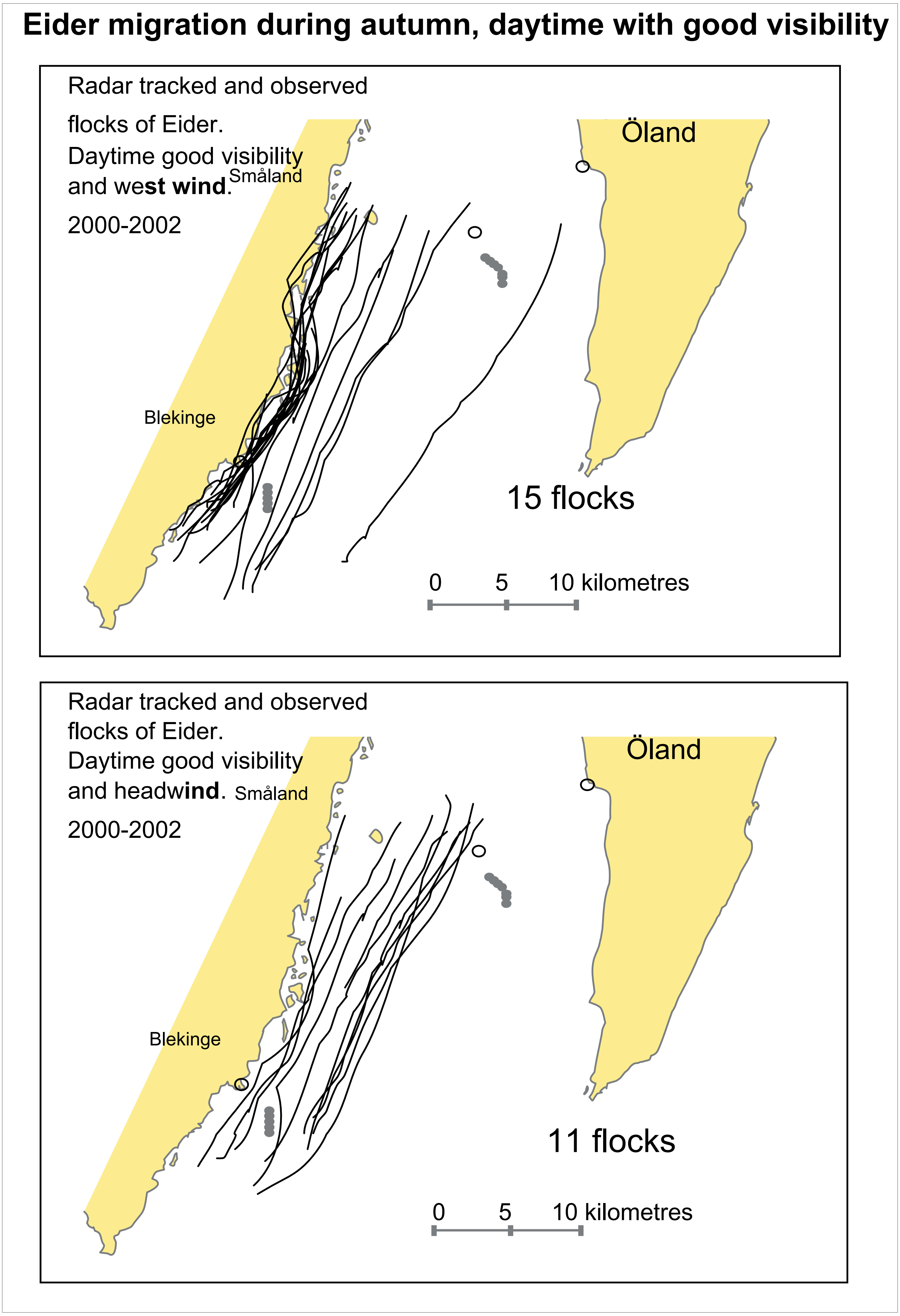


Figure 46 Radar-tracked flocks of Eider were recorded using a time comparison of identified radar echoes and field observations. Long trackings of flocks in westerly winds and headwinds are shown here.

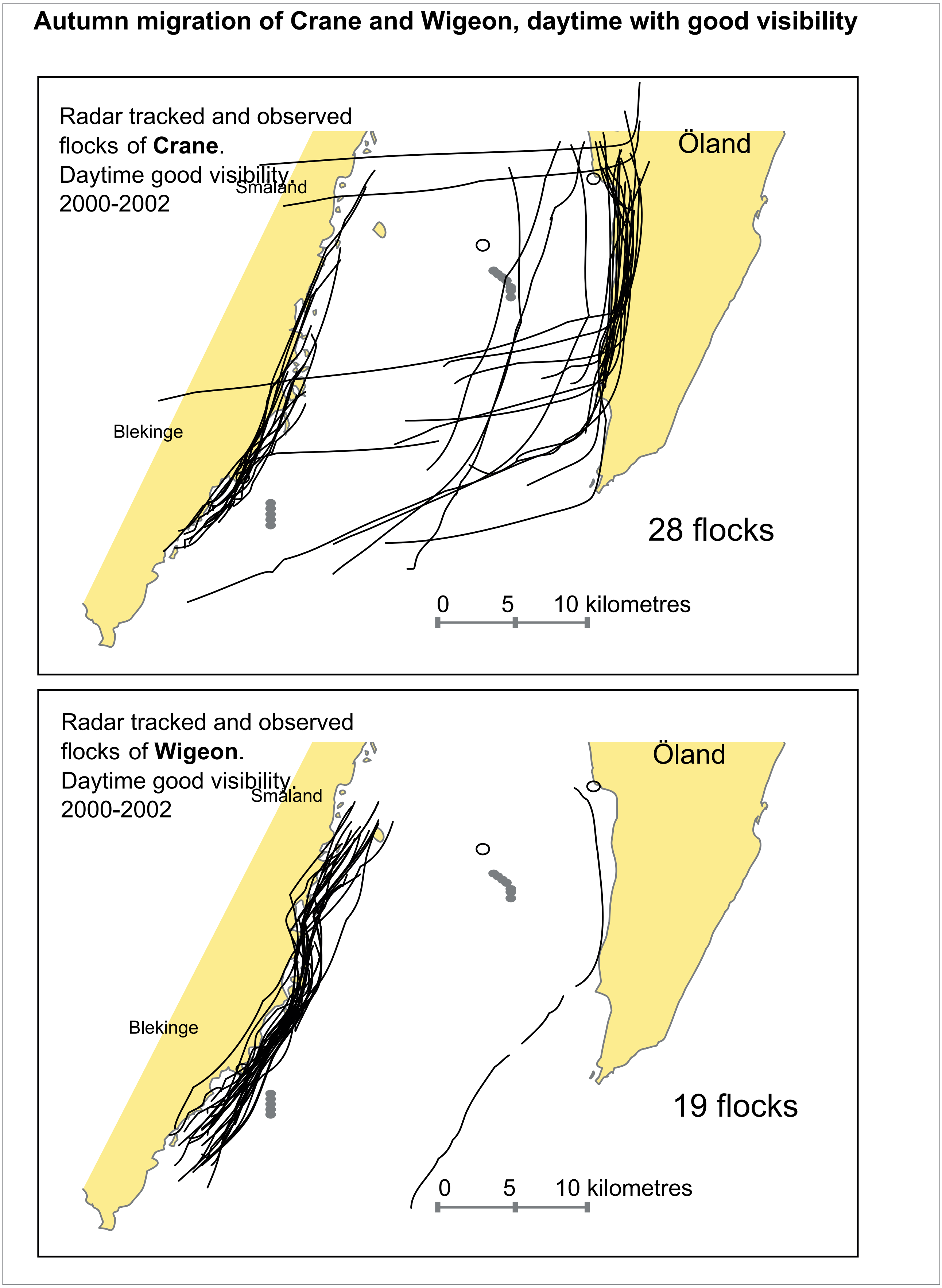
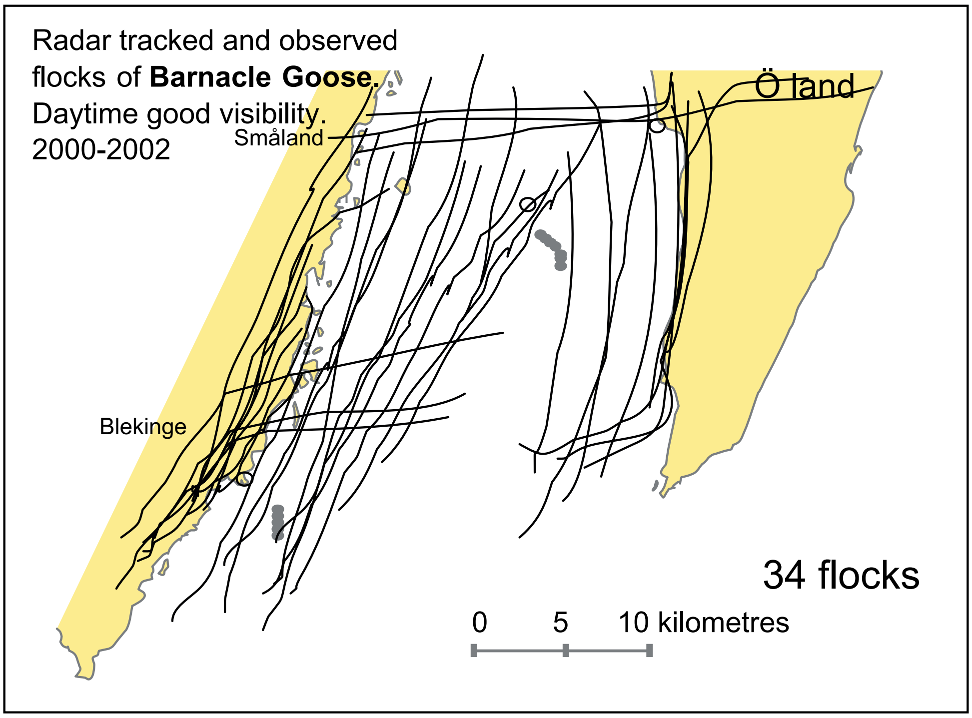


Figure 47 Radar- tracked flocks of Cranes and Wigeons were recorded using a time comparison of identified radar echoes and field observations. Long trackings of flocks identified in at least one place are shown here.

Autumn migration of Barnacle Goose and Cormorant, daytime with good visibility



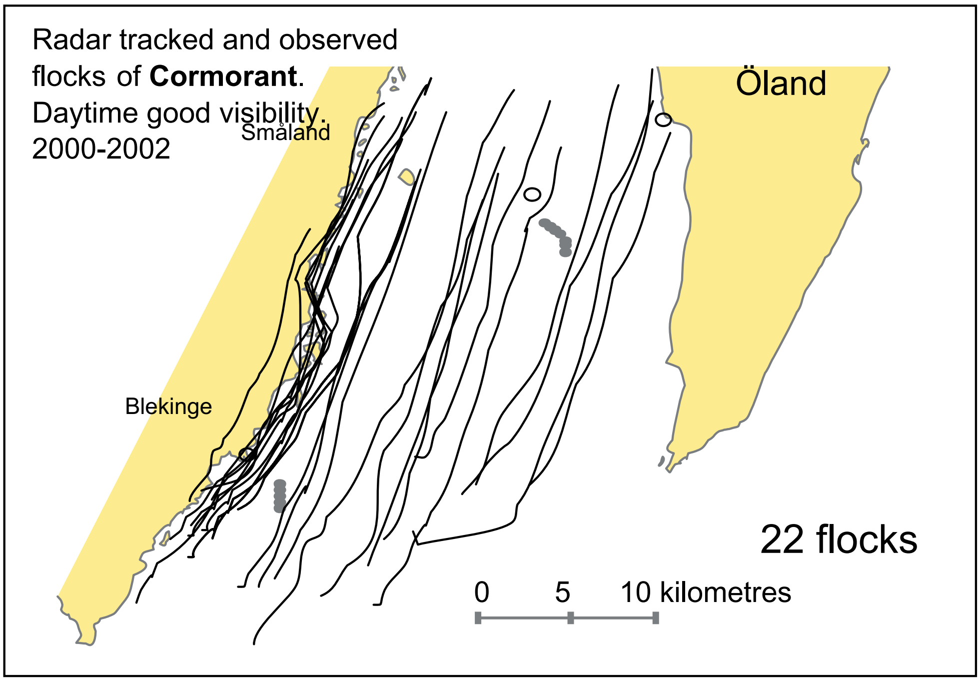


Figure 48 Radar tracked flocks of geese and Cormorants were recorded using a time comparison of identified radar echoes and field observations. Long trackings of flocks recorded by at least one observer are shown here.

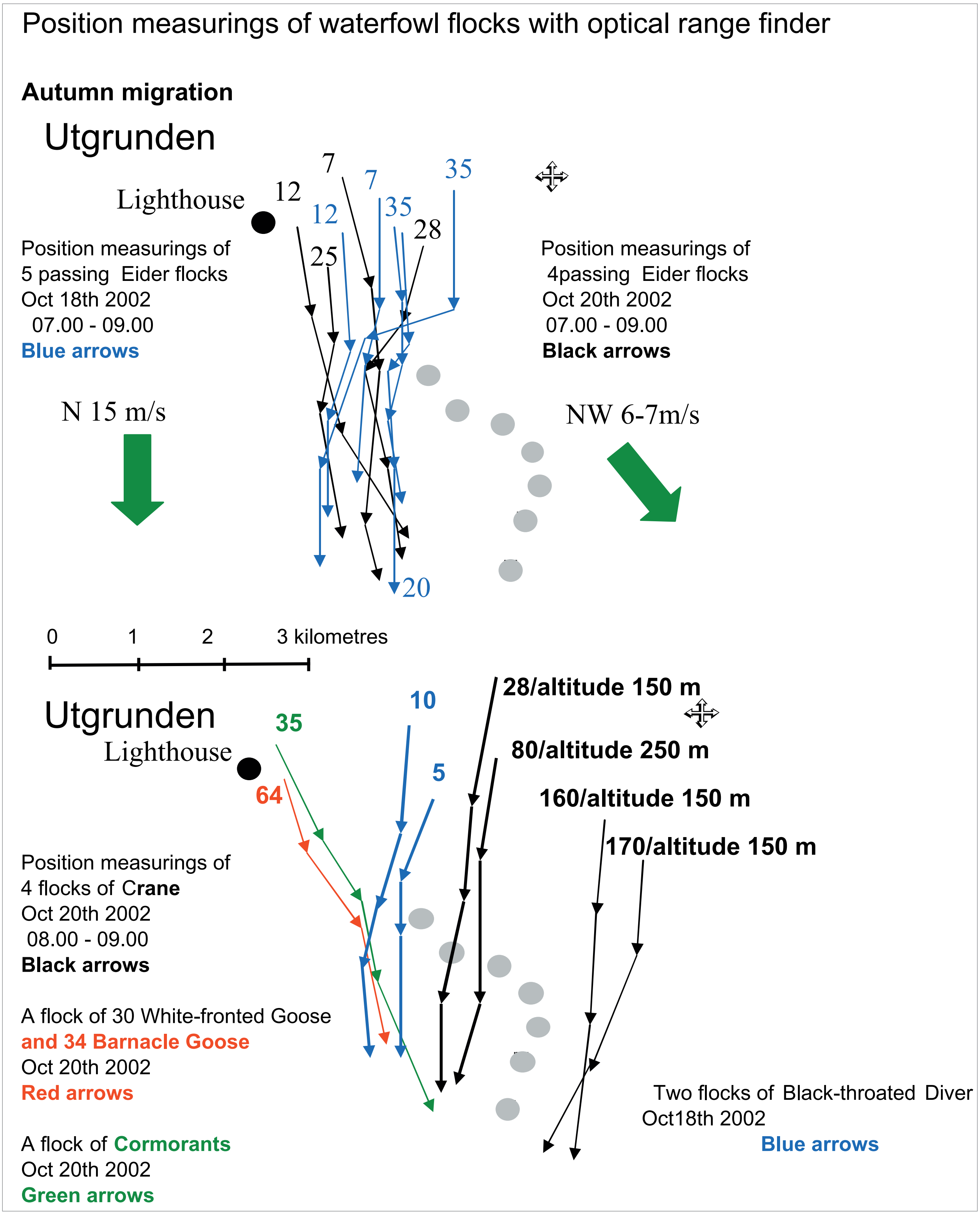


Figure 49 Position measurements of waterfowl flocks using an optical rangefinder every 20th second, or more often every minute. The measurements were made from the lighthouse. The flight path of each flock was drawn on a map on which the Utgrunden wind turbines were marked in grey and where position measurements of the flock were made along the flight line at the beginning and end of each small arrow.

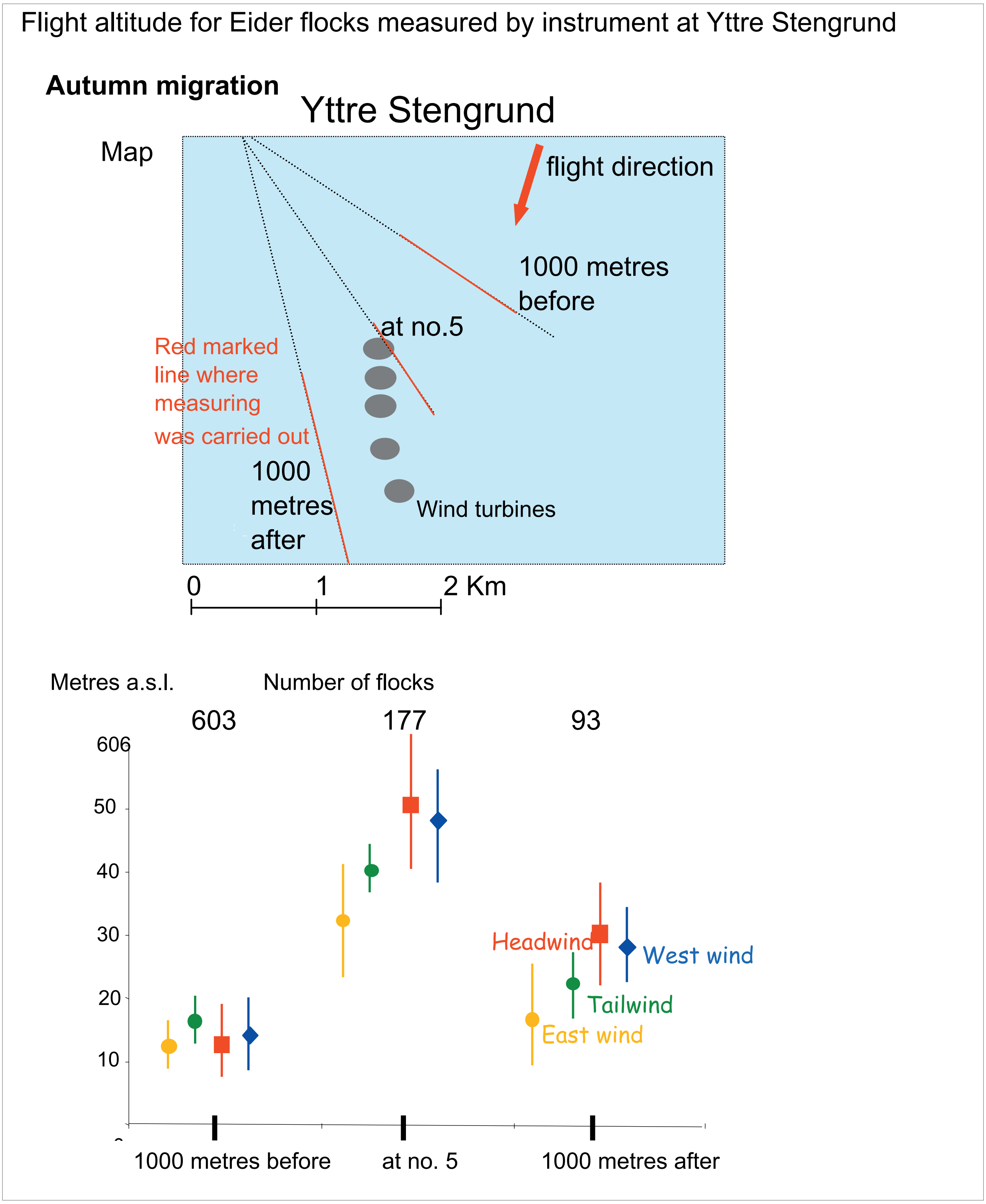


Figure 50 Flight altitudes of Eider flocks measured with an optical rangefinder on passing the previously marked lines indicated at the top of the map. The measurements were made at Yttre Stengrund in the autumn seasons 2002–2003. The flocks shown "at number 5" are only those flocks which have passed at a distance of not more than 300 metres from the nearest wind turbine.

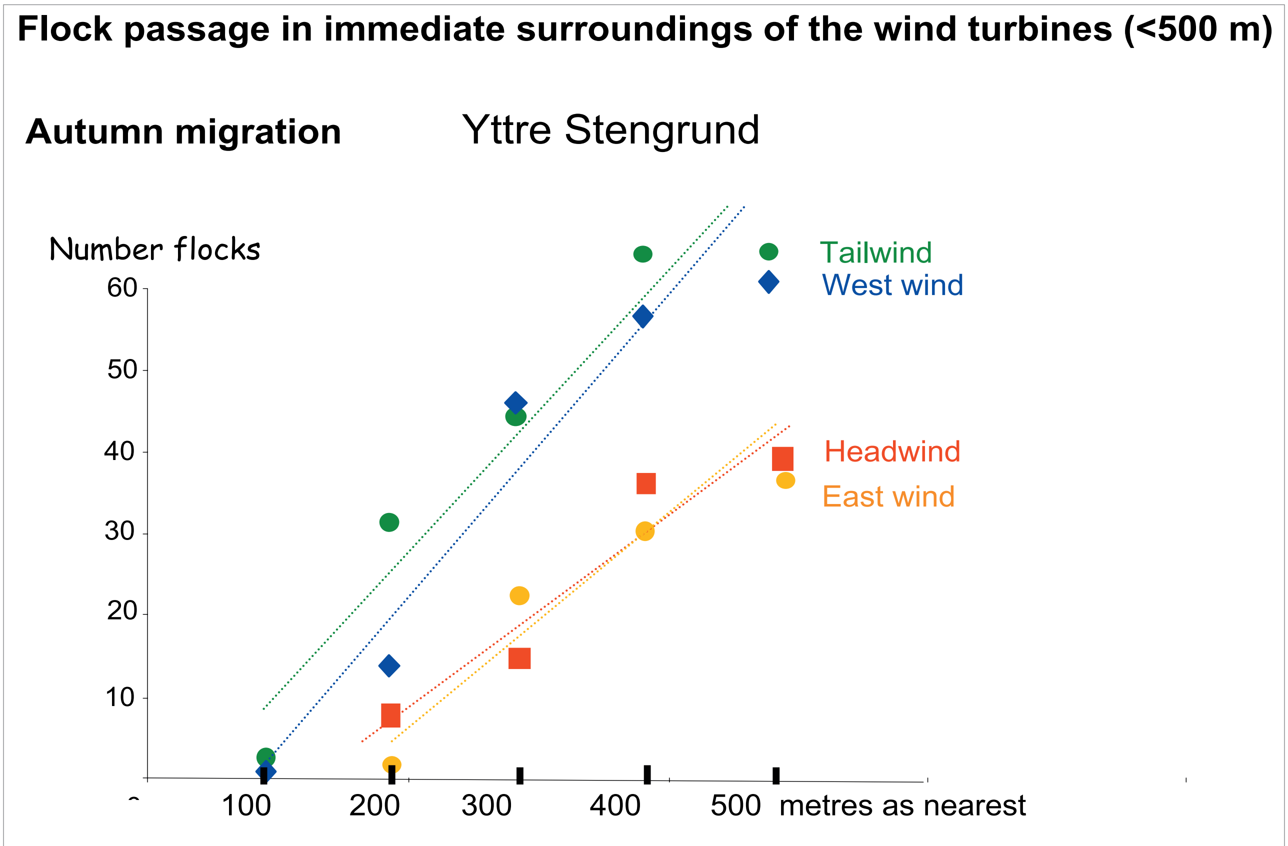


Figure 51 Number of Eider flocks which flew at a distance of 500 metres or less from the nearest wind turbine during the autumn seasons 2002–2003 at Yttre Stengrund. The figure includes a total of 552 recorded flocks.

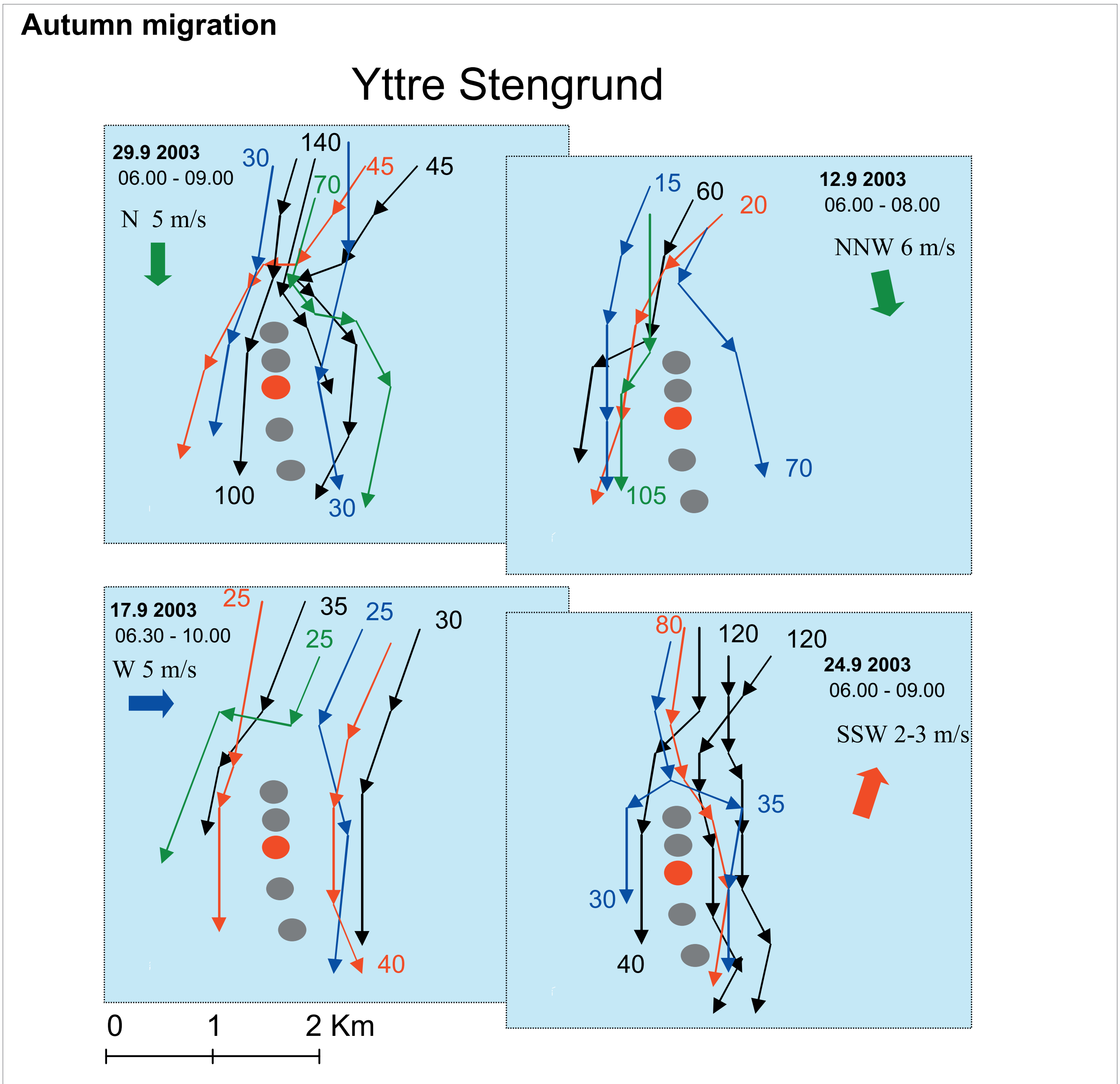


Figure 52 Eider flocks measured with an optical rangefinder during autumn 2003 at Yttre Stengrund. Wind turbines not in use on each occasion are marked in red. The flight path of the flock was drawn on a map on which position measurement of the flock was made along the flight line at the beginning and end of every small arrow. On the morning of 24 September there was only a light breeze between 06.00–09.00 and the turbines were out of operation for certain periods.

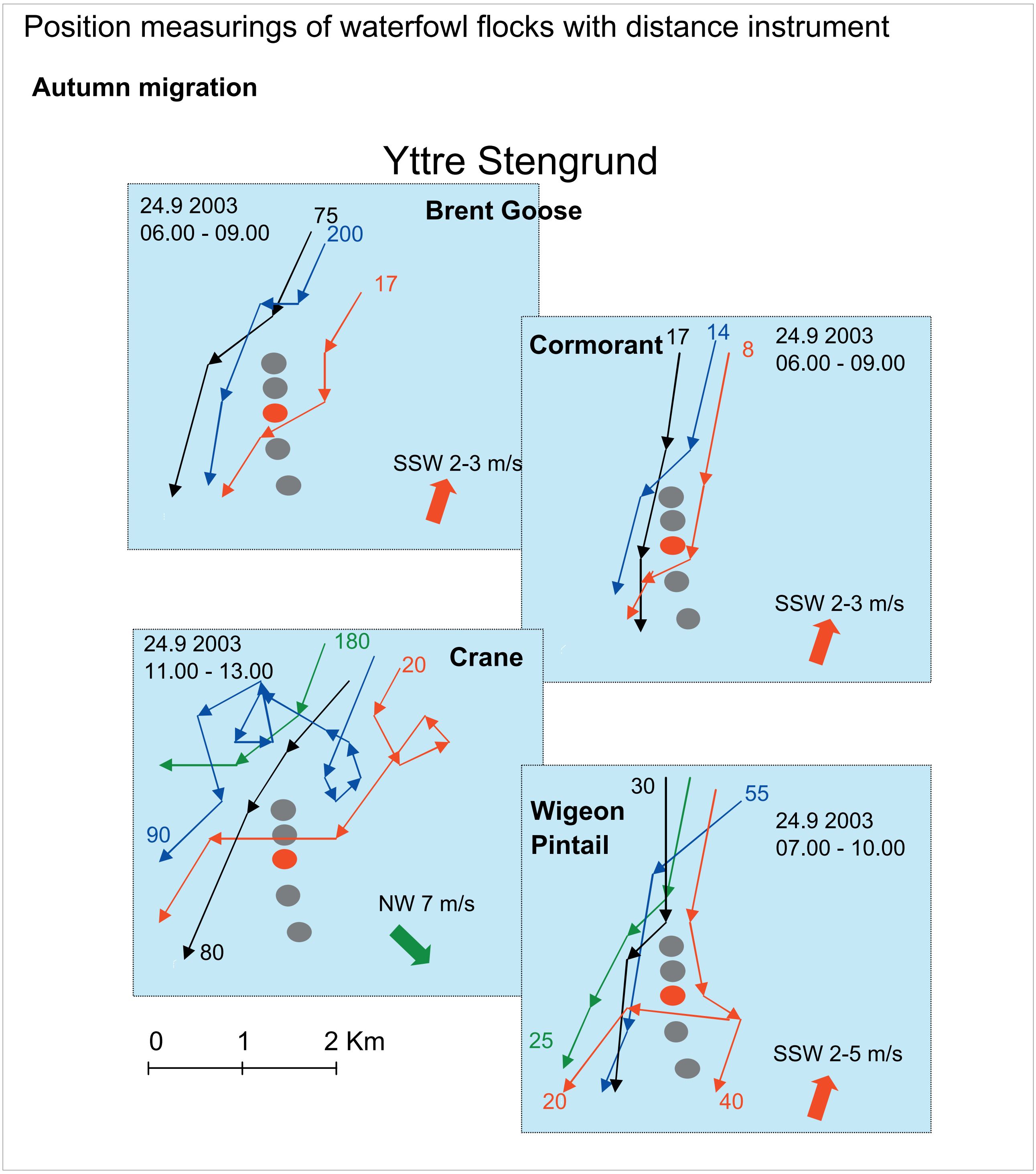


Figure 53 Waterfowl flocks of species other than Eider measured with an optical rangefinder, in which only flocks that show some change or correction of their flight path at the turbines are shown. Of the mixed flocks of Wigeon and Pintail, one flock flew between the turbines while the flock of Cranes seen passing the turbines does so at an altitude of 170 metres, or at least 70 metres over the highest point of the rotor. Wind turbines marked in red are temporarily out of operation. On the morning of 24 September there was only a light breeze between 06.00–09.00 and all the turbines were out of operation for certain periods.

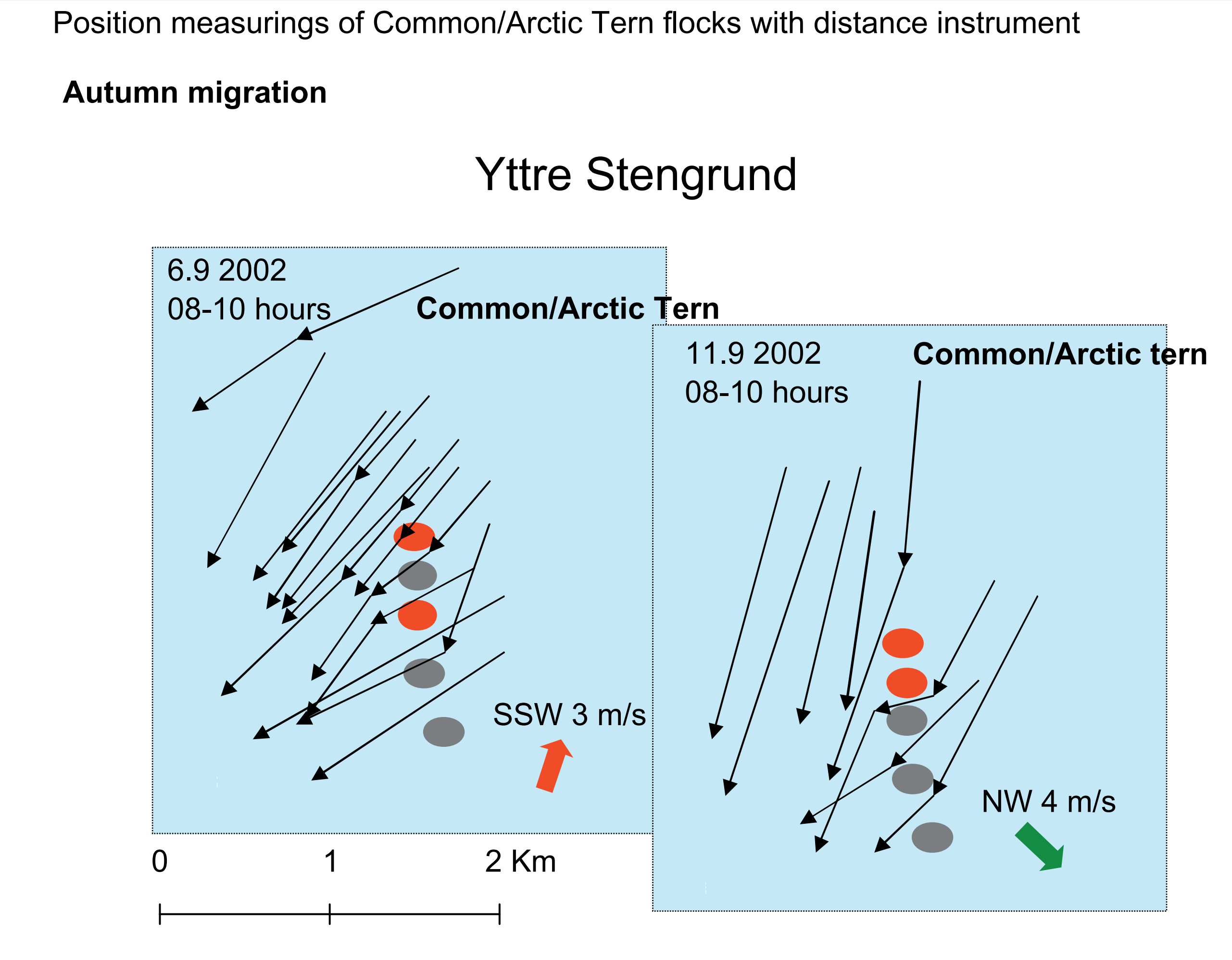


Figure 54 Flocks of terns (Common Tern and Arctic Tern) measured with an optical rangefinder. The flocks consisted of migrating birds with 6–27 birds per flock. No long trackings were made but in general there were two readings per flock. The flight altitude of the flocks is about 10 metres above sea level. Wind turbines marked in red are temporarily out of operation.

at a distance of less than 500 metres from the turbines. It may be stated that there is no risk of collision if the flock passes at a distance of 500 metres from the turbines. When passing at a distance of approximately 100 metres from the turbines there may be a risk of collision. During the whole observation period, only six flocks or 0.3 per cent of the total number of flocks through the area passed that close to the turbines.

The flock trackings made in 2003 show in more detail how Eider flocks pass the wind turbines at Yttre Stengrund (Figure 52). The same figure includes a presentation of 23 flocks in various wind conditions and on one occasion when all the wind turbines were out of operation. Flocks react about a kilometre before the turbines, sometimes a little later. Deviation from the straight flight path was less here than that shown in spring data from Utgrunden.

The flight path for a number of waterfowl species was plotted in Figure 53. All birds except cranes made a slight deviation from the straight path. Those crane flocks which hesitate near the turbines are seen to choose another solution: they begin to spiral and ascend to be able to fly over or alongside the turbines. In autumn 2002 when measurements were started at the beginning of September, migrant Common Terns and Arctic Terns could be seen passing the wind turbines at Yttre Stengrund at an altitude of approximately 10 metres above sea level. The terns passed in small flocks of 6–27 birds without making any great deviation manoeuvre and they also flew between or alongside the turbines (Figure 54).

4.7 A migrating waterfowl flock in collision with the wind turbines

During observations of waterfowl migration in autumn 2003 from Olsäng at the Yttre Stengrund wind farm, a collision was witnessed whose course is described in detail below. During observations at Utgrunden in spring 2001 and 2002, observations were made on two occasions of situations when there was a great risk of collision, but on both occasions the flocks avoided collision by deviating just in time. At Yttre Stengrund there were three occasions recorded during previous autumn observations in which a great risk of collision was assessed, but the flocks (which were small) veered off to one side or the other to avoid collision (observed by Johan Petersson). The collision described below is the only

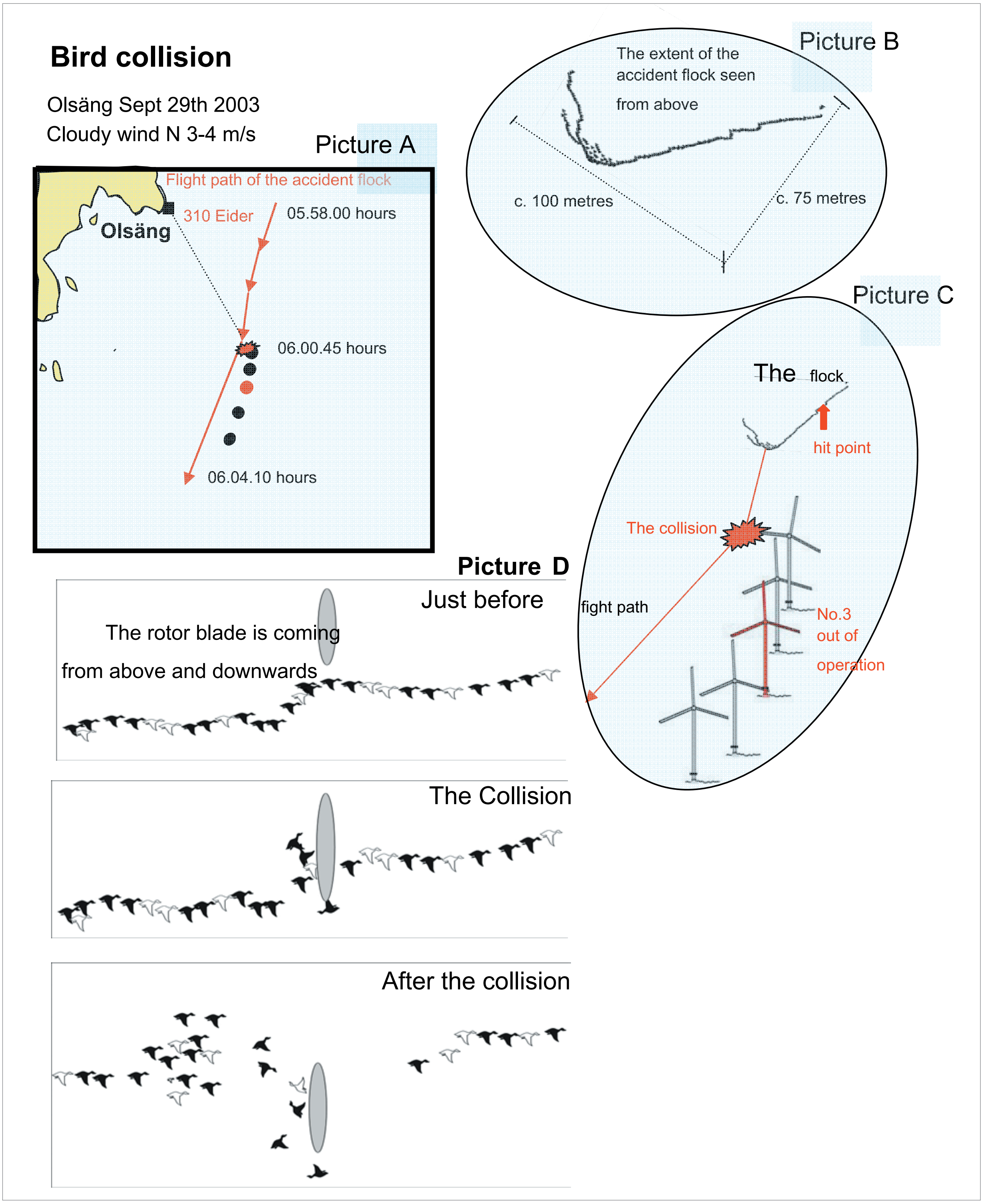


Figure 55 Collision between bird and wind turbine observed on the 29 September 2003 at Olsäng at the Yttre Stengrund wind farm. The observation was made by the author when making distance measurements. Picture A shows the flight path and time. Measurement of position on the flight path was made at the beginning and end of every small arrow. Picture B shows the extent of the flock. The flock was comparatively large with 310 birds. Picture C illustrates how the collision occurred with the rotor blade of turbine number 5 in the outer flank. Picture D shows the series of events observed in which one bird was killed. Three other Eiders fell into the water but at least two of them were later seen taking off from the same place. They joined the rear part of the flock of about 50 birds which had turned back, while the other part of the flock continued. See the method section for accuracy of the measurements of these distances.

one which was observed and recorded during the whole project period. During observations of approximately 20000 waterfowl flocks which were tracked and observed passing through Kalmar Sound during the whole study period, only five near-accidents and one collision were observed. From this experience it seems quite clear that these offshore wind turbines do not result in the death of many waterfowl – and whole populations are definitely not threatened.

On 29 September 2003 the author of this report, Jan Pettersson, was at Olsäng on the Blekinge coast. On this occasion there was a northerly wind of an estimated 3–4 m/s at the observation site. The wind was probably slightly stronger out by the wind turbines. Four of these were in operation – number three was not working. It was a relatively dark morning with sunrise at 06.40 and observation light from 05.47. The first flock which could be tracked by instrument arrived at 05.50 and veered off outside the turbines. The next flock which could be tracked came at 05.54, veering off inside the turbines. The waterfowl migration on this dark morning was relatively intense with one flock every second minute, mostly Eider. There was a cloud formation in the southeast which darkened the sky and the warning lights for ships on the wind turbines were switched off at approximately 05.50. A large Eider flock of 310 birds was measured at 05.58 approximately two kilometres north of the wind turbines and this flock was measured twice before it reached the turbines, after which it veered off slightly away from the shore into the Sound (Figure 55, Picture A). Approximately 100 metres before the flock reached the northernmost turbine it was at a distance of 3000 metres from the observation site at Olsäng. This data relating to 100 metres from the turbine means the measured distance and applies to the main group of the flock (see extension of the flock, Figure 55, Picture B).

When I changed from the rangefinder to the telescope (60x magnification) to follow the flock just before the wind turbines and after the last measurement, the collision could clearly be seen and later recorded (Figure 55, Pictures C and D). The flock was at an altitude of 60 metres. The collision happened at the rear of the flock, which obviously came too close and was hit by the rotor blade coming from above. On collision, one bird was seen to fall down towards the surface of the water immediately while three others fell with flapping wings towards the water. These three probably got off more lightly, but they all landed in the water. The rear part of the flock came to a halt, gathered into a tight group formation, veered off towards the mainland and flew back towards the scene of the accident. There they probably managed to get two or three out of the total of four Eider which had landed in the water to resume flight with them, after which this partial flock continued their migration south. My interpretation is that one individual was hit directly by the rotor (or more likely by its turbulence) while three of them were temporarily injured, probably only slightly as at least two of them could fly immediately and join the rest of the flock. The front part of the flock of approximately 260 Eider continued their migration path apparently unaffected by the incident and when the author of this report had pulled himself together after this experience the flock could not be measured until 4 minutes later just south of the southernmost wind turbine (Figure 55, Picture A).

4.8 Staging and wintering waterfowl in southern Kalmar Sound

To get a total picture of the number and structure of the species of waterfowl which spends time in the whole southern Kalmar Sound area for a long time period, a special compilation was ordered of the almost annual observations for this area made during winter periods by voluntary ornithologists. It was compiled by Leif Nilsson at Lund University (see Nilsson 2003).

4.8.1 Staging and wintering waterfowl by the wind farms

The international waterfowl counts which were made during midwinter in southern Kalmar Sound by voluntary ornithologists showed a great variation (between 1500 and 11700) in the total number of recorded waterfowl from one year to another (Nilsson 2003). A cold winter can certainly influence the variation as the coastal areas in southern Kalmar Sound become covered with ice quickly during cold winters. The counts of waterfowl made between 1969–2003 and which are compiled in a special report (Nilsson 2003) also include the shallow areas of the Sound. That means that neither Utgrunden nor the sector out towards Yttre Stengrund is included in the survey. In supplementary inventories from aircraft in the winter seasons of 1971, 1972, 1973 and 1993 it was not possible to count larger flocks of waterfowl on these outer banks. In an analysis of wintering sites for Long-tailed Ducks in particular along Swedish coasts (Nilsson 1980) Nilsson mentions that these shallow banks relatively near the coast do not generally provide significant wintering sites for waterfowl.

The last four winters have seen totally frozen sea at Utgrunden for a total of only 10 days and it is unlikely that the sea freezes there every winter. As parts of the sea near the shore are periodically covered with ice, as are shallow areas almost every winter, it would appear that conditions were good for these shallow areas to accommodate wintering waterfowl. The few counts which have been made in the winter months of December–February within the scope of the wind park project show that the Utgrunden areas UT1 and YT2 (Tables 30 and 31) have on average 1000 - 2000 or more staging waterfowl. These counts also show that in one winter there were up to 900 Eider in the area, which is an amazing result considering that Nilsson wrote that the Eider does not visit the area in winter (Nilsson 2003). All flocks of Tufted Duck and Scaup observed in the area are named as Tufted Duck/Scaup. These can in some cases include Scaup but in relatively small numbers as the Tufted Duck is the more common species. It should be noted that Nilsson (2003) does not mention Scaup as wintering in southern Kalmar Sound. There are up to 1500 Long-tailed Duck during the winter (see Tables 30 and 31) in the area, indicating that these banks function as a wintering site for Long-tailed Duck but with large annual variations. Taking into consideration the total number of wintering Long-tailed Duck in the Baltic this number is insignificant in comparison with areas just east of Öland where up to 10000 birds can be seen (Nilsson 2003) or further out in the Baltic on the Hoburg Bank and the Midsjö Bank where hundreds of thousands of Long-tailed Duck winter (Durinck et al 1993).

In connection with a special study in spring 1998, a relatively large number of staging waterfowl were noted within the areas chosen later at Utgrunden, UT1 and UT2. On 18 April a total of 11750 staging waterfowl were reported, dominated by 6500 Eider, 1800 Long-tailed Duck and 3300 Common Scoter (Pettersson & Lindell 1998). Now, three seasons after this observation, this accumulation of staging birds seems perhaps more accidental in comparison with the total averages of 2000–3000 staging waterfowl which these areas have seen in the spring periods March–April and the autumn periods October–November (see Tables 30 and 31). It may be that the Utgrunden area temporarily and perhaps during shorter periods is used as a short-term stopover site by a larger number of waterfowl during the spring migration. One reason that areas like this have such large variations in numbers of staging birds may be that waterfowl have large areas between which they can move, depending on food and winds. If we look at the limited area that these banks actually represent, large variations may well occur.

Of the two areas along the Blekinge coast where surveys were carried out within the scope of this project, one covers Yttre Stengrund, OL1, and the other the coastal area north of Yttre Stengrund. These counts show that the number of waterfowl wintering here amount to just under 1000 and that the number during the spring and autumn periods hardly deviates from this (see Tables 32 and 33). It is worth noting that no flocks of Long-tailed Duck, except for some occasional few birds, have been seen staging in these areas. Local ornithologists (from Karlskrona) who more or less regularly visit the area have observed that during winters when there is ice all the way out to Yttre Stengrund there can be up to hundreds of Long-tailed Ducks out near the edge of the ice. During the period when migration counts were made in the spring and autumn seasons, an observer reported that there were very few waterfowl in the immediate vicinity of the wind farm at Yttre Stengrund, the actual number always being less than 100.

4.8.2 Determining sites of staging birds

In spring 1999, before construction of the wind farms (see Figure 56,) two inventories were made of staging sites. Long-tailed Ducks and Eiders were chiefly found in the area but also other species e.g. Red-breasted Mergansers, Common Scoters and Cormorants.

During the period 27 March – 8 April in 1999–2003, counts were made on a total of 53 occasions at all times of the day in the areas UT10 and UT20 to establish how foraging and resting waterfowl behaved in the Utgrunden area. The occurrence and daily routines of the four most common species are shown in Figures 57–60.

The Red-breasted Merganser, which partly stages outside the bank itself, (Figure 61) showed a typical peak in both areas during the afternoon. The species is a fish eater and one reason might be that the accessibility of fish varies during the day with a possible peak during the afternoon. With regard to Eider there is no change of occurrence during the day and they occurred both before and after construction mainly outside the wind farm area itself. With regard to Common Scoter and Long-tailed Duck there are similarities in that more birds were counted during the early morning and late evening, mainly in the wind farm area UT10 (Figures 57 and 59).

Surveys were carried out on 4 April on several occasions during the day to determine how the positions of flocks were affected by the short visit of the service boat in the area (see Figures 62 and 63). The boat disturbed the Long-tailed Ducks and they looked for new sites further away, but it is also clear that the flocks in most cases returned at night (see also day routines Figure 57). The Long-tailed Ducks in the reference area UT20 showed no corresponding tendency towards decreased numbers during the day, having a more even distribution in the area during the whole day (Figure 57).

The visit of the service boat to the wind turbines did not seem to affect the number of staging Eider, probably due to the fact that they only stage north of the wind turbines where the boat is not around very often. It may also be due to the daily routines of the Eiders that they do not seem to show any variations in numbers during the day (Figure 58).

If the average number of Long-tailed Duck in the two Utgrunden areas in the four different autumn periods is compared with the number of visits by the boat which occurred during the observation periods in these areas, a linear relationship is seen between the boat visits and the occurrence of Long-tailed Duck flocks. This should probably be interpreted as the Long-tailed Duck splitting up into smaller flocks when disturbances due to the boat in the wind farm area exist to a greater extent than in the reference area UT20 (Figure 64). On a winter visit to the Utgrunden wind farm on 17 December 2002 it could be observed over 4 hours that after the boat had left the area on three occasions it took 21, 24 and 30 minutes respectively before the birds returned to the spot. This applied to both the few present Red-breasted Mergansers as well as to the 50 Long-tailed Ducks in the vicinity of the wind turbines. The Long-tailed Ducks were seen lifting when the boat arrived, flying towards the west and landing approximately 2 kilometres from the wind farm area. They remained there while the boat was present. The wind farm company reported that the reason for so many service visits to the wind turbines at that time was due to their being under development. Many technical experiments were carried out that were difficult to coordinate in time, which meant several visiting days.

The number of Long-tailed Ducks in the area decreased from 1999 to the observation period 2001–2003 in both the wind farm area (UT10) and the reference area (UT20)

(Figure 65). The decrease, which took place in both areas, has been difficult to interpret and is not necessarily caused by the wind turbines. Part of the reason may also lie in large annual variations. Although the reference area is located as near as 3 kilometres north of the wind turbines, it cannot be excluded that the area has been affected negatively by the turbines so that the number of Long-tailed Ducks decreased after their construction. Eider show no significant changes in numbers of staging birds during the spring periods investigated (Figure 65).

There are no surveys of staging waterfowl in the autumn at Utgrunden before construction of the wind turbines. An analysis of the situation after construction of the wind farms shows that the same differences exist between the choice of staging site in the area by Long-tailed Ducks and Eider as during the spring (Figure 66). Neither Long-tailed Duck nor Eider show any marked changes in the number of staging birds (Figure 67) in the investigated areas UT10 or UT20 during the limited autumn period 6 October – 27 October. When the first autumn study was made in 2000 there was large-scale construction work almost daily which meant a lot of activity in the wind farm area. Obviously these activities were so disturbing that no Long-tailed Ducks were to be found in the area. Shipping and other construction activities were in progress during the building period during the greater part of the day. There was no 24-hour observation of staging birds during this construction period, only occasional observations. Position measurements during the following autumn periods were all made after 1.00 p.m. The number of boat visits during the observation periods in autumn of 2001 and 2002 was 10 and 14 respectively, which is fewer than during the spring periods when the number of visits was on average just over one visit per day. There is no autumn study to compare with the spring period regarding any possible disturbance by boat traffic. As an observer at the Utgrunden lighthouse the author has a feeling that there are similar conditions during the autumn as during the spring, i.e. that the service visits create more of a disturbance than the wind turbines themselves.

4.8.3 The occurrence of mussels at the sites of staging birds at Utgrunden

To obtain more information on which to interpret birds' choice of staging sites in the wind farm area at Utgrunden, the University College in Kalmar was commissioned to make a limited study of bottom fauna in the area (Tobiasson et al. 2004). The investigation included six sites, three of which were within dense areas of staging birds and three within more sparse areas of staging birds. Each site was made up of a transect from the top of a hillside down to its base. Each site was mapped out and video filmed. A quantitative test was also made at each site at three different depths.

As the common sea mussel (Mytilus edulis) belongs to the staple food for waterfowl (Long-tailed Duck and Eider) in this part of the Baltic, the occurrence of these mussels is of special interest. The results of this investigation (Figure 68) show very clearly that the occurrence of common sea mussels is, both in number and in biomass, much more abundant where waterfowl usually stage in comparison with areas less frequented by waterfowl. Differences between the various areas, in terms of the number of mussels per unit area as well as biomass, are statistically significant (Tobiasson et al 2004).

4.9 Other birds in southern Kalmar Sound and at the wind farms

In the Appendix (Tables A1 and A2) there is a summary of all observations of birds made in southern Kalmar Sound during this study at all three observation sites. As the studies have concentrated on Eider and other waterfowl, gulls and other species are disproportionately represented in the tables, which should therefore only be regarded as a general indication of the occurrence of birds in the area. For smaller birds, only large flocks were reported. There are also observations of possible small birds in large groups which have been reported by radar trackings as migrating during the night over the southern part of the Sound. Observations of such probable flocks of small birds were recorded by radar on occasions when large groups of small birds were observed taking off from Öland at night and flying across the Sound, especially 15 October 2000, 17 October 2000 and both evenings 27 and 28 October 2000 (see Pettersson 2001).

The raptors included in the tables consist only of those which flew out over the Sound and not those which were only seen migrating over land along the coasts. In Appendix Table A3, all red listed species (Gärdenfors ed. 2000), rarities and raptors were noted and the zone of the Sound where they were seen flying. The species which appeared in zone C at the Utgrunden wind farm and those flying in zone A at the Yttre Stengrund wind farm are also in Tables A4 and A5 (Appendix) to show in detail the local zones of each wind farm zone where they flew. In Table A4 for Utgrunden it is Pintail, Scaup and Velvet Scoter that account for most migrants in the three wind farm zones, but there were fewer birds of these species passing through the wind farm zone before than after construction. There was an observation of a White-tailed Eagle made near the wind turbines, which flew approximately 500 metres west of the northernmost wind turbine at an altitude of 10 metres and was therefore not at risk of a collision. These odd species fly between the wind turbines occasionally, but as the Table shows they are few and most of them which fly through this five-kilometre-wide zone C fly nearest the lighthouse in local zone 1, which is more than one kilometre from the nearest wind turbine.

At Yttre Stengrund (Table A5) the wind turbines cover a zone which, seen from the north or the south, is approximately one kilometre wide and only autumn migrating birds were seen flying in this zone before and after the construction. Thus Pintail, Scaup and Velvet Scoter appeared in this zone and it may not be pure chance that those same species fly through the wind farm zone at Utgrunden. But most of these unusual species show that they clearly prefer to fly closer to the mainland than out near the wind farm zone, three kilometres out in the Sound. With regard to the raptors which have been seen in the wind farm area at Yttre Stengrund, all of them have flown at a higher altitude than that of the wind turbines' radius. Their flight altitudes were 150–200 metres and so they did not run any risk of collision.

Staging waterfowl at Utgrunden wind farm area

UT1

Year	Date	I	**Diver** *Gavia sp*	**Cormorant** *Phalacrocorax carbo*	**Tufted Duck/Scaup** *Aythya fuligula/marila*	**Eider** *Somateria mollissima*	**Common Scoter** *Melanitta nigra*	**Long-tailed Duck** *Clangula hyemalis*	**Goldeneye** *Bucephala clangula*	**Goosander** *Mergus merganser*	**Red-breasted Mergans** *Mergus serrator*	Total	Average m	Months
2001	09.03	B		50		150	15					215	**215**	September
2000	10.04	O				2 750						2 750		
2000	10.12	O				2 500						2 500		
2000	10.23	O				1 200		100				1 300		
2001	10.09	O		15		250	25	200			135	625		
2001	10.16	O		15		650	135	200			85	1 085	**1176**	October
2001	10.23	O				400	250	650			85	1 385		
2002	10.16	O				12	35	25				72		
2002	10.20	O				320	135	35				490		
2002	10.21	O				158	150	65				373		
2001	11.15	B				100	50	400			25	575	**575**	Novembeı
2000	12.12	F				1 050		200				1 250		
2000	12.16	F				350		200		10		560		
2000	12.21	B				700		225		15		940		
2002	12.09	B		3		5	35	280			10	333	**541**	December
2002	12.17	O		1		2	2	50			5	60		
2003	12.14	O				5		50	25	15	10	105		
2001	01.07	F				25		50				75	**75**	January
2001	02.19	B		15		350	15	50				430	**430**	February
2001	03.05	F				210		85		15		310		
2001	03.23	O		10		25		350			25	410		
2001	03.26	O		15		450		450			25	940		
2002	03.25	O				250		450				750		
2002	03.27	O				125		200				325		
2002	03.30	O				315		240			20	575	**571**	March
2003	03.23	O		15		0		230			15	260		
2003	03.25	O		25		20	5	450			25	525		
2003	03.28	O		10		30	15	600		4	80	739		
2003	03.30	O		15		450	35	350			25	875		
2001	04.05	O		20		700		250				970		
2002	04.02	O		15		235	30	120			20	420		
2002	04.04	O		15		40		25			15	95		
2003	04.01	O		20		350	75	430			35	910	**591**	April
2003	04.02	O		5		450	65	0			45	565		
2003	04.04	O		5		400	35	150			55	645		
2003	04.05	0		5		400	75	0			55	535		
2001	05.18	F		25		130	240					395	**395**	May

Table 30 Number of wintering and staging waterfowl in the area UT 1 at Utgrunden (see figure 4). Average is shown per month. In the table headings, "I" shows the survey method and "O" shows counts from the lighthouse; "B" counts from boat and "F" counts from the air.

Staging waterfowl in reference area at Utgrunden

UT 2

Year	Date	*	**Diver** *Gavia sp*	**Cormorant** *Phalacrocorax carbo*	**Tufted Duck/Scaup** *Aythya fuligula/marila*	**Eider** *Somateria mollissima*	**Common Scoter** *Melanitta nigra*	**Long-tailed Duck** *Clangula hyemalis*	**Goldeneye** *Bucephala clangula*	**Goosander** *Mergus merganser*	**Red-breasted Mergans** *Mergus serrator*	Total	Average m	Months
2001	09.03	B		20		125	200				25	370	**370**	September
2000	10.04	O		100		1 500						1 600		
2000	10.23	O		15		900		50				965		
2001	10.09	O	10	15		200	450	50			350	1 075		
2001	10.16	O		15		350	450	450			400	1 665		
2001	10.23	O		15		380	450	350			450	1 645	**1 358**	October
2002	10.16	O		12		100	200	600			35	947		
2002	10.20	O	6		30	35	120	1100			320	1 611		
2002	10.21	O	15	8		130	200	920			85	1 358		
2001	11.15	B		15		100		250			100	465	**465**	November
2000	12.12	F				900	50	200				1 150		
2000	12.16	F			150	550	15	225	50	20		1 010	**794**	December
2003	12.14	O	15		25	35		100	30	7	10	222		
2001	01.07	F		15		900		275				1 190	**1 190**	January
2001	02.19	B		15		850		350		75		1 290	**1 290**	February
2001	03.05	F		2		20		200		15		237		
2001	03.23	O						950			20	970		
2001	03.26	O		20		500		1550			40	2 110		
2002	03.25	O		7		137		100				244		
2002	03.27	O				250		250				500	**695**	March
2002	03.30	O	8			64	16	260			42	390		
2003	03.23	O				25		15		7	12	59		
2003	03.25	O	2	7		225		380	5	5	15	639		
2003	03.28	O		12		350	5	320		2	35	724		
2003	03.30	O		20		450	15	550			40	1 075		
2001	04.05	O				100	40	1100			20	1 280		
2002	04.02	O	12	15		120	90	500		32	70	839		
2002	04.04	O		12		35	120	15			90	274		
2003	04.01	O	8	10		600	70	450			55	1 193	**878**	April
2003	04.02	O	2	15		500	60	450			65	1 092		
2003	04.04	O	2	20		400	90	40			40	592		
2001	05.18	F		15		90	150					255	**255**	May

Table 31 Number of wintering and staging waterfowl in the area UT 2 (reference area) just north of the lighthouse (see Figure 4). In the table headings, "I" shows the survey method and "O" shows counts from the lighthouse; "B" counts from boat and "F" counts from the air.

Staging waterfowl in Yttre Stengrund wind farm area

OL1

Year	Date	I	**Diver** *Gavia sp*	**Cormorant** *Phalacrocorax carbo*	**Barnacle Goose** *Branta leucopsis*	**Mute Swan** *Cygnus olor*	**Mallard** *Anas platyrhynchos*	**Tufted Duck/Scaup** *Aythya fuligula/marila*	**Eider** *Somateria mollissima*	**Goldeneye** *Bucephala clangula*	**Goosander** *Mergus merganser*	**Red-breasted Merganser** *Mergus serrator*	Total	Average m	Months
2001	09.08	O	2	25					200	25	10	65	325		
2002	09.11	O	2	5		7	110		22			18	164		
2002	09.19	O	2	7		13	120		25			22	189	**204**	September
2003	09.07	O		9		22	80		35			6	152		
2003	09.24	O		11		28	95		45			9	188		
2000	10.27	O			900	30	100	50	150	25	5		1 260		
2001	10.29	O			600	35	250		50	30	5	25	995		
2002	10.10	O	4		80	25	450		20				579		
2002	10.30	O	4			29	120		10			35	194	**527**	October
2003	10.07	O		8	12	45	45		25	10		15	160		
2003	10.26	O				65	60		15	15		20	175		
2003	10.28	O	3			35	120	100		35	12	25	330		
2000	12.12	F			300	70	300			70	25		765		
2000	12.21	B			300	70	350			25	25		770	**768**	December
2001	01.07	F	3		300	65	200	300	90	25	20		1 003		
2002	01.12	O	2	5		25	45	100		35	35		247	**625**	January
2001	02.19	B		15		55	50			25	45		190		
2002	02.02	O	5	5		35	100	125		55	25	5	355	**273**	February
2001	03.05	F		15		70	250	50	10	45	55	25	520		
2001	03.25	O		10		45	25	15	45	20	5	35	200		
2001	03.26	O		15		25	100		100	15		25	280	**229**	March
2002	03.25	O		22		12	45	25	20			20	144		
2003	03.20	O		25		15	25	35	10	12	5	15	142		
2003	03.23	O		35		17	12	7	12			5	88		
2001	04.11	O		20		25	5		25	10	5	20	110		
2003	04.18	O		40		35	10	12	25			25	147	**145**	April
2003	04.21	O		45		45	5	15	14	14	15	25	178		
2001	05.18	F		25		15	5		200				245	**245**	May

Table 32 Number of staging waterfowl in the area OL 1 at Olsäng off the Blekinge coast (see Figure 4). In the table headings, "I" shows the survey method and "O" shows counts from the observation site Olsäng; "B" counts from boat and "F" counts from the air.

Staging waterfowl at Yttre Stengrund reference area

OL2

Year	Date	I	**Diver** *Gavia sp*	**Cormorant** *Phalacrocorax carbo*	**Barnacle Goose** *Branta leucopsis*	**Mute Swan** *Cygnus olor*	**Mallard** *Anas platyrhynchos*	**Tufted Duck/Scaup** *Aythya fuligula/marila*	**Eider** *Somateria mollissima*	**Goldeneye** *Bucephala clangula*	**Goosander** *Mergus merganser*	**Red-breasted Merganser** *Mergus serrator*	Total	Average m	Months
2001	09.08	O		5		15			25				45	**45**	September
2001	10.29	O		25		35	100		50	105			315	**348**	October
2003	10.28	O		15	25	10	220	70	20	15		5	380		
2000	12.12	F				40	150	600	400	200			1 390		
2000	12.16	F	4			35	150		200	150	70		609		
2000	12.21	B				40	150	200	100	200	35		725	**831**	December
2003	12.15	O	2	38		45	220	250	5	25	2	12	599		
2001	01.07	F	3			85	200	220	105	55	40		708		
2002	01.12	O		5		20	25	125	5	30	45		255	**482**	January
2001	02.19	B		15		35	100		50	45	12		257		
2002	02.02	O		5		40	125	250		25	10		455	**356**	February
2001	03.05	F		15		40	250		100	45	15		465		
2001	03.25	O		35		35	100		120	65	25	10	390		
2001	03.26	O		20		20	100		230	25	35	25	455	**300**	March
2002	03.25	O		35		3	18		12	2	7	12	89		
2003	03.20	O		40		4	20		13	2	6	15	100		
2001	04.11	O		50		15	25		250	10	5	25	380		
2003	04.18	O		3		5	4		24			10	46	**160**	April
2003	04.21	O		4		7	5		25			12	53		
2001	05.18	F		15		10	20		350	5		30	430	**430**	May

Table 33 Number of staging waterfowl in the area OL 2 at Olsäng off the Blekinge coast (see Figure 4). In the table headings, "I" shows the survey method and "O" shows counts from the observation site Olsäng; "B" counts from boat and "F" counts from the air.

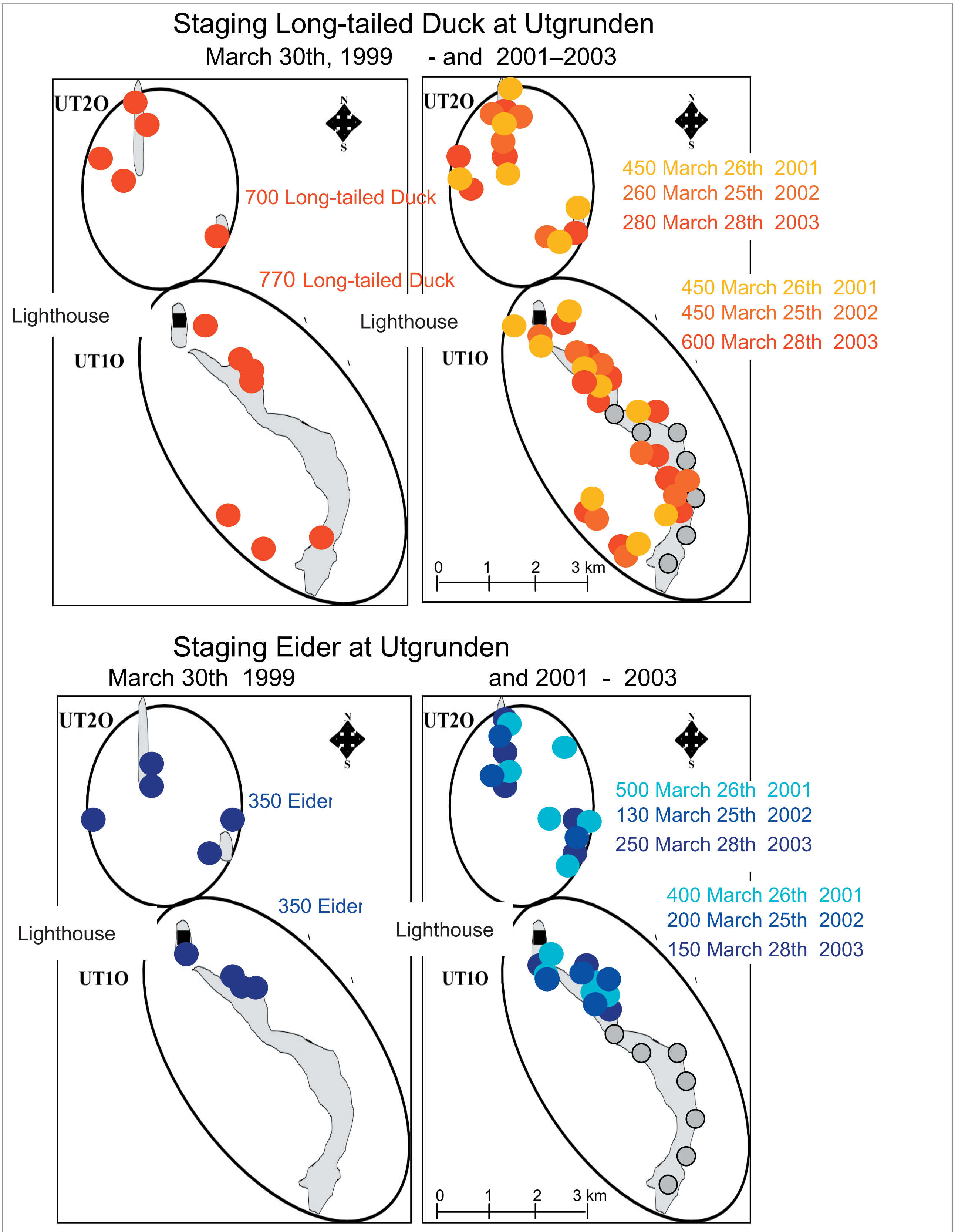


Figure 56 The survey areas for staging waterfowl at Utgrunden, UT 10 (with wind turbines) and UT 20 (reference area) with number of staging Longtailed Ducks and Eider before and after erection of the wind turbines. Shallow areas (less than 6 metres) are marked in grey. Grey circles show the location of wind turbines and coloured circles show flocks of birds measured for position. All observations were made in the afternoon.

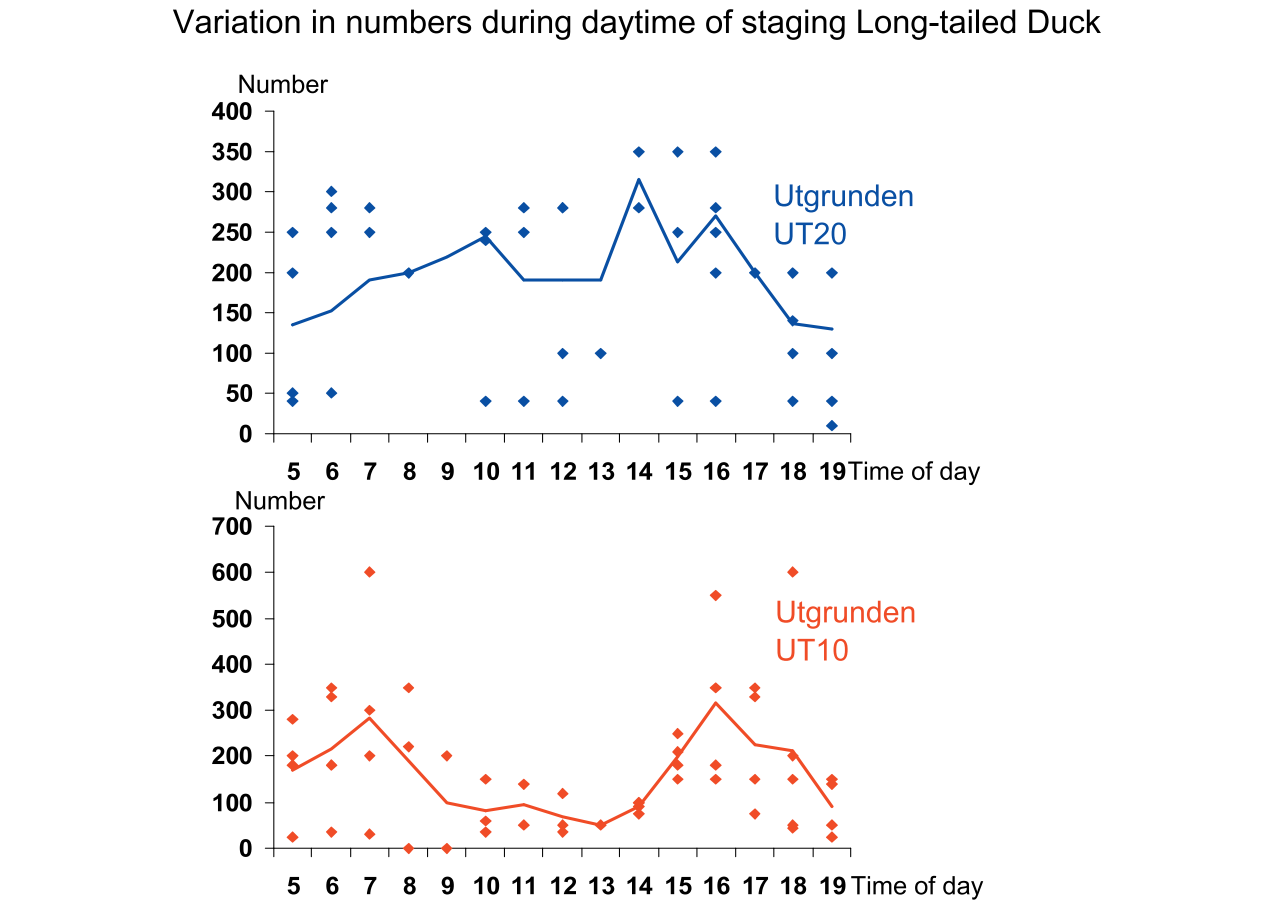


Figure 57 Numbers of staging Longtailed Ducks in the two Utgrunden areas UT 10 and UT 20 in the period 27/3–8/4 2003 (13 days) when the number of staging waterfowl were counted on 53 occasions at different times of the day.

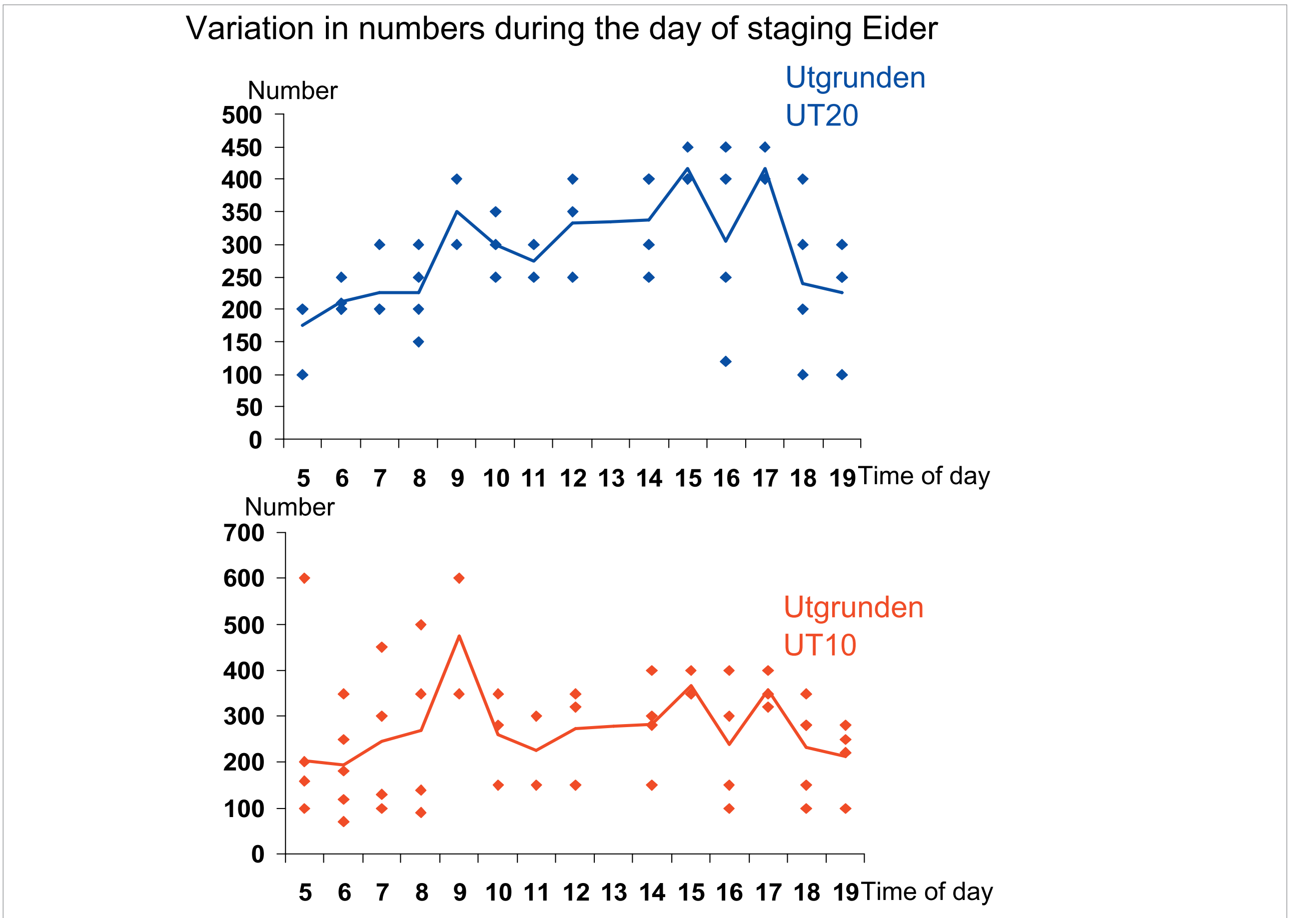


Figure 58 Number of staging Eider in the two Utgrunden areas UT 10 and UT 20 in the period 27/3–8/4 2003 (13 days) when the waterfowl were counted on 53 occasions at different times of the day.

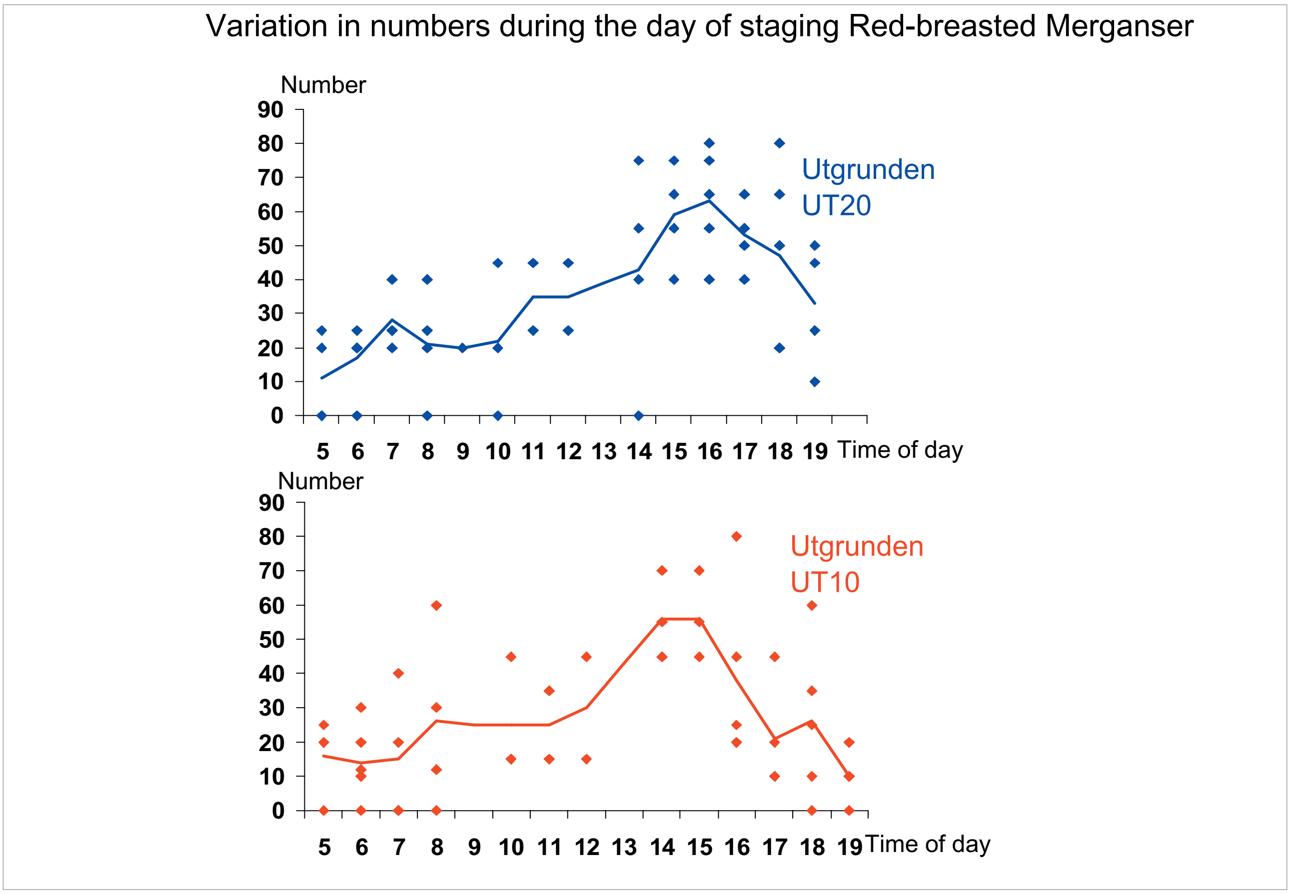


Figure 59 Number of staging Redbreasted Merganser in the two Utgrunden areas UT 10 and UT 20 in the period 27/3–8/4 2003 (13 days) when the number of staging waterfowl were counted on 53 occasions at different times of the day.

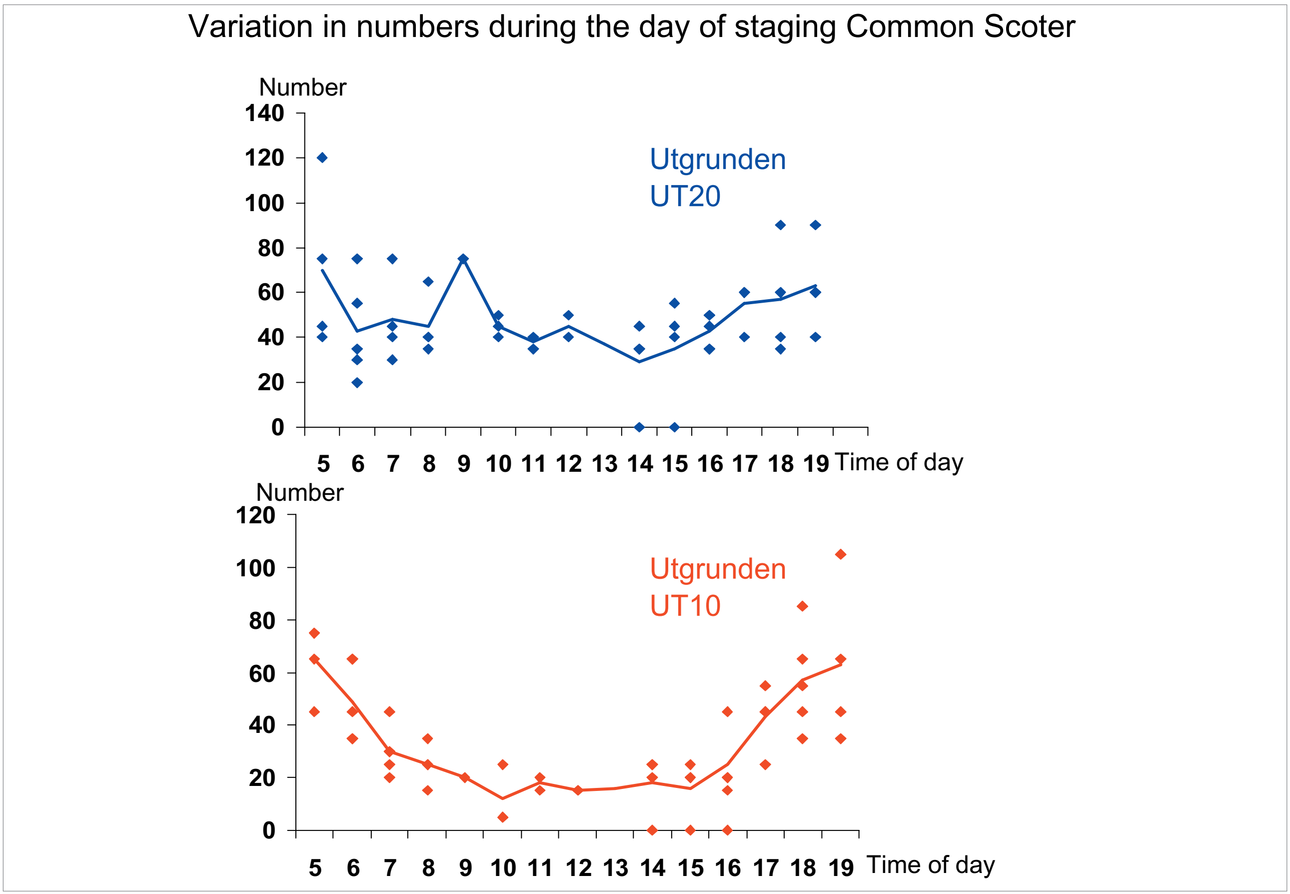


Figure 60 Number of staging Common Scoter in the two Utgrunden areas UT 10 and UT 20 in the period 27/3–8/4 2003 (13 days) when the number of staging waterfowl were counted on 53 occasions at different times of the day.

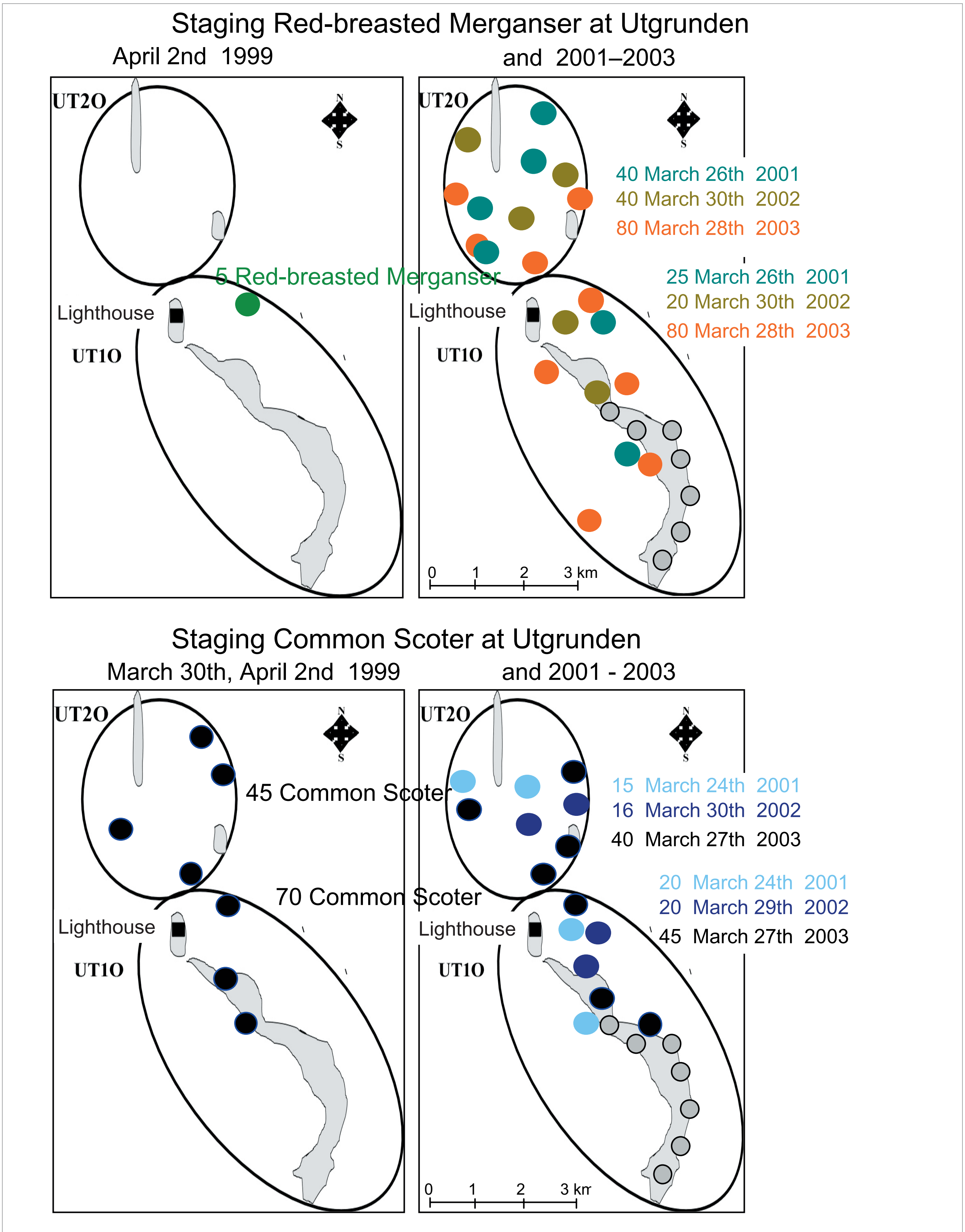


Figure 61 The survey areas for staging waterfowl at Utgrunden, UT 10 (with wind turbines) and UT 20 (reference area) with numbers of Longtailed Ducks and Common Scoters before and after erection of the wind turbines. Shallow areas (less than 6 metres) are marked in grey. Grey circles show the location of wind turbines and coloured circles show flocks of birds measured for position. Both the Redbreasted Merganser and the Common Scoter show a more divided picture of choice of sites and do not concentrate in the shallow areas in the same way as Longtailed Ducks and Eider.

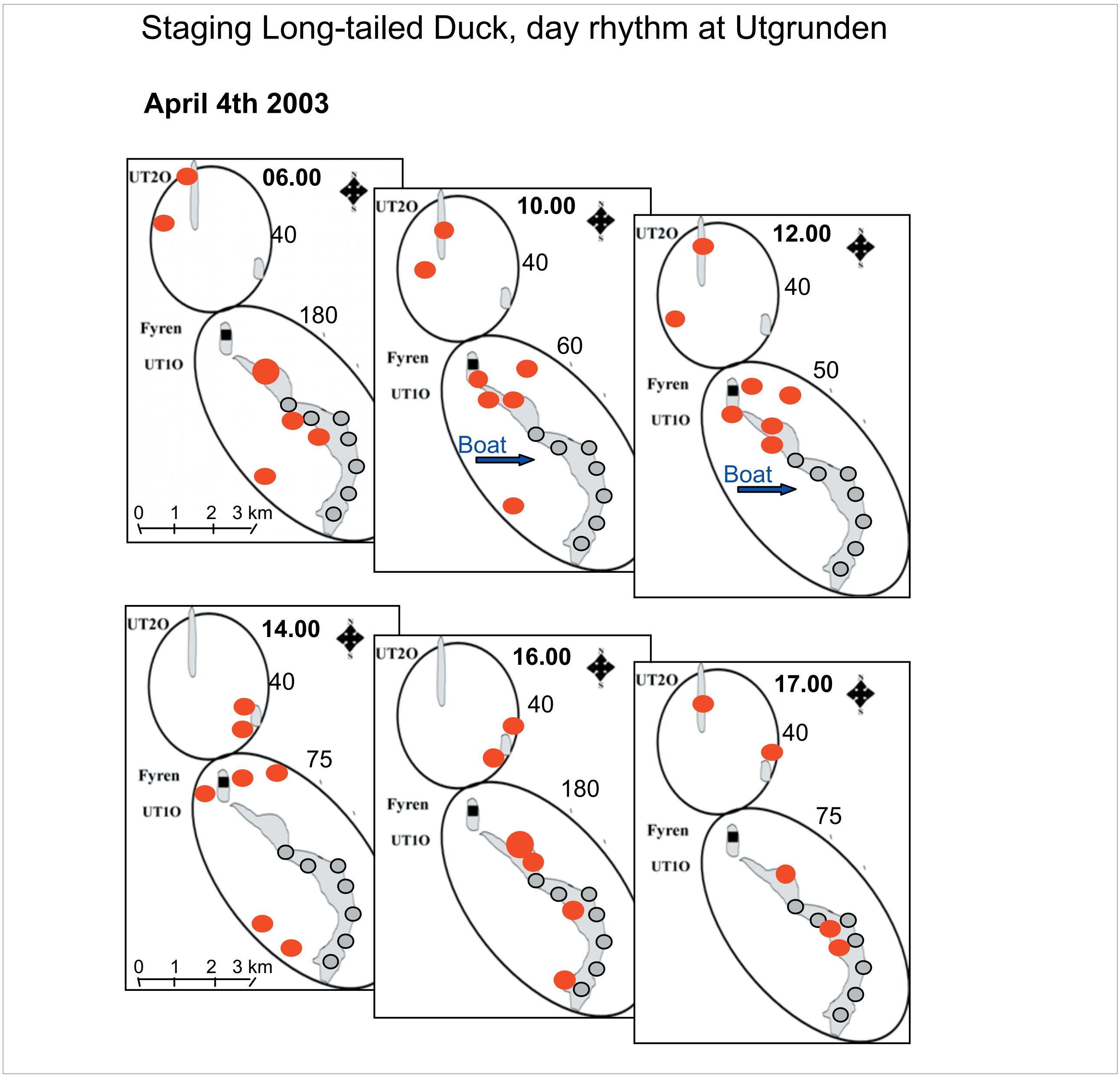


Figure 62 Flocks of Longtailed Duck (10–130 birds) and their positions (marked in red) at different times on one day when the service boat for the wind turbines was in the area. The large circles show flocks of more than 100 birds. The blue arrow shows the visits of the service boat in the wind farm area. The weather on this day was slightly cloudy with a NNW wind at 4–8 m/s during the afternoon.

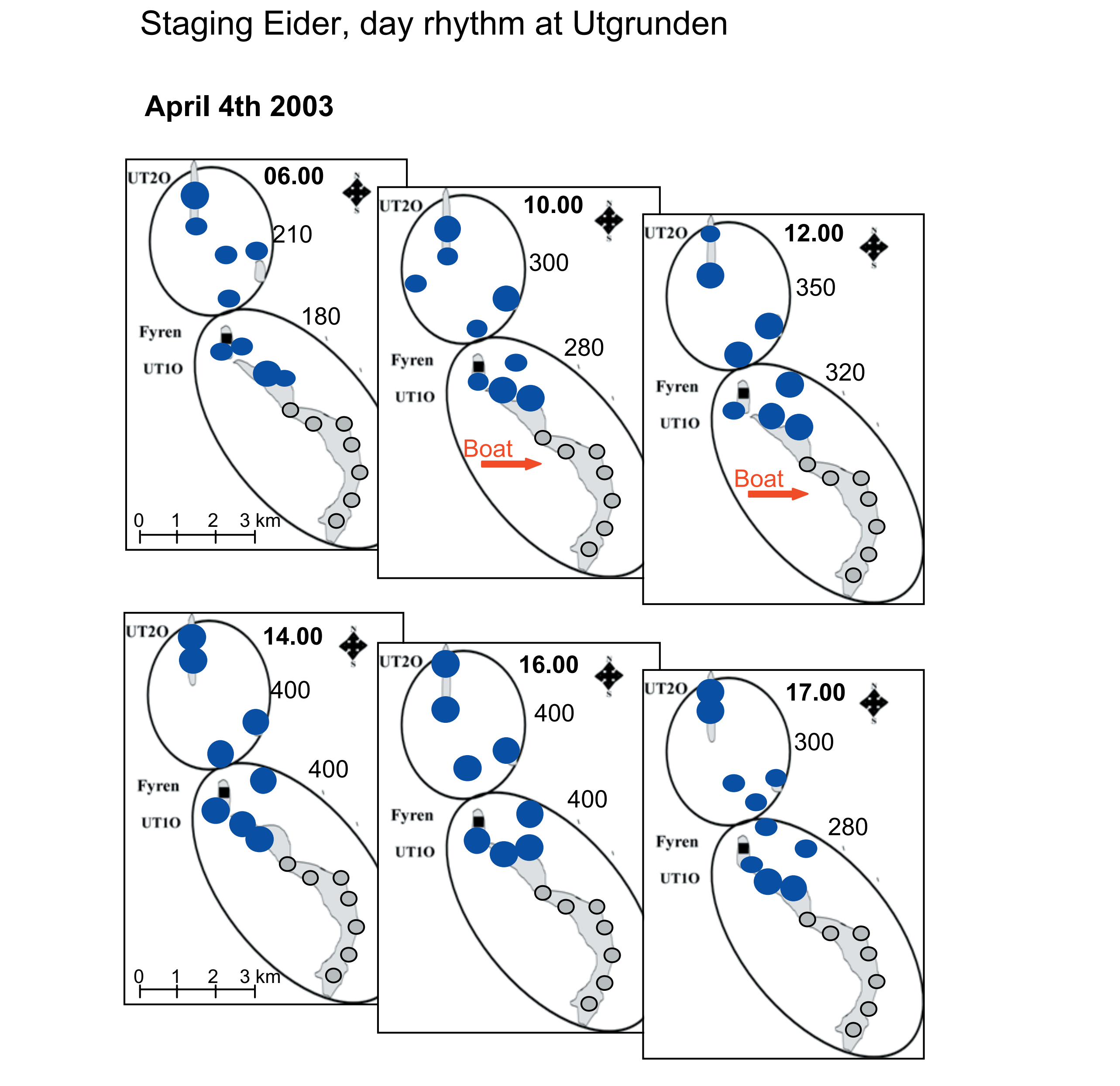


Figure 63 Flocks of Eider (20–140 birds) and their positions (marked in blue) at different times on one day when the service boat for the wind turbines was in the area. The large circles show flocks of more than 100 birds. The red arrow shows the visits of the service boat in the wind farm area. The weather on this day was slightly cloudy with a N–NW wind at 4–8 m/s.

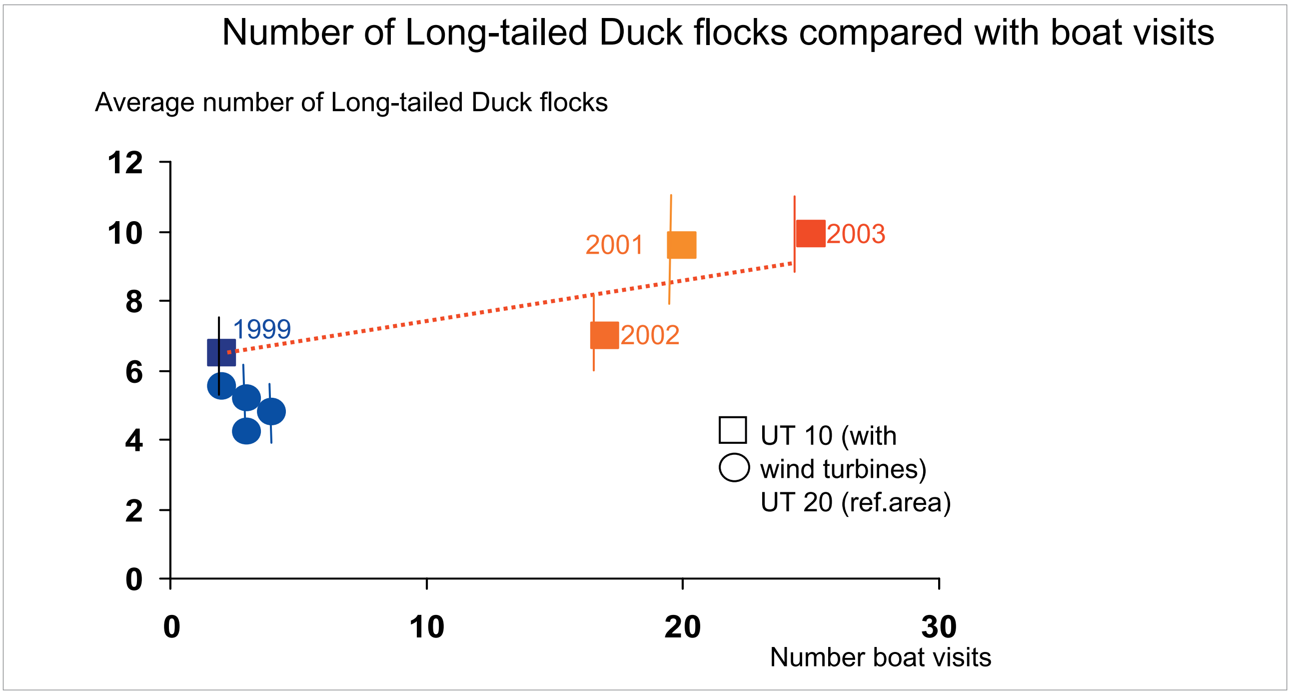


Figure 64 Number of Long-tailed Ducks on average per spring compared with the number of visits of a boat in the two areas UT 10 and UT 20 at Utgrunden. The observations were carried out over 21 days in total. The dotted line is a support line which was marked but without stated values.

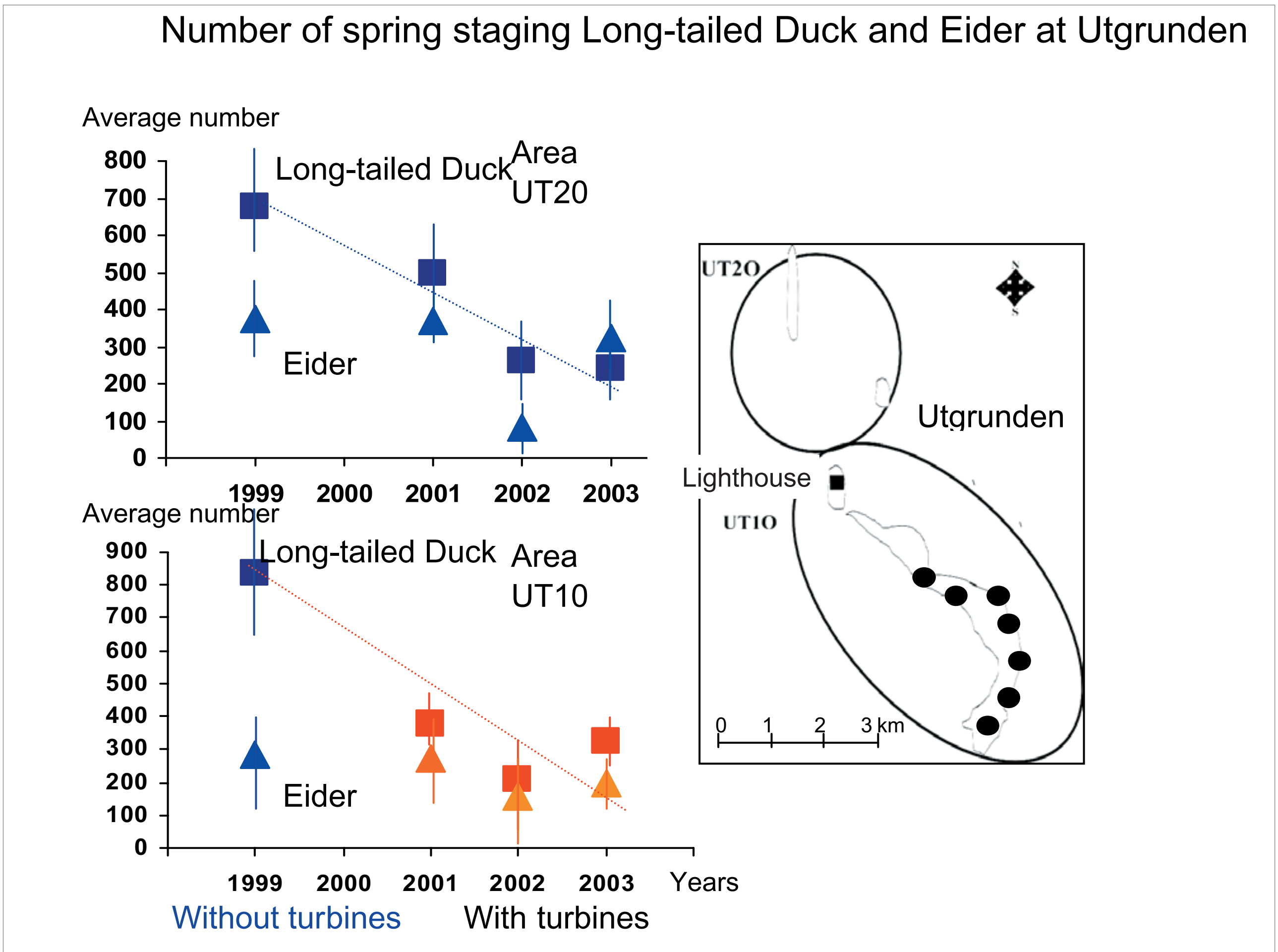


Figure 65 The number of staging Long-tailed Duck and Eider in the Utgrunden areas UT 10 (with wind turbines) and UT 20 (reference area); two to eight surveys per spring were carried out, all from the Utgrunden lighthouse. The dotted line is a support line which has been marked but without stated values.

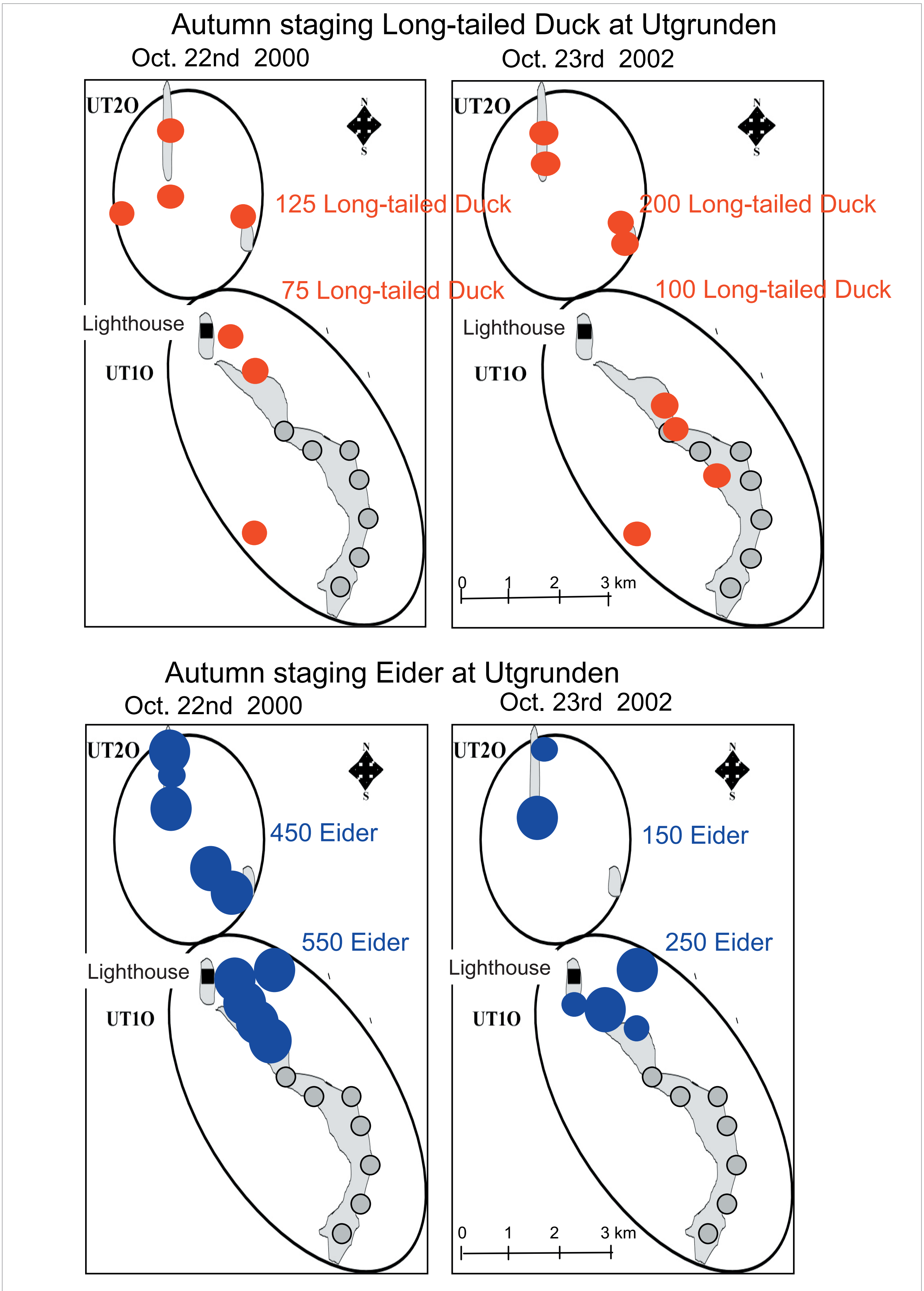


Figure 66 The survey areas at Utgrunden, UT 10 (with wind turbines) and UT 20 (reference area) in the autumn showing staging Longtailed Ducks and Eider. Shallow areas (less than 6 metres) are marked in grey. Grey circles show the location of wind turbines and coloured circles show flocks of birds measured for position. Two days were selected to show the distribution of certain species in the area, and the numbers of Longtailed Duck in the wind farm area.

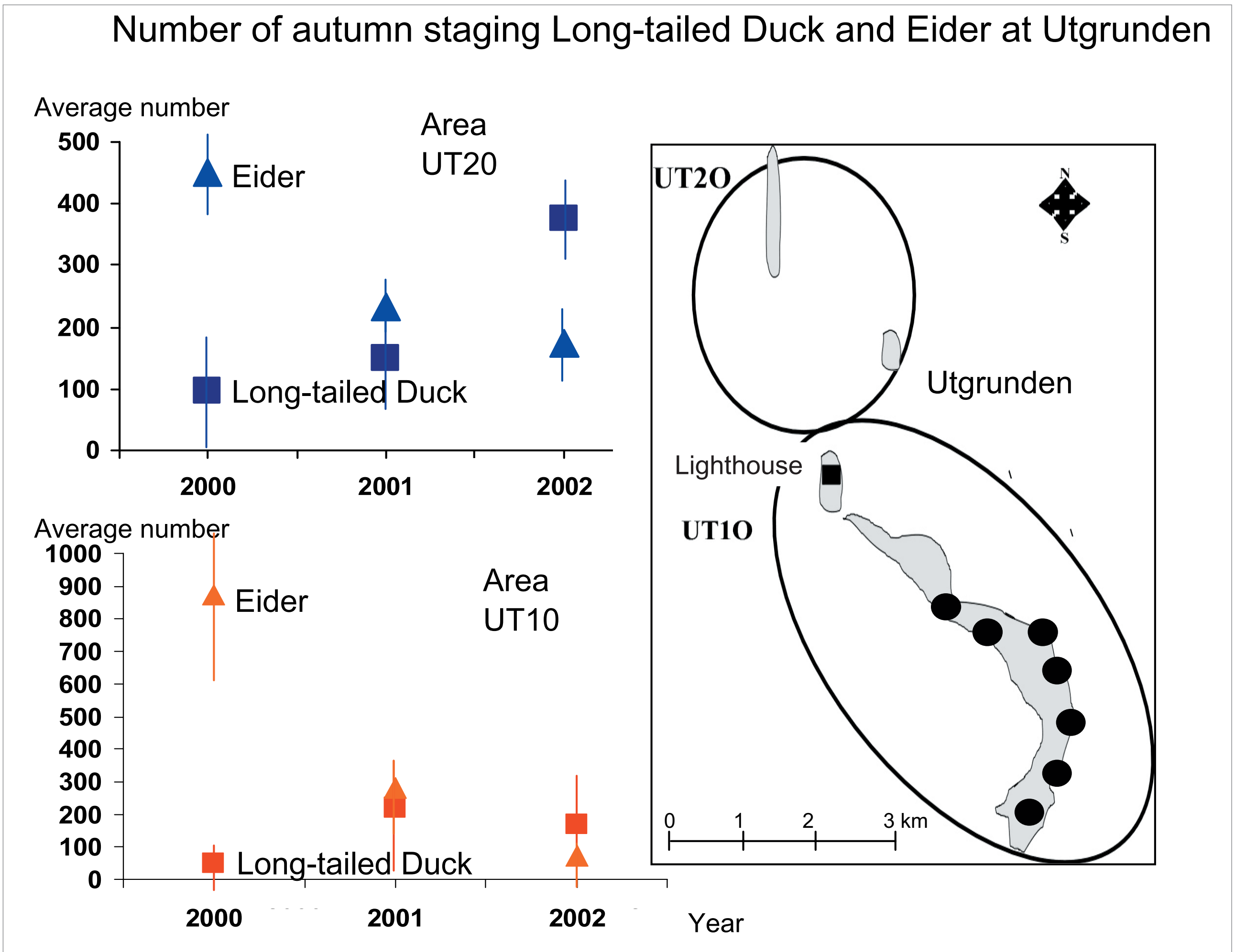


Figure 67 Number of staging Longtailed Ducks and Eider on average per autumn. No autumn observations exist from the time before the wind turbines were erected in the area UT 10.

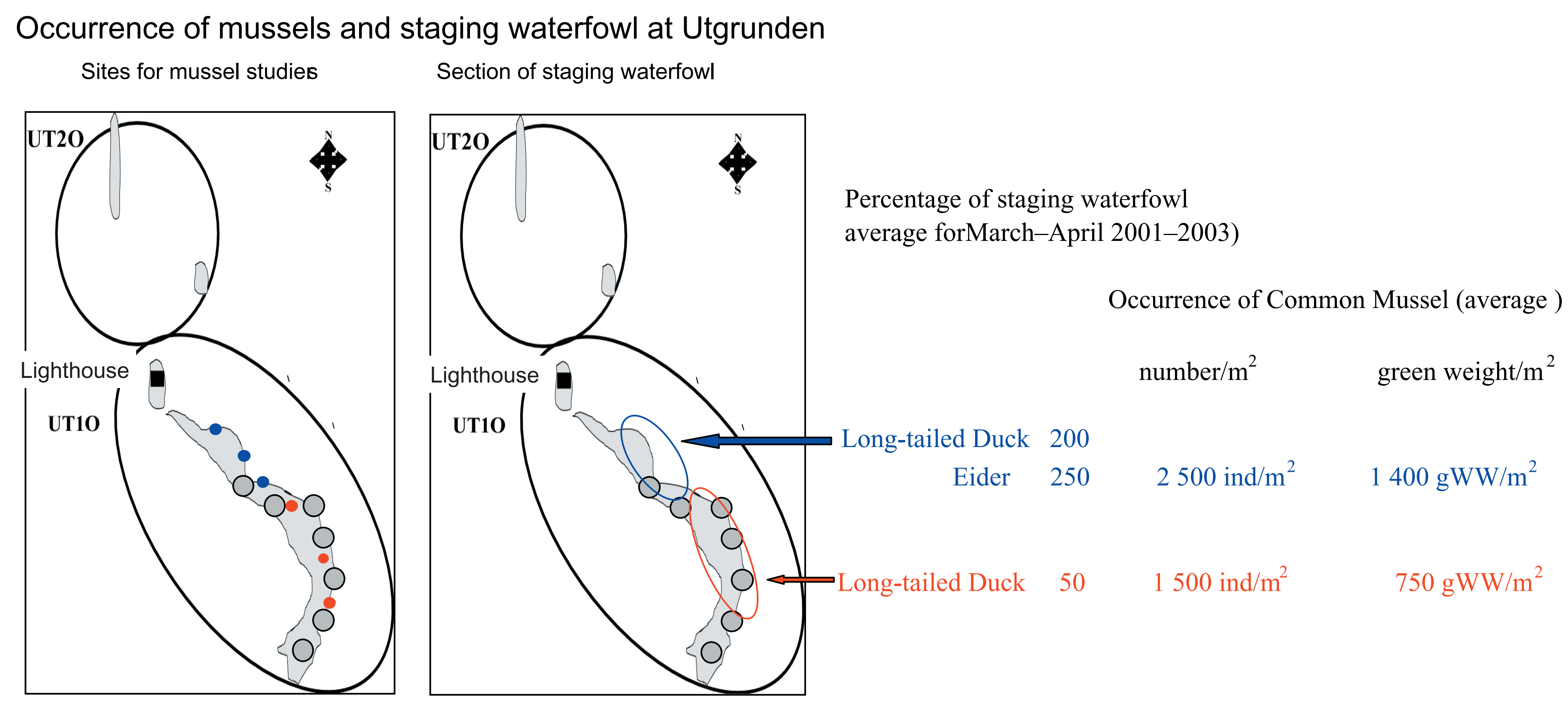


Figure 68 Studies of the occurrence of mussels (Mytilus edulis) at six sites at Utgrunden in two sections with large and small numbers of staging waterfowl. The study of mussels was planned on the basis of results from the ornithological study. Report from Högskolan in Kalmar (Tobiasson et al 2004).

5 Discussion and conclusions

5.1 Scope of the study

The overall aim of this study was to determine the impact, if any, of the offshore wind farms at Utgrunden and Yttre Stengrund in southern Kalmar Sound on bird life.

One main aim was to observe how migrant birds of different species react on encountering wind turbines and to evaluate the collision risk that might exist in different wind, weather and light conditions.

Another aim was to determine to what extent the wind turbines may affect the behaviour of staging and wintering birds in potential resting and foraging grounds in the vicinity of the wind farm areas.

In order to produce as extensive data as possible to answer the above questions, observations were concentrated to the three-week migration period each spring and autumn when migration intensity is highest in Kalmar Sound. The studies include a total of about 850 000 spring migrant waterfowl and about 670000 waterfowl in the autumn. Eider is the predominant species in waterfowl migration through Kalmar Sound and has a relatively concentrated migration period in both the spring and autumn. This is also reflected in the study data, of which 95 per cent in spring and 56 per cent in autumn refer to Eider.

5.2 How do the wind turbines affect the migration corridor of Eider in the Sound?

The study carried out in spring 1999 from Utgrunden lighthouse is the only source of reference that exists on the distribution of waterfowl migration in southern Kalmar Sound before construction of the wind farms. Even if this study was limited in scope, it showed that the Eider migration corridor in this part of the Sound before construction was located in the middle of the Sound and that most migration took place in tailwinds and in westerly winds.

After construction of the seven wind turbines at Utgrunden, the spring migration corridor shifted further to the east. This was perhaps to be expected as migration usually takes place in winds that cause the least expenditure of energy for the flocks. In order to avoid the wind turbines the flocks follow the prevailing winds for a while longer and thus pass to the east of the wind turbines, instead of changing direction and flying to the west of the turbines which might entail a flight path through the area which would require up more energy. Both observations and radar studies clearly showed this change in the Eider migration corridor. This displacement of a large proportion of Eider nearer to Öland after the construction is probably most obvious during the daytime in good visibility. During the spring periods of 2002 and 2003, after the turbines had been erected at Yttre Stengrund, another distinct eastwards shift of the flight paths occurred. The main path of Eider was already two kilometres east of the Utgrunden wind farm before they reached the turbines and the main flight path on passage was again about two kilometres east of the turbines. It seems that in good visibility the flocks make allowance for this obstacle a long time in advance and bypass it without directly extending the flight path. During the two most recent spring seasons hardly any of the Eider migration occurred inside the wind turbines at Yttre Stengrund, which occurred to some extent before the wind turbines were erected there. This again confirms the overall displacement of Eider to the Öland side of the Sound. This displacement is probably not a result of wind influence on flight paths as the most intense Eider migration along the Öland side occurs in all types of winds. Easterly winds seem to be the only factor that may cause slight displacement of the flight paths towards the western side of the Sound, but even in these winds the main corridors are along the Öland side.

A spring with prevailing easterly winds would mean that the birds would be forced to fly in other wind conditions than those normally prevailing in the spring. It is highly probable that the distribution and migration paths would be different than in the most commonly occurring tailwinds and westerly winds. The migration paths would then probably be distributed as for easterly winds in section 4.2.1 and in Table 13, namely 40 per cent west and 60 per cent east of the Utgrunden wind farm, This might mean that wind turbines were more in the path of the Eiders than in more usual wind conditions, but most probably it still would not change their evasive behaviour in the immediate vicinity of the turbines.

Normally in this area the spring brings low pressure zones from the west which cause southerly or westerly winds, which the Eider appear to take advantage of during their migration. Spring seasons with predominantly easterly winds are rare and even under such conditions there would probably be shorter or longer periods of westerly and southerly winds. Eider flying over land in the spring were well documented in 1972 (Alerstam et al 1974, 1974b) from southern Kalmar Sound, particularly when Eider crossing southern Sweden during the night came to southern Kalmar Sound in the morning on a level with Yttre Stengrund. In such a scenario, the wind turbines at Yttre Stengrund may affect the migration paths differently from those described above for normal migration in tail and west winds. Such a pattern occurred on several mornings in spring 2001, when the flocks came to southern Kalmar Sound after flying overland and reached the section between Yttre Stengrund and Bergkvara. Most of the 16 flocks reported as coming from land continued flying further out into the Sound than the projected wind turbine area at Yttre Stengrund (three kilometres out in the Sound) before they veered off to the north.

Unfortunately, as mentioned above, there were no preliminary studies before the Utgrunden wind farm was constructed. Eider migrated in the five-kilometre wide zone along the west side of the Sound in all three autumn periods. This was the case in autumn 2000 too, before the wind farm was constructed at Yttre Stengrund. Thus, construction of the wind farms could hardly have had a general impact on migrating waterfowl in southern Kalmar Sound in the autumn. The Eider appear to choose the western zone for their flight path in all wind conditions, but in westerly winds the flight path is displaced a little and more flocks choose to fly out into the Sound in zone B. Fewer Eider flocks fly out into the Sound in autumn as less than 5 per cent of overall migration occurs there. This means that the Utgrunden wind farm should have a minimal impact on the autumn flight path.

At Yttre Stengrund, where an autumn study was carried out before the construction of the farm, the Eider migration corridor was wholly located to the 5-kilometre-wide zone A both before and after construction. The Eider here appear to choose to pass both inside and outside the wind turbines. In tailwinds, when migration is at its most intensive, it appears that the majority pass outside the turbines whilst the flight paths in easterly, westerly and headwinds pass to a greater extent inside the turbines. The decision to fly around or past these wind turbines appears to occur at least one kilometre before the turbines. Those flocks that choose to fly outside the turbines in tailwinds have a longer flight path unless they make their choice of path long before they reach the turbines. According to the radar trackings, it would appear that the majority of flocks choose to fly outside the turbines in good visibility. In neither of the two autumn periods after construction of the turbines at Yttre Stengrund did Eider migration in the 1.5-kilometre-wide partial zone 1 (nearest land) show a density even approaching that before the turbines were erected. As far as can be judged, the wind turbines at Yttre Stengrund have moved the Eider autumn migration corridor a little further out in the Sound.

5.3 How do the wind turbines affect the choice of migrating corridor of other waterfowl in the Sound?

Many of the other groups of waterfowl appeared to generally follow the coasts during spring migration. Species that are more sea oriented such as divers, Auks, Long-tailed Ducks, Common Scoters, and Velvet Scoters seem to more often shift their flight paths further out in the Sound. As with Eiders and other waterfowl, this group seems to avoid zone C at Utgrunden since the wind turbines were erected there. Locally at Yttre Stengrund it would appear that after the wind farm construction both geese and Cormorants generally flew nearer to the mainland (inside the turbines). Those species that showed a choice of flight path further out in the Sound, divers and others, appeared to fly mainly outside the wind turbines at Yttre Stengrund during both the spring seasons studied.

The autumn migration includes many different species of waterfowl and most of them show a choice of path with a similar distribution to that of the Eiders: the predominant corridors in terms of frequency are along the mainland side. During the autumn, on the other hand, other waterfowl species showed a larger concentration along the coast of the Sound than out in the Sound itself. This means that the group of other waterfowl species also migrate to a certain extent along the Öland side, which Eider do not. A larger proportion of those species that are more sea oriented occur in zone B, a little further out in the Sound than other species. Very few birds pass in zone C where the Utgrunden wind turbines are situated, and neither do many sea oriented species such as divers, Auk, Grebe, Common Scoter, Velvet Scoter and Long-tailed Duck. In easterly winds and tailwinds, all waterfowl species occur to a small extent in zone C. At Yttre Stengrund it appears that no waterfowl species except Eider showed much migration activity in the wind farm zone itself either before or after the construction. Geese, however, fly in this zone after erection of the wind turbines.

5.4 How do waterfowl flocks fly in the immediate vicinity of the wind turbines?

Instrument measurements at Utgrunden wind farm show quite clearly that Eider flocks approaching the wind turbines (approximately 300 metres) or flying between the turbines (approximately 200 metres from the nearest wind turbine) ascend to a flight altitude of about 60 metres, which is on a level with the turbine bosses. Before the flocks come near the turbines they usually have an altitude of 10–15 metres and then climb to the height they maintain when they pass the turbines. This seems to be the case for about 1 per cent of all passing waterfowl flocks. Very few (0.3 per cent of all the passing flocks) of the tracked Eider flocks spent extra energy hesitating and flying one or several circles before they passed the turbines. Most of them pass without seeming to take any notice of the turbines, while 30 per cent of the total number of waterfowl at Utgrunden in the spring change their flight path in some way or fly in a curve around the turbines. In good visibility most of the flocks make their choice of path at a distance of more than one kilometre before the turbines. The data from this type of local tracking showed that there were very few flocks (only 7 of 603 studied) that flew in the immediate vicinity of the turbines, i.e. 100 metres or less. Flying at such a close distance to the turbines could entail a collision risk. Naturally such direct observations were only possible during daytime in good visibility.

During autumn observations at Utgrunden a number of Crane flocks were observed flying high above the turbines. A total of 7 flocks were measured at heights of 150 to 250 metres. Other Crane flocks were observed altitudes as high as 300 - 400 metres when they flew over the Sound. Flocks of other waterfowl observed approaching the turbines at Utgrunden in the autumn tended to veer off at a distance of at least 500 metres. In good visibility the majority of flocks decided which side to pass the turbines about 1000 metres before reaching them. This means that the turbines did not greatly affect their flight path, either in the distance of the flight or the flying time. At Yttre Stengrund flocks also chose their flight path around the turbines at about the same distance, about one kilometre in advance. Only a few (3 per cent) of all the flocks of Eider and other waterfowl that passed were affected by the necessity of having to climb on approaching the wind turbines at Yttre Stengrund. There were even fewer in the autumn periods that hesitated and flew above or between the wind turbines at Yttre Stengrund (in total 0.05 per cent of the passing flocks). Most of those that were influenced by the turbines (14 per cent of the total number of waterfowl in the autumn at Yttre Stengrund) made a small correction or just flew in a curve around the turbines.

5.5 How is the nocturnal migration of waterfowl in the Sound affected?

Eider migration was investigated in spring 1972 and it was assessed that the night migration in Skåne, Blekinge and southern Kalmar Sound accounted for as much as 20 per cent of the total number of migrating birds (Alerstam, et al 1974, 1974b). In the preliminary study in spring 1999 (Pettersson & Lindell 1999) a wind-based study showed that night migration accounted for about 20% of passing Eider. In this study, where radar tracking data from three spring migration periods were analysed, the overall picture shows that 22 per cent of flocks in the area pass during the night. This calculation was based on the assumptions that radar records as well (or as badly) at night as by day and that waterfowl flocks fly as low at night and that there is no difference in the size of the flocks at night and in the daytime. There is no definite information regarding these assumptions, except that the Eider flocks flying over Skåne during the night are at least as large as those that fly along the coast in daytime flight (Karlsson 1976). As long as there are no more details about nocturnally migrating waterfowl with regard to altitude and flock sizes, the assumption that these parameters are the same during the day and night must be considered valid. In this study radar analysis of the spring periods was carried out in 65 quarters during the night when it was also assessed that it was foggy in the Sound. It was not possible to observe any migration activity on the radar film in such conditions.

During the autumn, the number of waterfowl flocks that were recorded by radar at night was 27 per cent of the total number of flocks recorded by radar in periods with 24-hour coverage. It should be noted here that the average size of a flock is larger in the autumn, with 76 Eider/flock compared with 40 Eider/flock in the spring, which means that radar records more flocks in the autumn than in the spring. As many as 25 per cent of all the autumn migrating waterfowl flocks were recorded by radar, which should be compared with only 1 per cent of waterfowl flocks recorded in the spring using the same technique.

It was possible to make radar trackings of waterfowl flocks on misty nights in the autumn, with decreased visibility. It was night-time and misty for 5 per cent of the number of quarters in which radar analysis was carried out, and 5 per cent of the 24-hour periods with radar coverage. No significant difference could be deduced from these trackings as to whether bird flocks at night and in mist fly in a different way from those that fly at night without mist. It was clear that the flight path at night is generally located further out in the Sound than by day. At Utgrunden wind farm during the spring, some flocks flew in the direction of the wind turbines at night, but they veered off in the same way as flocks that flew by day in good visibility. These observations would suggest that nocturnal migrant flocks really perceive the turbines to similar extent than those that migrate by day.

At Yttre Stengrund the main migration corridor was to the east of the wind turbines both in spring and autumn, which appears to have been the situation before the wind turbines were constructed. Thus, there is nothing in the data to indicate that nocturnal migrant waterfowl flocks tended to fly nearer the wind turbines and therefore run a greater risk of collision. On the contrary, autumn flocks at Yttre Stengrund seemed to choose a migration path further out from land and therefore well outside the turbines.

5.6 How is the waterfowl migration in the Sound affected in fog and mist in daytime?

In the spring periods in daytime foggy and misty conditions, about 5 per cent of all the waterfowl flocks recorded during the 24-hour periods were on radar. This percentage is as large as the number of quarters with this type of weather during the spring.

Almost the same conditions were to be found during the autumn, when 5 per cent of migrating flocks were recorded in 9 per cent of the total time when mist or fog was reported. In this case, however, more certain flock trackings provided the basis for acceptable radar recording of migrating flocks. During both autumn and spring there were relatively few waterfowl migrating in fog or mist in "normal" wind and weather conditions. This means that even if the birds were to be exposed to a slightly higher collision risk, this would only affect a small number in practice.

It is possible to consider periods in spring or autumn with more frequent mist or fog in the Sound for longer periods of time. Such a scenario would probably prolong the migration period as the birds would be hesitant. If foggy conditions were to continue, the birds would probably migrate anyhow under these conditions. The distribution of flight paths would no doubt be wider, which might mean that more flocks would head towards the turbines.

5.7 What impact do the wind turbines have on the length of the flight path?

In order to measure and calculate the extra distance which an evasive flight round the wind turbines might entail, longer radar trackings (approximately 3–4 km) were made for a number of flocks. The average flight distance of the plotted flight paths was calculated compared to a straight path through the wind farm area without any evasive manoeuvre. For 16 per cent of the flocks that passed Utgrunden, the flight path in daytime in good visibility increased by 1.2–2.9 km. Corresponding values for the spring data at Yttre Stengrund are 1.2–1.9 km, which is only valid for 9 per cent of the total number of flocks. For Eider, which migrate from the overwintering areas in Danish waters to the Stockholm archipelago (a rather normal migration distance for those Eider that pass southern Kalmar Sound) the ordinary flight path on average would be about 800 kilometres. The extension of migration path round these wind farms would then be 0.2–0.4 per cent of the total flight path. Few flocks pass the immediate vicinity of both Yttre Stengrund and Utgrunden, causing two detours on the migration flight path. Reckoned as flight time past the wind farm areas in southern Kalmar Sound, this extension would entail 2–4 minutes longer flight time. Very few flocks hesitate or turn back at the wind turbines and the increased altitude for a small number of flocks is not so great as to significantly increase the flight time. Of the 15 or so hours that it takes for the whole migration (average flight speed is around 50–70 km/h, Karlsson 1976, Kahlert et al 2002) the extension of the migration flight time is only about 0.2–0.5 per cent.

It is certain that waterfowl flocks must make corresponding or longer detours on several occasions when they encounter boats, headlands, rain showers or when all the flocks must pass over the bridge (Ölandsbron) further up the Sound. The author, in connection with his own studies at Ölandsbron in the latter half of spring 2003, recorded frequent extensions of the migration path there of one or several kilometres. Using the same optical rangefinder as in the project, 125 flocks were calculated as having an extended flight path of 1.3 km on average. At Ölandsbron many flocks ascend to an altitude of 150 metres before they pass the bridge, which takes time as they turn and climb into the wind. For the 125 flocks measured, the flight time was four minutes longer on average in comparison with the flocks that pass the bridge by increasing their flight altitude by only 60 metres without turning round and hesitating before passage. This would suggest that Ölandsbron is a greater hindrance and requires a larger extra expenditure of energy for migrating Eider flocks than the two wind farm groups in southern Kalmar Sound. This, however, accounts for only a small percentage of the birds' total energy expenditure or flight time required for the whole migration.

Migration in mist or fog is relatively limited to around 5–6 per cent of the total number of passing birds. Fog or mist was also present for 5–9 per cent of the observation time. In poor visibility, such as in fog or mist in daytime and at night, the radar trackings show that waterfowl flocks which approach the wind turbines at Utgrunden wind farm appear to pass the turbines in a slightly narrower curve than those that make a similar manoeuvre in good visibility. This curve in fog corresponds to a prolonged flight path of up to about two kilometres. This curve proves, as stated above, that the birds are able to detect the wind turbines in poorer visibility too.

The few waterfowl flocks that approach Utgrunden wind farm in the autumn and have to make an evasive manoeuvre show very similar behaviour to the flocks during the spring. It is almost always at Yttre Stengrund that several flocks come in towards the wind turbines in the autumn - about 14 per cent of the total number of observed flocks at Yttre Stengrund in good visibility.

Local flock trackings showed how some flocks detour in a curve around the wind turbines and have a slightly longer flight path as a result. This extension of the flight distance and flight time is the same as during the spring, which is less than 0.4 per cent of the flight distance and time of the total Eider migration.

5.8 What is the collision risk factor for migrant waterfowl?

The risk of a collision between a bird flock and a wind turbine may certainly be greater than the single collision that was recorded during the whole study period, see section 4.7. It is reasonable to suppose that during the years of the study, incidents happened unobserved. To obtain the best and most plausible calculation of the collision risk for migrant birds and turbines, it should be possible to use the data produced in this study. Data on the total number of migrant flocks, flight paths for both large and small flocks, flight altitudes of the flocks and the proportion of the flocks that fly in the immediate vicinity of the wind turbines can be used to calculate a risk factor. This risk factor can give us an idea of the magnitude of the risk, even if its calculation requires a number of uncertain assumptions.

5.8.1 Collision risk during spring migration

If a bird flock passes the wind turbines at 100 metres or less this implies a certain collision risk, confirmed by the recorded collision at Yttre Stengrund where several birds in the flock were hit by the rotor blade.

During spring 2002, 100 flocks were recorded as flying near (500 metres or less) to Utgrunden wind farm and four of these flocks (4 per cent) flew as near as 100 metres (Figure 23). In spring 2003, 156 flocks flew relatively near

Number of waterfowl flocks estimated at risk of collision

Species or groups of species and percentage of the migration	Visibility and radar recorded percentage of the migration	Total counted number/season	Estimated number	Number passing Utgrunden (spring) and Yttre Stengrund (aut.)	Average flock size 28 (spring) and 41 (autumn)	Percentage flocks within 0-100 m from wind turbine	Number flocks within 0 -100 m from wind turbine	Number flocks within rotor radius (0-35 m), 35% of 0-100 m	6% (spring) respectively 10% (autumn) with collision risk. Cf fig. 59
	Visibility type perc.%	number	number	number	flocks	%	flocks	flocks	flocks
Spring migration									
Eider 95 %	Good visibility	350 000							
	day 73%		370 000	370 000	13 210	0,2 - 0,8	26-106	9-37	**1-2**
Other Water-	Good visib.day	20 000							
fowl 5%	Fog & mist 5 %		26 000	26 000	930	0,4 - 1,6	4-15	1-5	**0,1-0,5**
	Night 22 %		110 000	110 000	3 930	0,4 - 1,6	16-63	6-22	**0-1**
Total migration during spring			506 000	506 000	14 060		36-143	12-50	**1-4**
Autumn migration									
Eider 56 %	Good visib.day	300 000							
	68%		550 000	495 000*	12 070	1,4	169	59	**6**
Other Water-	Good visib.day	250 000							
fowl 44%	Fog.& mist 5%		36000	36 000	880	3	26	9	**1**
	Night 27%		220 000	110 000**	2 680	3	80	26	**3**
Total migration during autumn			810 000	641 000	15 630		275	94	**10**
	Visibility type perc. %	number	number	number	flocks	%	flocks	flocks	flocks

* = 90 % of the total autumn migration in the Sound take place in zone A at Yttre Stengrund.
**= 50 % of the total night migration in the autumn in the Sound take place in zone A at Yttre Stengrund

Table 34 The observed number of migrant waterfowl in spring and autumn and the estimated total for the whole study period – where the 24hour figures were compiled by means of the radar studies. The sections of the flocks that fly within 100 metres of the wind turbines are used to estimate the collision risk. From this number of flocks, the risk of any flock flying into one of the wind turbines is then estimated. These estimates assume that all flocks flying at a distance of 100 metres to the wind turbines fly straight ahead without deviating around the wind turbines. The estimates are also based on the distribution of the flight altitude of the flocks during the spring and autumn migration (see Figure 69).

the turbines and three of these flocks (1.9 per cent) flew at a distance of 100 metres from the nearest turbine (Figure 23). These figures, together with the number of observed waterfowl, formed a basis for the following calculation of collision risk (Table 34). Amongst the waterfowl flocks that were seen flying over the turbines in 2002 there were 13 that flew lower than 100 metres from the rotor blade's highest point, and in 2003 there were 12 flocks (Figure 22). During the time that these detailed studies were made, 12 flocks in spring 2002 and 28 flocks in spring 2003, there was no time to record them with an instrument but they were observed flying as near as roughly 200 metres from the turbines. Thus the figure cited for the number of flocks in the following calculation of collision risk is uncertain; in 2002 there were 4 flocks level with the turbines and 13 above them, making 17 flocks, and with further 12 uncertain flocks takes the total to 29 flocks as the highest figure. In 2003 there were 3 flocks that flew level with and 12 above the turbines. Adding a further 28 uncertain flocks brings the potential total to 43 flocks.

During the eight study days in spring 2002, between 17 and 29 flocks out of 3784 flocks in total observed (or 0.5–0.8 per cent of the flocks) passed the Utgrunden area within 100 m of the turbines. Corresponding figures for the 15 study days in spring 2003 were 15–43 flocks, or 0.2–0.6 per cent of the observed 6870 waterfowl flocks (see section 4.3.5).

We know from annual observations carried out voluntarily in the Sound that about 350 000 Eider and roughly 20 000 other waterfowl migrate each spring through Kalmar Sound. Of the total migration volume, 5 per cent is made up of waterfowl other than Eider. During spring the waterfowl flocks consist on average of 28 birds, which brings the total number of flocks during the spring migration to 13 210. It has been shown above that this is within the variation 0.2–0.8 per cent of the flocks, which implies 26–106 flocks per spring that flew so close that they ran the risk of colliding with the turbines. The rotor radius of the turbine is 35 metres, so that this is the distance from the turbine tower within which there is a direct collision risk. This means that 35 per cent of the total number of flocks that fly within 100 metres of the turbines risk ending up in this collision area, which amounts to 9–37 flocks (Figure 69). This assumption is based on the flocks not deviating or veering off, and we know that most of them do. But not all flocks make such a detour and the calculation is made on the assumption that no flocks deviate from the straight flight path. However, it can be logically calculated, according to the diagram of the immediate vicinity of the wind turbines (Figure 69), that 94 per cent of the flocks during the spring in this immediate vicinity will manage without colliding, provided that they do not deviate from their straight course. This is valid since they fly under or beside operational area of the three-winged rotors (Figure 69) which implies that 1–2 flocks risk a collision if they do not detect the danger and veer off.

In order to calculate a similar risk factor for flocks flying in fog or mist by day and which come so near that they must veer off, a similar argument has been made, and it has been shown in section 4.3.2 that 5 per cent of the total migration occurs in fog or mist. The observations showed that during the spring a total of approximately 370 000 waterfowl migrate through the Sound in the daytime in good visibility. As 22 per cent of the migration was calculated as occurring at night, which should give 110 000 waterfowl, and 5 per cent of the migration occurs in fog or mist by day, which should give 26 000 waterfowl, the total number of migrating waterfowl should be 506 000. The established flock size in the daytime during the spring migration periods studied was on average 28 waterfowl/flock, which means that 930 flocks per spring migrated through the Sound in the daytime in fog or mist.

The number of waterfowl flocks in daytime in fog or mist that deviate on approaching the turbines is larger than that in daytime in good visibility. This has been shown through radar trackings.

Thus the risk of flocks coming within 100 metres of the turbines should also be greater, and to avoid underestimating numbers, twice that number in mist or fog was counted in comparison to diurnal migration in good visibility. This presumes that about 0.4–1.6 per cent of flocks would fly into the risk zone, which translates to 4–15 flocks. If the previous line of argument is pursued, that only those that fly as near as 35 metres from the turbines (Figure 69) can be killed and that there is only a 6 per cent collision risk if they fly through the vicinity (Figure 69), then this adds up to 0.1–0.5 flocks that would collide with turbines under these conditions each season.

If the same calculation is applied to the whole spring migration then the calculated 110 000 waterfowl that migrate at night should be in 3930 flocks. The number of flocks which, according to the radar, fly so close at night that they make a curve around the turbines is twice as many as the number of flocks which do the same in daytime in good visibility. According to the same method of calculation applied to migration in fog and mist, 0.4–1.6 per cent of the nocturnally migrating flocks would then be at risk flying at a distance of 100 metres or less from the turbines, or 16–63 waterfowl flocks. Then if the previous argument is pursued that only those that fly as near as 35 metres from the tower can be hit and that there is a 6 per cent risk of collision when flying through the immediate vicinity of the turbines (Figure 69), that makes 0–1 flocks in the spring that run the risk of colliding with the wind turbines at night.

There are very few waterfowl flocks during the spring that deviate from or are affected by the wind turbines at Yttre Stengrund as the birds mainly appear to choose another flight path and do not fly in the vicinity of the wind turbines. This means that the values for collision risks calculated for spring at Utgrunden ought to be valid as the total risk factor for all wind farms in Kalmar Sound at present. Spring migrating waterfowl have hardly any contact with Yttre Stengrund. In summary, it was established that 1–4 flocks per spring run the risk of colliding with any of the wind turbines in the Sound.

If the bird collision observed at Yttre Stengrund on 29 September 2003 is considered representative of how a collision could occur in autumn or spring, then it can be said

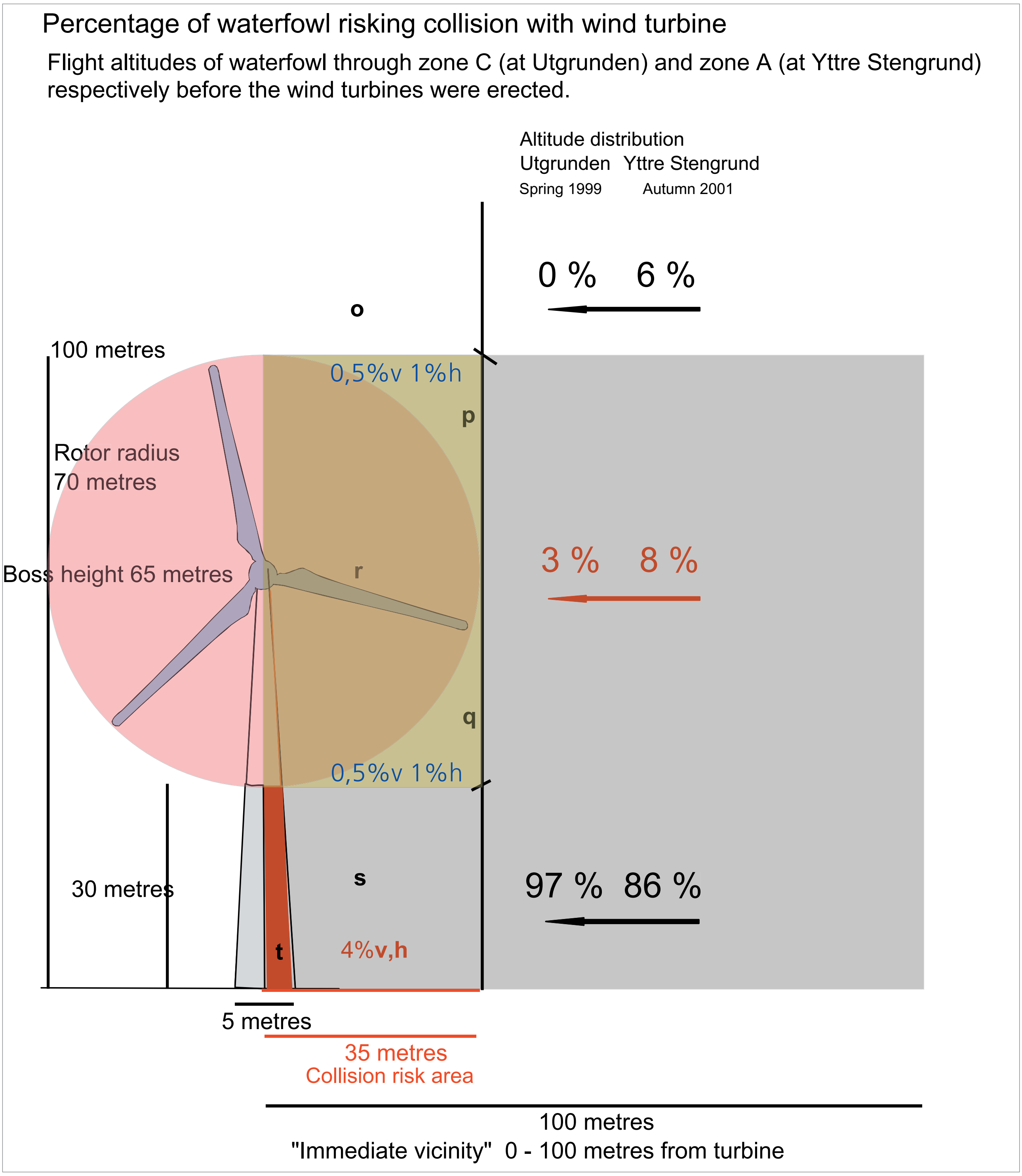


Figure 69 A direct risk of collision might exist for some of the flocks flying in the immediate vicinity (0–100 metres) of the wind turbines. Flocks flying 0–35 metres from the tower (called the collision risk area) are exposed to a greater risk of collision. The majority of these flocks (97% and 86%) fly under the lowest level of the rotor blade in this sector and a minority fly over the sweep area of the rotor blades. Furthermore, flocks which fly through the corner sectors of the sweep area are not within reach of the rotors. Of the flocks which pass through the sector 0–35 metres from the tower (the whole height interval) the percentage which risk collision can be estimated as described below:
For spring migration (at Utgrunden): **3%** through the rotor section pqr and **4%** towards the tower through the lower tower section t minus **-2x0.5v=1%** through pq of the rotor section, which gives **6%** of the number through the sector 0–35 metres (compare table 34).
For spring migration (at Yttre Stengrund): **8%** through the rotor section pqr and **4%** towards the tower through the lower tower section t minus **-2x1h=2%** through pq of the rotor section, which gives **10%** of the number through the sector 0–35 metres.
This calculation of collision risk is theoretically based on all flocks which fly directly towards the wind turbine section without making any evasive manoeuvre, which in reality does not occur.

that one bird per collision dies and about three are injured. The wind turbines would risk killing at most 1–4 waterfowl per spring and injure a further 3–12 birds. As no fatal collision has been observed in spring it is most probable that the number of birds in the spring migration which run the risk of being killed in a collision with one of the wind turbines in Kalmar Sound is between zero and four.

5.8.2 Collision risk in autumn

In the autumn seasons of 2002 and 2003, 683 waterfowl flocks were observed flying near Yttre Stengrund wind farm (closer than 500 metres) and six flocks flew as near as 100 metres or closer (Figure 51). Among the waterfowl flocks observed flying over the turbines in the autumn seasons of 2002 and 2003, there was a total of 11 flocks that flew lower than 100 metres from the rotor's highest point. In the time period that these flocks were being observed in detail and measured, 4 plus 6 flocks passed the immediate vicinity of the wind turbines, but there was no time to record these flocks in detail (see section 4.6). The risk calculation above, together with the observed number of waterfowl, forms the basis of the collision risk calculation below (Table 34). During the 11 study days in autumn 2002 a total of 1122 flocks were observed passing the Yttre Stengrund area and 822 flocks passed in the 7 study days in autumn 2003. The number of flocks in these two autumn periods seen flying as near the wind turbines as 100 metres was 27 (6+10+11), if the uncertain observations above are included. These make up 1.4 per cent of the total 1944 observed flocks. As mentioned earlier in the report, autumn migration in daytime and good visibility in Kalmar Sound comprises 250 000 birds from the group of other waterfowl, which makes up 44 per cent of the total number of passing birds. Add to this the 300 000 Eider and the total migration volume is 550 000 birds in daytime. Of these, 90 per cent fly past Yttre Stengrund wind farm which means that about 495 000 waterfowl pass there and as it was established that the average flock in the autumn days studied had on average 41 birds, this translates to an autumn migration of 12 070 flocks. As reported above, it was calculated that 1.4 per cent or 169 flocks each autumn fly so close to the wind turbines that they risk colliding with them. The rotor radius is 35 metres, which means that collisions can only occur inside this circle swept by rotor blades and the tower itself. Mathematically, only 35 per cent of the flocks that fly within 100 metres of the towers risk a collision, or 59 flocks. It is logical to calculate that 90 per cent do not collide if they fly straight through the immediate vicinity of the wind turbines (Figure 69). This means that 6 flocks risk a collision.

It was reported earlier that 5 per cent of the birds migrate in fog or mist in daytime.

The total number of waterfowl during the autumn, based on observations made in daytime in good visibility, is calculated at around 780 000, which means that 39 000 birds may be estimated as migrating in fog or mist in daytime.

During the daytime flocks average 41 birds and if it is assumed that the flock size is the same at night then 880 flocks migrate each autumn in fog or mist. According to radar trackings of the few flocks that migrate in mist or fog compared with diurnal migrants in good visibility, almost twice as many of them make an evasive manoeuvre near the wind turbines. Thus the risk of these migrants of coming within 100 metres of the turbines should also be twice as great. According to this assumption, 2 times 1.4 per cent, or about 3 per cent of the flocks fly through the risk zone (100 metres) which means about 26 flocks. About 35 per cent of these, or 9 flocks, fly through the immediate vicinity of the turbines and it is presumed that 90 per cent of these manage to avoid a collision, so that one flock each autumn migration runs the risk of a collision.

Using the same method of calculation for night migration, 5360 nocturnally migrating flocks were observed in the autumn, but as the radar trackings show that only 50 per cent of the night migration is through the Sound in zone A (containing Yttre Stengrund wind farm) it can be assumed that only 2680 flocks fly through this zone. As the radar trackings show that the part of the flock at night that flies so close to the turbines that they make an evasive manoeuvre is twice as large as that in daytime in good visibility. The same calculation as above regarding migration in fog or mist, shows that 3 per cent of nocturnally migrating flocks risk flying in the immediate vicinity of 100 metres or less from the turbines, which means 80 flocks in this zone. With the same estimation and assumption as above 35 per cent, or 26 flocks, fly through the immediate vicinity of the turbines. Considering that 90 per cent of these flocks have a good chance flying through without collisions (Figure 69), the result is that 5 flocks run a risk of collision.

How many birds collide and are killed or injured in autumn migration? If we assume from the collision observed in autumn 2003 (see section 4.7), the only collision seen during the whole of this three-year study, that this is typical of the extent and course of a possible collision, then one bird per collision dies and another three are injured. Taking into account the above collision calculations for autumn migration, there is a collision risk for 6 flocks in daytime in good visibility, for one flock in mist or fog and for 3 flocks at night. This means that 10 flocks each autumn season fly in such a way at Yttre Stengrund that they risk colliding with the turbines. These collisions would kill about 10 waterfowl and injure a further 30.

5.8.3 Summary of collision risk

The most recent information on migrant birds and the collision risk with offshore wind turbines is available today in a summary of literature in report no. 5139 by the Swedish Environmental Protection Agency (Naturvårdsverket 2001). A summary of the most up-to-date information on birds and wind farms in general, as well as the risk of collision, is available in literature from Holland (Lensink et al 1999) and from USA (Erickson et al 2002). The most recent information before this report on migrant birds and offshore wind farms in Sweden is limited to research at the one wind turbine at Nogersund (Karlsson 1983, 1987 and 1988). The prediction from results gained at this single wind turbine was that waterfowl would fly around it, confirmed by subsequent Danish studies at Tunø Knob wind farm (Tulp et al 1999) and at several other offshore wind farms. The preliminary research carried out at the large Danish farms (70–80 wind farms) such as Horns Rev (Noer et al 2000) and Nysteds wind farm at Rødsand (Kahlert et al 2000 and 2002) are also excellent studies for discovering the state of current and past information when this research was started. The first results of research into these two large parks of offshore wind farms in Denmark have now been published (Kahlert et al 2004 and Christensen et al 2004). Waterfowl show evasive migration paths at these large parks, in the same way as the results from Kalmar Sound.

A theoretical calculation was presented of the number of waterfowl that might be killed at the offshore wind farms. This calculation was cited a number of times before construction of the large wind parks in Denmark, and it states the collision risk as one waterfowl per wind turbine and month of bird migration (SEAS 2000). For other groups of birds, such as small migrant birds, knowledge of the collision risk with wind turbines at sea is still extremely limited.

The collision risk between migrant waterfowl and existing wind turbines in southern Kalmar Sound in spring and autumn calculated above is based on several assumptions, which in turn are based mainly on observations and facts produced by this research. The calculated risk factors must be seen as valuable and give a plausible estimate of the collision risk. During the whole of this study period only one collision was observed, but approximately 1–4 flocks in spring migration and about 10 flocks in autumn migration were reported as flying so close to the wind turbines that they ran the risk of colliding with them.

The risk factor that was calculated plus some basic facts can show that the true collision risk for waterfowl is of the same magnitude or less, compared with the risk factor that was theoretically calculated in conjunction with planning the large offshore wind parks in Denmark (SEAS 2000).

The risk figure that was calculated in this study is based on the assumption that flocks that fly as near as 100 metres from the turbines fly straight ahead without swerving. Observations, however, show that nearly all flocks make an evasive manoeuvre of one kind or another, so the risk of collision should be less than that calculated. On the other hand, it is not probable that the number of collisions was as low as the single collision observed in a period of three spring and three autumn seasons. In summary, it can be stated that collisions between migrant birds and the two groups of wind turbines in southern Kalmar Sound may occur, but that the number of collisions are at worst 4 in the spring season and perhaps 10 in the autumn. At a rough estimate, there would be about half the number of collisions as those in the Danish calculations. A rapid change in the weather causing a worse situation is, of course, not an impossible scenario.

In order to see this collision factor in relation to other factors and events that affect the number of deaths of waterfowl during migration, a comparison may be made with shooting statistics. These show that in the whole of Sweden about 3500 Eider are shot annually in the shooting season from 1/9 to 31/1. Shooting statistics forecast the same number for 2002 and 2003 (Kindberg 2003). The number of waterfowl killed by other factors such as oil spillages is difficult to calculate with any degree of certainty, but it is likely that such factors cause far more bird deaths in southern Kalmar Sound than the wind turbines with a figure of about 11–14 per year.

5.9 What impact do the wind turbines have on staging and wintering waterfowl?

From the winter surveys of waterfowl carried out in 1969–2003 (Nilsson 2003) it is shown that southern Kalmar Sound provides shelter to a varying number of wintering birds and that about 5000–6000 waterfowl annually are to be found solely on the coasts.

The survey made in this study concentrated more on the spring and autumn periods, but these too show a great number of variations. In spring 1998 about 11 000 staging waterfowl were recorded in the Utgrunden area (Pettersson & Lindell 1998). Later recordings have not indicated such a high figure and in recent spring seasons an average of 1000–2000 waterfowl have been observed in the areas around Utgrunden. At Yttre Stengrund the number of staging waterfowl is even less, as in the two neighbouring areas, and between 500 - 1300 waterfowl have been recorded annually. The number of staging birds at or next to the wind farm area at Yttre Stengrund was very limited, both before and after construction of the turbines, and included at most about ten birds.

Within the framework of this study the investigation became gradually focused on detailed studies of waterfowl movements and behaviour. These studies show clear differences in how various species use separate sections of the area. Detailed studies of the number of waterfowl in spring 2003 show how the Long-tailed Duck (and perhaps also the Common Scoter) that stage in the wind farm area leave the area when the service boat comes, but seem to return in the evening when it is absent. The Long-tailed Ducks that stage in the reference area north of the lighthouse where there is little boat traffic do not show the same daily rhythm,

Eider are not affected by the appearance of the boat and they stay within the wind farm area, probably because they stage in the section north of the wind turbines and the service boat moves much less in this area. This proves that boat disturbance is limited to the immediate vicinity of the boat's movements. During recent spring periods the number of Long-tailed Duck flocks has increased in the wind farm area, but not in the reference area. This situation may also have arisen as a result of boat disturbance as the Long-tailed Ducks usually divided into smaller flocks when moving to and from the site in the wind farm area. The number of

Long-tailed Ducks has definitely decreased in comparison with the time before wind farms, both in the wind farm area and in the reference area north of it. It is difficult to draw any hard and fast conclusions. The claim that the reference area is negatively affected and fewer Long-tailed Ducks dare to stay there because of the wind turbines about 3 kilometres to the south cannot be rejected altogether and makes conclusions rather uncertain. It should be noted too that the annual fluctuations in the number of birds are very great, which has been confirmed on other occasions in this area. It is quite clear that Long-tailed Duck rest and forage within the wind farm areas, at least in the mornings and evenings when there is no boat traffic in the area, which proves that they do not avoid staying near the wind farm. Although the birds are disturbed by the boats it would seem that the food (mussels) is so attractive that they choose to tolerate them in their own way. It should perhaps be noted here that studies were made in conjunction with a wind farm where the wind turbines were placed in a simple bow formation. This meant that the birds could fly to their foraging sites next to the existing wind turbines from both directions, without having to pass a number of other turbines. Long-tailed Duck were occasionally seen flying between the turbines in their flights between separate foraging sites without any visible hesitation. The possibility that avoidance effects might arise in a larger wind farm remains and can be studied when a suitable area comes about.

5.9.1 The importance of mussels for the choice of staging site

The pilot studies that were carried out showed quite clearly that it is the supply of food, in this case primarily the common sea mussel, that determines at which sites in shallow areas waterfowl choose to stay. The study also shows how the supply of food can vary from place to place within a shallow area like Utgrunden, and that the birds are very skilled in finding and exploiting the richest foraging sites.

It may not be possible to deduce directly from the study if the wind turbines had a disturbing effect on staging birds, but definitely that the birds found sites with the greatest supply of food. If there was a wind turbine in the immediate vicinity of the foraging site it was not of primary importance and did not hinder the birds' instinct to obtain good energy-rich food.

5.10 How do rare and red-listed species fly near the wind turbines?

In this study there were no observations of incidents by the wind turbines regarding birds of prey, rarities or red-listed bird species. In the immediate vicinity of the wind farm areas both at Utgrunden and at Yttre Stengrund it was mostly Pintail, Velvet Scoter and Scaup in the red-listed species, raptors and rarities that flew near and between the wind turbines. These show similar behaviour and flight patterns to those of more sea-oriented species such as divers, Auks and Common Scoters. All of them show a decreased tendency to fly through the zones where wind turbines were erected. Several of the migrant raptors observed flying in the wind farm area at Yttre Stengrund flew at a high altitude over the turbines, but the majority of raptors pass in the section between the turbines and the mainland. These species do not seem to have any direct avoidance behaviour in comparison with the more commonly occurring species. It is worth noting that the study does not cover the whole migration of various gulls and small birds, especially on those occasions when observers have had to concentrate on waterfowl migration at its most intensive. In the early autumn periods some Common and Arctic Tern were recorded at Yttre Stengrund. According to those observations the Tern seemed to pass the wind turbines by flying between them or right next to them without veering off in curves in the way waterfowl do.

5.11 The percentage of migrant waterfowl affected by the offshore wind turbines.

How many waterfowl are affected by offshore wind farms naturally depends on the extent of waterfowl migration in the wind farm area. Another important aspect is how the wind turbines are located, how the group (or the "park") is constructed with regard to the migration paths of waterfowl in the area. The compactness of the group of wind turbines is also of importance with regard to how flocks choose their flight path at the wind turbines, and what alternative flight paths exist. The above cited collision risk (section 5.8) must not be confused with how many waterfowl are affected by the wind turbines, Preliminary research for the construction of the Utgrunden wind farm established that 2–32 per cent of the total waterfowl migration volume might be affected by this group of wind turbines (Pettersson & Lindell 1998). According to the research recently carried out in the spring periods, 30 per cent of waterfowl flocks (about 150 000 birds) are affected by the seven wind turbines erected at Utgrunden. In this calculation of the number of waterfowl affected, all flocks were taken into consideration when observations were made of corrections in the migration path (large or small, but visible), those flocks that flew between the turbines and those few that flew over them. The flocks that migrated at night or in poor visibility were also included in this calculation when they seemed to behave in a similar way (according to radar recordings) to the diurnal migrant birds. However, it must be pointed out that even the flocks that correct their migration path are affected very little. This entails a slightly greater expenditure of energy for the flight. As these flocks would probably not have made this migration path correction if the wind turbines had not existed, the flocks must be considered as affected by the wind turbines even if to a small extent. In the autumn Utgrunden is visited by about 5 per cent of the total number of migration birds, which means that fewer than 50 flocks in the autumn are affected as they consistently fly alongside the wind turbines. In spring at Yttre Stengrund 9 per cent of the flocks (10 000 waterfowl) are affected, while in the autumn it was established that about 15 per cent of the flocks (100 000 waterfowl) are affected as they are obliged to fly alongside or, as some do, fly between or even over the wind turbines.

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The author Jan Pettersson staging
at the Utgrunden lighthouse – his home during weeks of observations.

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8 Appendix

All birds observed in the project are reported in tables, with one table for all the spring periods (A1) and one for all the autumn periods (A2). All bird observations are reported, including any double counts between observers at different sites, and evening observations at Utgrunden. All the recordings of red-listed bird species are reported in a special table (A3), including birds of prey and rarities, and the zone in the Sound where they were observed flying. Birds in the groups above that were seen flying in zone C at Utgrunden wind farm and zone A at Yttre Stengrund wind farm are reported in detail with regard to the local zones where they were flying (Tables A4 and A5).

Total number of observed birds during spring studies

Species		Spring 1999	Spr. 2001	Spr. 2002	Spr. 2003	Spring Total
Red-throated Diver	*Gavia stellata*	167	108	222	74	571
Black-throated Diver	*Gavia arctica*	256	148	176	114	694
Black-/Red-throated Diver	*G. arctica/stellata*	155	762	141		1058
Diver spec.	*Gavia sp.*	2	9	67	98	176
Great Crested Grebe	*Podiceps cristatus*	5	7	3	3	18
Red-necked Grebe	*Podiceps grisegena*	3	2	20	15	40
Slavonian Grebe	*Podiceps auritus*	2	1	5	1	9
Grebe spec.	*Podiceps sp*		1			1
Cormorant	*Phalacrocorax carbo*	807	2736	2337	1783	7663
Heron	*Ardea cinerea*	6	24	32	29	91
Mute Swan	*Cygnus olor*	35	376	163	250	824
Bewick´s Swan	*Cygnus columbianus/bewickii*	324	207	222	378	1131
Whooper Swan	*Cygnus cygnus*	13	93	28	69	203
Swan spec.	*Cygnus sp.*	35	65	8	213	321
Bean Goose	*Anser fabalis*	7	12	67	11	97
Pink-footed Goose	*Anser brachyrhynchus*	4	7			11
White-fronted Goose	*Anser albifrons*		44	1	5	50
Grey Lag Goose	*Anser anser*	128	278	249	106	761
Goose/Anser spec.	*Anser sp*		85		21	106
Canada Goose	*Branta canadensis*	14	171	120	170	475
Barnacle Goose	*Branta leucopsis*	602	1085	1231	616	3534
Brent Goose	*Branta bernicla*	28				28
Goose/Ans./Bran. Spec.	*Anser/Branta*		94			94
Shelduck	*Tordorna tadorna*	18	326	73	130	547
Wigeon	*Anas penelope*	110	458	856	311	1735
Gadwall	*Anas strepera*		3	8	8	19
Teal	*Anas crecca*	5	145	393	26	569
Mallard	*Anas platyrhynchos*	221	378	129	61	789
Pintail	*Anas acuta*	52	125	50	33	260
Garganey	*Anas querquedula*			6		6
Shoveler	*Anas clypeata*	17	11	10	17	55
Pochard	*Aythya ferina*	3	14	2		19
Tufted Duck	*Aythya fuligula*	114	43	87	63	307
Scaup	*Aythya marila*		11	31	4	46
Tufted Duck/Scaup	*A.fuligula/marila*		2			2
Eider	*Somateria mollissima*	120097	263463	201893	234131	819584
King Eider	*Somateria spectabilis*	2	6	6	7	21
Steller´s Eider	*Polysticta stelleri*			4		4
Long-tailed Duck	*Clangula hyemalis*	432	190	24	42	688
Common Scoter	*Melanitta nigra*	234	354	547	786	1921
Velvet Scoter	*Melanitta fusca*	78	73	342	29	522
Goldeneye	*Bucephala clangula*	52	316	50	82	500
Smew	*Mergus albellus*		2		3	5
Red-breasted Merganser	*Mergus serrator*	754	1958	800	805	4317
Goosander	*Mergus merganser*	19	411	295	351	1076
White-tailed Eagle	*Haliaeëtus albicilla*	2	1		1	4
Marsh Harrier	*Circus aerugibosus*				1	1
Sparrow hawk	*Accipiter nisus*	2	1	1		4
Rough-legged Buzzard	*Buteo lagopus*				1	1
Osprey	*Pandion haliaëtus*				1	1
Kestrel	*Falco tinnunculus*	2	1			3
Peregrine	*Falco peregrinus*			1		1
Crane	*Grus grus*	62	152	*223*	*108*	545
Oystercatcher	*Haematopus ostralegus*	*54*	352	*120*	*224*	750
Avocet	*Recurvirostra avosetta*	7	32	31	17	87

Continued

Continued

Species		Spring 1999	Spr. 2001	Spr. 2002	Spr. 2003	Spring Total
Ringed Plover	*Charadrius hiaticula*		81		5	86
Golden Plover	*Pluvialis apricaria*		22	1		23
Lapwing	*Vanellus vanellus*	27	50		6	83
Dunlin	*Calidris alpina*	5	1		13	19
Snipe	*Gallinago gallinago*		7		2	9
Black-tailed Godwit	*Limosa limosa*			1		1
Bar-tailed Godwit	*Limosa lapponica*			1	1	2
Curlew	*Numenius arquata*	27	65	16	16	124
Redshank	*Tringa totanus*	8	8		1	17
Green Sandpiper	*Tringa ochropus*		11			11
Arctic Skua	*Stercorarius parasiticus*	2				2
Little Gull	*Larus minutus*	2				2
Black-headed Gull	*Larus ridibundus*	276	190	538	973	1977
Common Gull	*Larus canus*	76	17	101	15	209
Lesser Black-backed Gull	*Larus fuscus*	9	36	2	5	52
Herring Gull	*Larus argentatus*	56	82	48	23	209
Great Black-backed Gull	*Larus marinus*	17	7			24
Caspian Tern	*Sterna caspia*		1		1	2
Sandwich Tern	*Stena sandvicensis*		3	3	7	13
Arctic Tern	*Sterna paradisaea*	2			1	3
Guillemot	*Uria aalge*			1		1
Razorbill	*Alca torda*	34	47	81	24	186
Raz./Guill. spec.	*Alca/Uria sp*	2		2		4
Black Guillemot	*Cepphus grylle*	31	76	27	45	179
Auk spec.	*Alca sp*		1		1	2
Wood Pigeon	*Columba palumbus*				58	58
Long-eared Owl	*Asio otus*				1	1
Wood Lark	*Lullula arborea*		14			14
Sky Lark	*Alauda arvensis*	456	12			468
Meadow Pipit	*Anthus pratensis*	380				380
White Wagtail	*Motacilla alba*	96				96
Rook	*Corvus frugilegus*		80		6	86
Starling	*Sturnus vulgaris*	240				240
Sum:		126676	275954	211896	242402	856928

Table A1 All observations of the spring studies over the whole project period. The observations were primarily concentrated on waterfowl and to some extent birds of prey. All observations were included in this table including those recorded at the Utgrunden lighthouse in afternoons and evenings. Different gulls were only recorded when time permitted, which was also the case for passerines. Low priority species and groups of species were not fully observed, and thus the figures given for these species are considerably lower than the actual number of birds which flew over the Sound during the project period.

Total number observed birds during autumn studies

Species		Aut.2000	Aut.2001	Aut.2002	A*2002	A*2003	A Total
Red-throated Diver	*Gavia stellata*	37	38	90	12	8	185
Black-throated Diver	*Gavia arctica*	439	106	140	63	39	787
Black/Red-throated Diver	*G. arctica/stellata*		143	144	25	12	324
Great Northern Diver	*Gavia immer*			1			1
Diver spec.	*Gavia sp.*	14	11	6			31
Great Crested Grebe	*Podiceps cristatus*	31	34	8	5	14	92
Red-necked Grebe	*Podiceps grisegena*	11	1	26	4	5	47
Slavonian Grebe	*Podiceps auritus*	3		5			2 10
Cormorant	*Phalacrocorax carbo*	3187	2417	3812	4159	3462	17037
Heron	*Ardea cinerea*	39	21	1	27	28	116
Mute Swan	*Cygnus olor*	66	157	82	115	84	504
Bewick´s Swan	*Cygnus columbianus*	159	721	1124			2004
Whooper Swan	*Cygnus cygnus*	13	32	36			81
Swan spec.	*Cygnus sp.*	7	141	21	6	8	183
Bean Goose	*Anser fabalis*	26	197	9			232
Pink-footed Goose	*Anser brachyrhynchus*	16	3				19
White-fronted Goose	*Anser albifrons*	2577	9736	167		83	12563
Grey Lag Goose	*Anser anser*	510	266	38	314	170	1298
Goose/Anser spec.	*Anser sp*	126		7			133
Canada Goose	*Branta canadensis*	71	4		7	14	96
Barnacle Goose	*Branta leucopsis*	16594	56438	6589	3041	872	83534
Brent Goose	*Branta bernicla*	3153	14520	284	433	2355	20745
Red-breasted Goose	*Branta ruficollis*		1				1
Branta spec.	*Branta sp.*				605	18	623
Goose/Ans./Bran. spec.	*Anser/Branta*		4965	300			5265
Shelduck	*Tordorna tadorna*		1		9	27	37
Wigeon	*Anas penelope*	5602	5373	4784	6693	978	23430
Gadwall	*Anas strepera*		5	11	6	12	34
Teal	*Anas crecca*	546	558	276	324	87	1791
Mallard	*Anas platyrhynchos*	3436	830	423	60	43	4792
Pintail	*Anas acuta*	135	202	394	662	266	1659
Shoveler	*Anas clypeata*	20	27	3	51	32	133
Dabbling Duck spec.	*Anas sp*			1			1
Pochard	*Aythya ferina*	8	17	76	39	12	152
Tufted Duck	*Aythya fuligula*	819	2883	1515	530	121	5868
Scaup	*Aythya marila*	130	81	106	7		324
Tufted Duck/Scaup	*A.fuligula/marila*	155	122	17			294
Eider	*Somateria mollissima*	122962	141912	120306	44117	14233	443530
King Eider	*Somateria spectabilis*	5	1				6
Long-tailed Duck	*Clangula hyemalis*	2497	280	1003			3780
Common Scoter	*Melanitta nigra*	556	1279	435	65	74	2409
Velvet Scoter	*Melanitta fusca*	277	237	448	79	51	1092
Goldeneye	*Bucephala clangula*	1162	604	391	90	381	2628
Smew	*Mergus albellus*		4	15			19
Red-breasted Merganser	*Mergus serrator*	1736	1638	1046	304	247	4971
Goosander	*Mergus merganser*	141	175	99		18	433
Honey Buzzard	*Pernis apivorus*					1	1
White-tailed Eagle	*Haliaeëtus albicilla*	6	5	18		4	33
Marsh Harrier	*Circus aeruginosus*				2		2
Hen Harrier	*Circus cyaneus*	2	2	3			8
Goshawk	*Accipter gentilis*			1			1
Sparrow hawk	*Accipter nisus*	5		20	2	35	62
Buzzard	*Buteo buteo*		1				1
Rough-legged Buzzard	*Buteo lagopus*	1	9	3	1	1	15
Osprey	*Pandion haliaëtus*					1	1

Continued.

Continued

Species		Aut.2000	Aut.2001	Aut.2002	A*2002	A*2003	Aut.Total
Merlin	*Falco columbarius*			3	1	2	6
Hobby	*Falco subbuteo*				2		2
Peregrine	*Falco peregrinus*			3			3
Crane	*Grus grus*	3226	12222	2612	605	1637	20302
Oystercatcher	*Haematopus ostralegus*				71	11	82
Avocet	*Recurvirostra avosetta*					17	17
Ringed Plover	*Charadrius hiaticula*				16	8	24
Golden Plover	*Pluvialis apricaria*	180	270	3	10	5	468
Grey Plover	*Pluvialis squatarola*	4					4
Lapwing	*Vanellus vanellus*	29	30			7	66
Purple Sandpiper	*Calidris maritima*			10			10
Dunlin	*Calidris alpina*	17	24		360	255	656
Ruff / Reeve	*Philomachus pugnax*				5	16	21
Snipe	*Gallinago gallinago*				1		1
Bar-tailed Godwit	*Limosa lapponica*		1		56	22	79
Whimbrel	*Numenius phaeopus*				7		7
Curlew	*Numenius arquata*	5				2	7
Spotted Redshank	*Tringa erythropus*				5		5
Turnstone	*Arenaria interpres*		1				1
Pomarine Skua	*Stercorarius pomarinus*	3					3
Arctic Skua	*Stercorarius parasiticus*	4	9	1			14
Little Gull	*Larus minutus*	14	72	493	1	2	582
Black-headed Gull	*Larus ridibundus*	1257	114	218		187	1776
Common Gull	*Larus canus*	433	77	636		123	1269
Lesser Black-backed Gull	*Larus fuscus*	21	1	2		17	41
Herring Gull	*Larus argentatus*	473	8	645		44	1170
Great Black-backed Gull	*Larus marinus*	15					15
Kittiwake	*Rissa tridactyla*		2	12			14
Caspian Tern	*Sterna caspia*				3		3
Sandwich Tern	*Sterna sandvicensis*				11	11	22
Common Tern	*Sterna hirundo*			2		2	4
Arctic Tern	*Sterna paradisatea*				3	4	7
Common/Arctic Tern	*S. hirundo/paradisatea*				883	137	1020
Little Tern	*Sterna albifrons*				4		4
Guillemot	*Uria aalge*	1	1				2
Razorbill	*Alca torda*	22	52	39			113
Black Guillemot	*Cepphus grylle*		23	6			29
Puffin	*Fratercula arctica*			1			1
Auk spec.	*Alca sp*	3	1				4
Wood Pigeon	*Columba palumbus*		64	170			234
Short-eared Owl	*Asio flammeus*		2	5			7
Sky Lark	*Alauda arvensis*	103		226			329
Meadow Pipit	*Anthus pratensis*	30					30
Rook	*Corvus frugilegus*	126	30	167			323
Crow	*Corvus corone*			42			42
Starling	*Sturnus vulgaris*		600	150			750
Chaffinch/Brambling	Fringilla coelebs/montifringilla		1250				1250
Sum:		173246	261053	149730	63901	26307	674237

Table A2 All observations for autumn studies over the whole project period. The observations were primarily concentrated on waterfowl and to some extent birds of prey. All observations were included in this table including those recorded at the Utgrunden lighthouse in afternoons and evenings. Different gulls were only recorded when time permitted, which was also the case for passerines. Low priority species and groups of species were not fully observed and thus the figures given for these species are considerably lower than the actual number of birds which flew over the Sound during the project period. Ht*2002 refers to early autumn 2002 with observations over 13 days at Yttre Stengrund period 2/9–2/10.Ht*2003 refers to early autumn 2003 with observations over 8 days at Yttre Stengrund period 2/9–7/10.

Total number red-listed species,rarities and raptors

Species		Type	Season	Southern Kalmar Sound in four zones from west to east A	B	C	D	Total
Great Northern Diver	*Gavia immer*	R	Spring					
			Autumn				1	1
Red-necked Grebe	*Podiceps auritus*	VU		3		2	1	6
				4	2	2	2	10
Pink-footed Goose	*Anser brachyrhynchus*	R			11			11
				7			12	19
Red-breasted Goose	*Branta ruficollis*	R						
							1	1
Gadwall	*Anas strepera*	NT		1			18	19
				22			12	34
Pintail	*Anas acuta*	NT		60	22	12	166	260
				1286	320		53	1659
Shoveler	*Anas clypeata*	NT		11	8	6	30	55
				68	1		64	133
Garganey	*Anas querquedula*	VU					6	6
Pochard	*Aythya ferina*	VU		14	2		3	19
				105	7		40	152
Scaup	*Aythya marila*	VU		4			42	46
				208	52	14	50	324
King Eider	*Somateria spectabilis*	R		1	3	1	16	21
				6				6
Steller´s Eider	*Polysticta stelleri*	R				4		4
Velvet Scoter	*Melanitta fusca*	NT		210	132	37	143	522
				409	612	36	35	1092
Smew	*Mergus albellus*	NT		1		3	1	5
				14			5	19
Honey Buzzard	*Pernis apivorus*	VU						
				1				1
White-tailed Eagle	*Haliaeëtus albicilla*	VU		1	2	1		4
				26	5		2	33
Marsh Harrier	*Circus aeruginosus*	Rov			1			1
				2				2
Hen Harrier	*Circus cyaneus*	Rov						
				3	2		3	8
Goshawk	*Accipter gentilis*	Rov						
						1		1
Sparrow hawk	*Accipter nisus*	Rov		1	3			4
				49	10	2	1	62
Buzzard	*Buteo buteo*	Rov						
					1			1
Rough-legged Buzzard	*Buteo lagopus*	NT			1			1
				6	8	1		15
Osprey	*Pandion haliaëtus*	Rov				1		1
				1				1
Kestrel	*Falco tinnunculus*	Rov			2	1		3
Merlin	*Falco columbarius*	Rov						
				4			2	6
Hobby	*Falco subbuteo*	Rov						
				2				2
Peregrine	*Falco peregrinus*	VU				1		1
				1			2	3

Continued

Continued

				Southern Kalmar Sound in four zones from west to east				
Species		**Type**	**Seasons**	**A**	**B**	**C**	**D**	**Total**
Avocet	*Recurvirostra avosetta*	NT	Spring	48	11		28	87
			Autumn	17				17
Black-tailed Godwit	*Limosa limosa*	VU					1	1
Bar-tailed Godwit	*Limosa lapponica*	VU					2	2
				78			1	79
Curlew	*Numenius arquata*	NT		54	19	20	31	124
				7				7
Turnstone	*Arenaria interpres*	NT						
							1	1
Pomarine Skua	*Stercorarius pomarinus*	R						
							3	3
LesserBlack-backed Gull	*Larus fuscus*	EN		3	24	7	18	52
				20	3		18	41
Kittiwake	*Rissa tridactyla*	R						
				1	6	1	6	14
Caspian Tern	*Sterna caspia*	EN		1		1		2
				3				3
Little Tern	*Sterna albifrons*	VU						
				4				4
Black Guillemot	*Cepphus grylle*	VU		3	90	43	43	179
					19	3	7	29
Puffin	*Fratercula arctica*	R						
							1	1
Short-eared Owl	*Asio flammeus*	NT						
				3	1	3		7

Table A3 Number of birds in the groups rarities, birds of prey and redlisted species which were seen migrating through the different zones in southern Kalmar Sound during this study. All observations are shown for autumn and spring separately. The status of the redlisted species is shown with markings "NT" for "near threatened", "VU" for "vulnerable" and "EN" for "endangered" (see Gärdenfors [ed.]) 2000). Rarity is also indicated as "R" and birds of prey as "Rov".
The species in this table observed flying through zones A or C are also shown in table A8 (Utgrunden zone C) and in table A9 (Yttre Stengrund zone A), which shows bird flights in the more detailed local zone division of these two zones.

Red-listed species, rarities and raptors at Utgrunden

					Local zones at Utgrunden from the lighthouse and eastward					
							Wind farm area			
Species		**Typ**	**Sum**	**x**	**1**	**2**	**3**	**4**	**5**	**Tot**
Slavonian Grebe	*Podiceps auritus*	VU	Sprin	e	2					2
			Autur	e	2					2
Pintail	*Anas acuta*	NT	Sprin	F			8	2		10
			Sprin	e	2					2
Shoveler	*Anas clypeata*	NT	Sprin	e	4		2			6
Scaup	*Aythya marila*	VU	Autur	e			14			14
King Eider	*Somateria spectabilis*	R	Sprin	F	1					1
Steller´s Eider	*Polysticta stelleri*	R	Sprin	e	4					4
Velvet Scoter	*Melanitta fusca*	NT	Sprin	F	5	6	11	5	5	32
			Sprin	e	3	2				5
			Autur	e	30	6				36
Smew	*Mergus albellus*	NT	Sprin	F			3			3
White-tailed Eagle	*Haliaeetus albicilla*	VU	Sprin	e			1			1
Goshawk	*Accipter gentilis*	Rov	Autur	e	1					1
Sparrow Hawk	*Accipter nisus*	Rov	Autur	e	1	1				2
Rough-legged Buzzard	*Buteo lagopus*	NT	Autur	e					1	1
Osprey	*Pandion haliaetus*	Rov	Sprin	e	1					1
Kestrel	*Falco tinnunculus*	Rov	Sprin	F						
			Sprin	e		1				1
Peregrine	*Falco peregrinus*	VU	Sprin	e	1					1
Curlew	*Numenius arquata*	NT	Sprin	F		6	3	2		11
			Sprin	e	5	1		2	1	9
Lesser black-backed Gull	*Larus fuscus*	EN	Sprin	F	2		2			4
			Sprin	e	3					3
Kittiwake	*Rissa tridactyla*	R	Autur	e	1					1
Caspian Tern	*Sterna caspia*	EN	Sprin	e	1					1
Black Guillemot	*Cepphus grylle*	VU	Sprin	F	2	6	4			12
			Sprin	e	31					31
			Autur	e	3					3
Short-eared owl	*Asio flammeus*	NT	Autur	e	3					3

Table A4 Number of birds of the groups of rarities, birds of prey and redlisted species which were observed migrating through the five local zones, each of them one kilometre wide, at Utgrunden in this study. The table shows the number of birds that flew through the wind farm zone C and how they were distributed in the local zones 1–5, in which the wind turbines are located in zones 3–5. The figures in red are the number of birds which flew through the area after the wind turbines have been erected, while black figures show migration before the turbines were built.
The status of the redlisted species is shown with markings "NT" for "near threatened", "VU" for "vulnerable" and "EN" for "endangered" (see Gärdenfors [ed.]) 2000). Rarity is also indicated as "R" and birds of prey as "Rov".
"F" shows observation period before the turbines were built and "e" shows observation period after the turbines had been built.

Red-listed species, rarities and raptors at Yttre Stengrund

Species		Type	Season	X	Local zones at Yttre Stengrund from west: 1	2	3 (Wind farm area)	4	Tot
Slavonian Grebe	*Podiceps auritus*	VU	Spring	F		1			1
			Spring	e	2				2
			Autumn	F	1				1
			Autumn	e	1	2			3
Pink-footed Goose	*Anser brachyrhynchus*	R	Autumn	F	7				7
Gadwall	*Anas strepera*	NT	Spring	e	1				1
			Autumn	e	22				22
Pintail	*Anas acuta*	NT	Spring	F	4	49			53
			Spring	e	2				2
			Autumn	F	77	49			126
			Autumn	e	713	307	88	52	1160
Shoveler	*Anas clypeata*	NT	Spring	e	2				2
			Autumn	F	7				7
			Autumn	e	52	9			61
Pochard	*Aythya ferina*	VU	Spring	F	14				14
			Autumn	e	78	27			105
Scaup	*Aythya marila*	VU	Spring	F	4				4
			Autumn	F	56				56
			Autumn	e	64	57	31		152
King Eider	*Somateria spectabilis*	R	Spring	e		1			1
			Autumn	F	4	1			5
			Autumn	e	1				1
Velvet Scoter	*Melanitta fusca*	NT	Spring	F	8	11			19
			Spring	e	23	165			188
			Autumn	F	3	166	55		224
			Autumn	e	16	89	20	60	185
Smew	*Mergus albellus*	NT	Spring	F	1				1
			Autumn	e	14				14
Honey Buzzard	*Pernis apivorus*	VU	Autumn	e			1		1
White-tailed Eagle	*Haliaeetus albicilla*	VU	Autumn	F	5		1		6
			Autumn	e	17	3			20
Marsh Harrier	*Circus aeruginosus*	Rov	Autumn	e	2				2
Hen Harrier	*Circus cyaneus*	Rov	Autumn	e	3				3
Sparrow Hawk	*Accipter nisus*	Rov	Spring	F		1			1
			Autumn	F	3				3
			Autumn	e	37	9			46
Rough-legged Buzzard	*Buteo lagopus*	NT	Autumn	F	1				1
			Autumn	e	4		1		5
Osprey	*Pandion haliaetus*	Rov	Autumn	e		1			1
Merlin	*Falco columbarius*	Rov	Autumn	e	4				4
Hobby	*Falco subbuteo*	Rov	Autumn	e	2				2
Peregrine	*Falco peregrinus*	VU	Autumn	e	1				1
Avocet	*Recurvirostra avosetta*	NT	Spring	F	26				26
			Spring	e	14	8			22
			Autumn	e	17				17
Bar-tailed Godwit	*Limosa lapponica*	VU	Autumn	e	55	23			78
Curlew	*Numenius arquata*	NT	Spring	F	31	9			40
			Spring	e	3	7			10
			Autumn	F	5				5
			Autumn	e	2				2

Continued

Continued

Species		Type	Season	X	1	2	3 (Wind farm area)	4	Tot
					Local zones at Yttre Stengrund from west				
Lesser black-backed Gull	*Larus fuscus*	EN	Autumn	F	3				3
			Autumn	e		15		2	17
Kittiwake	*Rissa tridactyla*	R	Autumn	e	1				1
Caspian Tern	*Sterna caspia*	EN	Spring	F	1				1
			Autumn	e	2	1			3
Little Tern	*Sterna albifrons*	VU	Autumn	e		4			4
Black Guillemot	*Cepphus grylle*	VU	Spring	F	1				1
Short-eared Owl	*Asio flammeus*	NT	Autumn	e	2	1			3

Table A5 Number of birds in the groups rarity, birds of prey and redlisted species which were observed migrating through the four local zones 1–4 (each of them 1–1.5 km wide) at Yttre Stengrund in this study. These local zones make up zone A in the Sound. The wind turbines were built in summer 2001 in local zone 3. "F" includes observations made before the wind turbines were constructed (autumn 2000 and spring 2001), and "e" includes observations made after the wind turbines were in place (spring seasons 2002 and 2003 and autumn seasons 2001 and 2002 and to a certain extent autumn 2003). The status of the redlisted species is shown with markings "NT" for "near threatened", "VU" for "vulnerable" and "EN" for "endangered" (see Gärdenfors (ed.) 2000). Rarity is also indicated as "R" and birds of prey as "Rov".


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