SPRING MIGRATION OF EIDERS *SOMATERIA MOLLISSIMA* IN SOUTHERN SCANDINAVIA

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The spring migration of Eider *Somateria molissima* in southern Scandinavia is a spectacular event during the first half of April. The birds concerned belong to the Baltic breeding population and winter in Danish and German waters (Fig. 1). The principal wintering areas, indicated by recoveries of Eiders ringed in Sweden and Finland, lie between Zealand and Jutland, extending to the northern part of Kattegatt and the shoals west of Jutland (Paludan 1962, Behrends 1966, Joensen 1968 and *in litt.*). Smaller numbers winter in West German Baltic and North Sea waters (Bauer & Glutz 1969). Negligible numbers of Eider winter along the coast of Sweden; the few recorded in the northern part of the west coast are probably recruited from Skagerack (L. Nilsson pers. comm.). A few thousands winter in the fiords around Trondheim in Norway, departing eastwards over the mountain chain in spring to an unknown destination (Folkestad & Moksnes 1970).

Studies of the spring migration of Eiders in southern Scandinavia (Svärdson 1953, Mathiasson 1962, Swegen 1972) have instanced southward movements in the province of Halland (Ulfstrand 1950) and through the Sound as examples of the influence of topographical features on migratory routes. Eider flocks heading east at a high altitude have, however, also been noted in spring over the Danish islands of Fyn and Zealand (Raböl & Noer 1970). Large-scale migration of Eiders through the Kalmar sound, between Öland and the Swedish mainland, have been observed yearly since 1958 by associates of Ottenby Bird Station (Edberg 1960, 1961, 1965, Rodebrand 1972), but no overland crossings have been recorded in this area.

During the spring 1971 a pilot study, using the radar at Bulltofta Airport, Malmö, and simultaneous field observations, detected high-altitude movements of Eiders crossing the land-mass of Skåne. These results encouraged the Swedish Air Force to initiate a project to map, in space and time, the chief movements of migratory birds in southern Scandinavia. The present study, part of this project, involved three radar stations in combination with simultaneous field observations at ten localities (Fig. 2). In this report, the broad pattern of Eider movements are described; a more detailed description of migration and migratory behaviour at the observation sites has been given elsewhere (Alerstam *et al.* in press).

METHODS

RADAR

The principal radar station (station R), situated on the ridge of Romele, Skåne, was a high-power, L-band radar, fitted with moving target indicator (MTI) which prevents stationary or slow, weak echoes from being registered on the plan position indicator (PPI), but has no significant effect on echoes relevant to this study. The range used was 135 km. By correlation with field observations it was noted that Eider migration off the south coast of Skåne was detected at less than 30 m above the water surface, while movements in the Sound had to reach heights of 50–100 m to be registered. The subsidiary stations, B in Blekinge and Ö on the island of Öland, were filmed alternately.

The PPIs of all radars were filmed with 16 mm film using time-lapse technique (2·5 frames/min). Station R was filmed from 4 to 23 April continuously by day and night; stations B and Ö were filmed between 6 and 18 April, from 06.00–18.30 hrs.

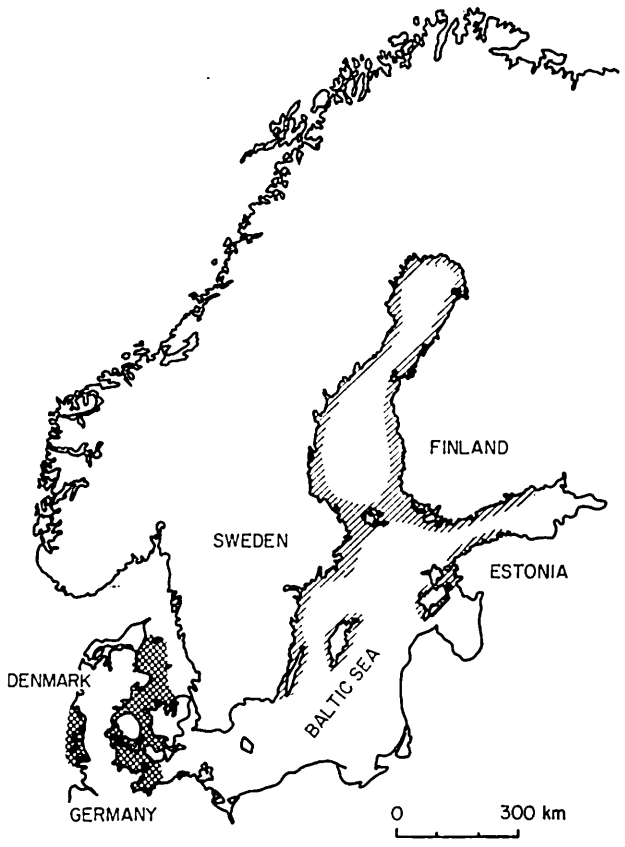


FIGURE 1. The breeding range (hatched), based on Onno (1970) for Estonia and *Förteckning över Sveriges fåglar* (1970) and Salomonsen (1963) for Sweden and Finland, and wintering area (cross-hatched) of the Baltic population of the Eider. Eiders also breed in Denmark and southernmost Sweden but are not indicated in the figure as they take no part in the migration studied.

The films were analysed with respect to spatial and temporal patterns, and as many bird echo cohorts as possible were distinguished and treated separately. The numbers of echoes referred to Eider flocks were counted for periods of 30 min to give not only the temporal pattern but also the magnitude of total passage; this technique has been used quantitatively with Woodpigeons *Columba palumbus* (Alerstam & Ulfstrand 1972) and Cranes *Grus grus* (Alerstam & Bauer 1973). Counts were made as close as possible to the radar sites and in areas where the MTI effect was minimal. The figures obtained are therefore very accurate and can safely be used for broad quantitative discussions.

Ground speeds and track directions were determined by plotting individual echoes over at least 20 km (frequently 30—60 km), averaging the direction and reading the time to the closest full minute. The radar equipment provided no information on the height of the bird movement. The problem of echo identification is dealt with in Appendix 1.

FIELD

Field observations were made during the periods 06.00–11.00 and 14.30–18.30 hrs. The observers noted all migratory movements, recording for each 30-min period the total numbers of flocks and individuals, directions of movements and height. Kalmar

sound was covered from the mainland and from Öland. The observations from Öland continued from March to June; the hours were slightly different, and on some days records were continuous throughout the day. Individual variation between observers has been tested, and fell in the range 5–12% (Källander *et al.* 1972).

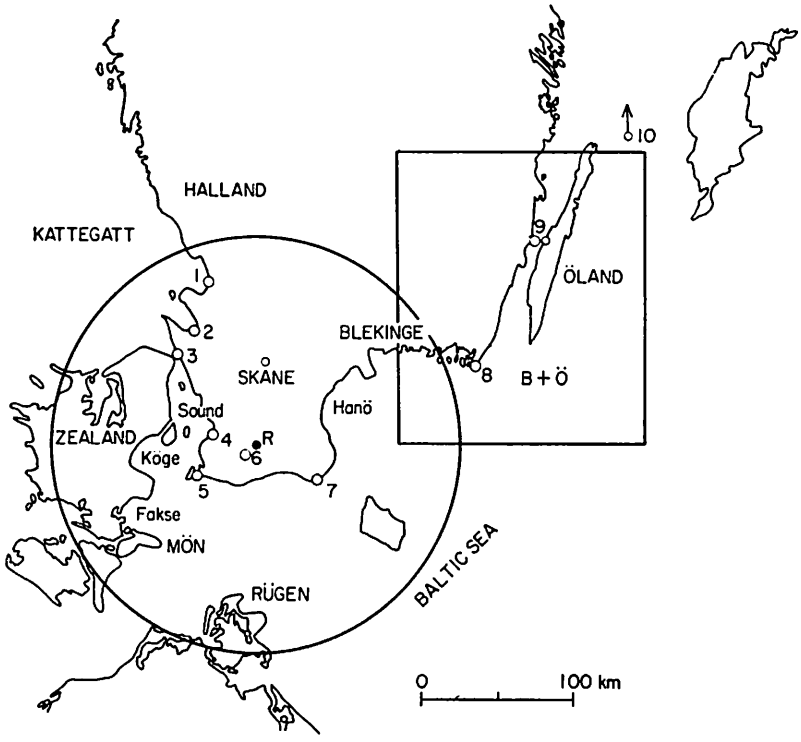


FIGURE 2. Study area. The field observation sites (1–10) and radar stations (R, B and Ö).

GEOGRAPHICAL PATTERNS OF EIDER MOVEMENTS

DENMARK AND SKÅNE

Patterns of Eider migration detected by radar station R are exemplified in Figure 3. The most striking feature was the massive movement over Zealand. Most echoes entered the display in the vicinity of the bays of Köge and Fakse, and were somewhat sparser over northern Zealand. A few first appeared near the islands south of Zealand and, as seen in Figure 3 (a) and (b), arrivals were also noted from the sound between Denmark and Germany south of the island of Mön. The track direction in the south averaged ENE, but shifted progressively towards ESE over north Zealand, and to SE over Kattegatt. Evidently Eiders wintering in northern Danish waters depart on their spring migration towards ESE–SE, those in southern waters towards ENE–NE and birds in between these geographical extremes on intermediate courses around E.

After passing over Zealand, most flocks crossed the Sound and Skåne without any reaction to topographical features. Those from northern wintering areas continued on tracks heading south of east over Skåne, while those from the south followed courses north of east. Thus, over inland Skåne simultaneous echoes were often seen moving ENE, ESE or on intermediate bearings. Large numbers of Eiders often spent the night in the Sound, particularly off site 4, heading inland on departure early in the morning. The echoes on these occasions were seen to depart on bearings in the sector ENE–ESE,

continuing over Skåne on the same paths as echoes from over Zealand. Migration inland over Skåne also occurred from the western part of the south coast during darkness or on days with poor visibility (Fig. 3b, c, d).

Flights over Skåne generally extended overland for a distance of 50–90 km, reaching the sea at the east coast or at the eastern part of the south coast. Some echoes continued far eastwards over the Baltic, but the majority disappeared 5–15 km off the east coast. Apparently, after crossing Skåne, the ducks descended rapidly to fly over the sea at altitudes below radar coverage. Very often, by day, the echoes were noted turning towards northeast immediately before their disappearance.

The movements described so far were not recorded by field observers. Presumably the birds flew at high altitudes beyond the range of vision. There were, however, many migratory movements noted by field observers which simultaneously appeared on the radar display. Inland migration towards E to SE took place from the bays at sites 1, 2 and 4 (Fig. 2). The observer at site 6 noted migration from the bay at site 4 directed ESE. Land crossings from sites 1 and 2, involved 100–140 km diagonally over Skåne, and exceptionally up to 200 km on a course heading east over Blekinge.

Field observers also noted low-altitude coast-bound movements southwards along the west coast of Skåne, and eastwards along the south coast. Visible migration in the Sound closely followed the coast of Skåne, as seen on the radar. Most Eiders migrating south in the Sound arrived from the Kattegatt, but some arrived from over Zealand. A proportion of the ducks migrating along the south coast had passed the Falsterbo peninsula at site 5. Others arrived from over the Baltic, flying E to ENE, and still other flocks flew over land, to join the stream at the eastern part of the south coast. Some echoes were seen departing inland where the coastline bends southeast, immediately west of site 7, but the majority followed the coast and were seen at this site. After having passed the southeasternmost point, the echoes shifted course towards NE over the open sea.

BLEKINGE AND ÖLAND

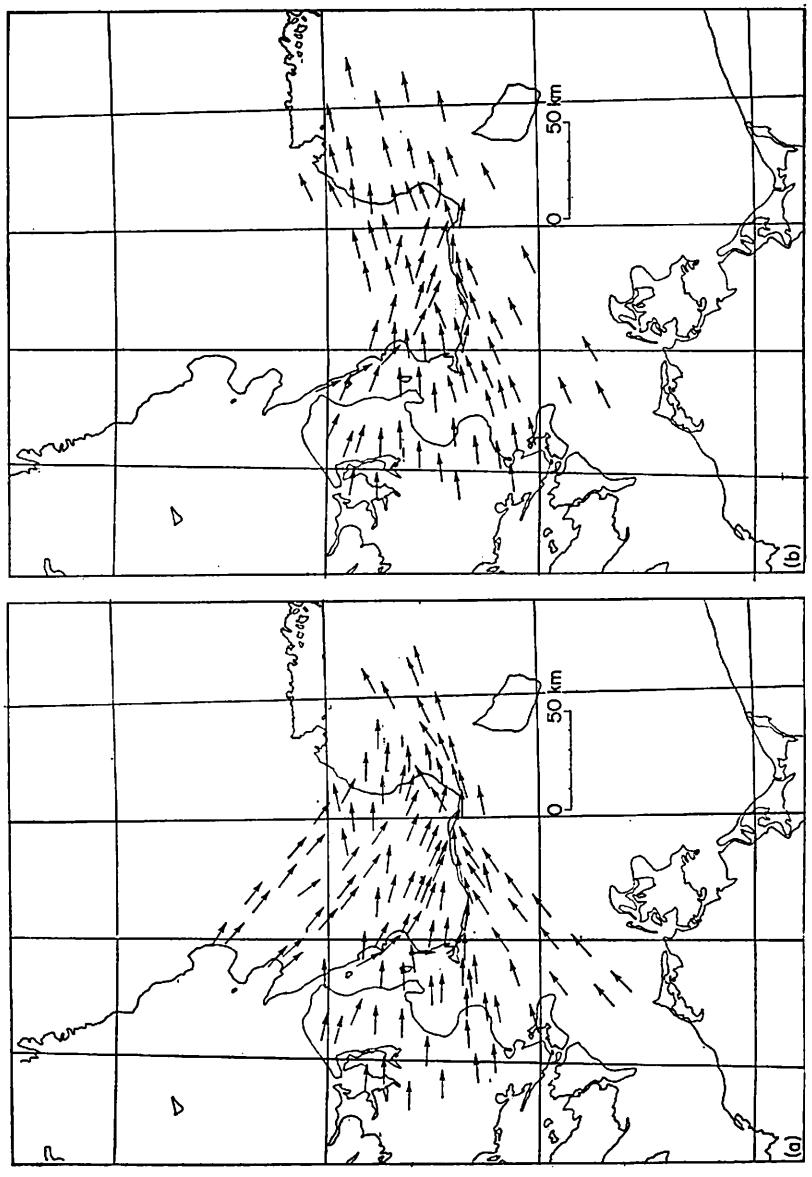
After rounding Sandhammaren (site 7) or arriving over the east coast of Skåne, echoes turned towards NE. This change of direction occurred several kilometres beyond the coast, and the flocks turned on a radius of 5–10 km. As described above the echoes then disappeared from the display of radar station R over the bay of Hanö, as the flocks descended to a lower altitude.

At radar station B many echoes were seen moving NE towards the middle of the Blekinge shore (Fig. 4). At the coast the Eiders were deflected E to ESE, returning to an approximate NE direction after passing the peninsula of Torhamn (site 8). At least 17% of the echoes of Eider flocks passed south and then east of Öland. The majority, however, turned sharply to the north, to follow the west coast of Öland. After passing Öland, it is likely that most Eiders retained a NNE to NE course, continuing over the open sea.

Most remarkable was the restriction of flights over land after the ducks left Skåne. A few echoes moved eastwards over Blekinge on 9 April, originating from the bay of Laholm (site 1), and a few echoes (possibly not Eiders) crossed southern Öland, moving NE, during the last day of the investigation. Many echoes crossed the peninsula of Torhamn, after having passed through the archipelago of Blekinge, but only 5–8 km of land were overflown.

NUMBERS OF MIGRATING EIDERS

Calculated numbers of Eiders passing the observation sites are compared to radar estimates in Table 1. The very large number (290 000) migrating through Kalmar sound (passing site 9) is striking. Since at least 17% of the Eiders passed east of Öland the total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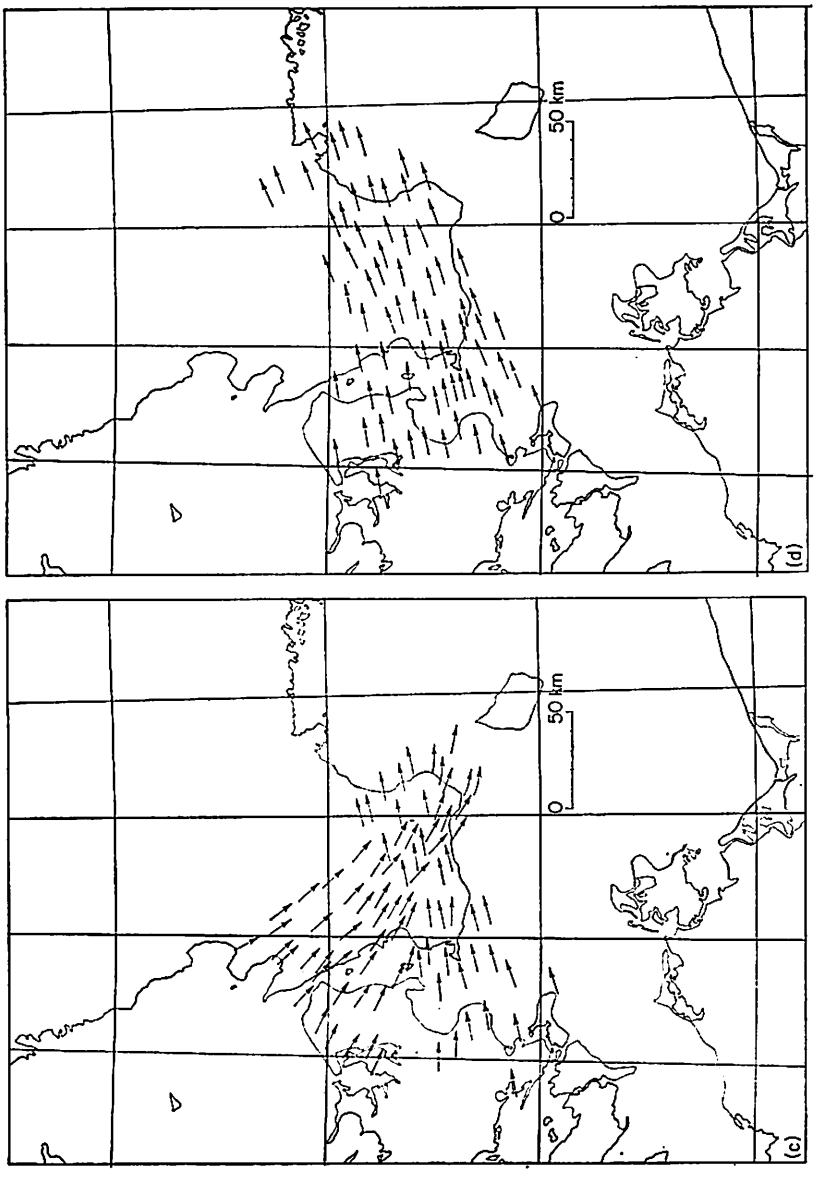

FIGURE 3 (a)–(d). Examples of echo patterns over Skåne, identified as Eider migration: (a), 7 April (morning); (b), 13 April (morning); (c), 12 April (19.00–20.00); (d), 14 April (19.00–22.00).

passage at this sector during the study period is deduced to be about 350 000 ducks. This figure agrees closely with estimates of migration in Skåne based on radar echo counts (370 000 individuals). Radar records indicated that a majority of migrating flocks crossed Skåne overland. Radar and field observations agreed that the route along the south coast of Skåne was followed by about one-third of the total (*c.* 110 000 individuals).

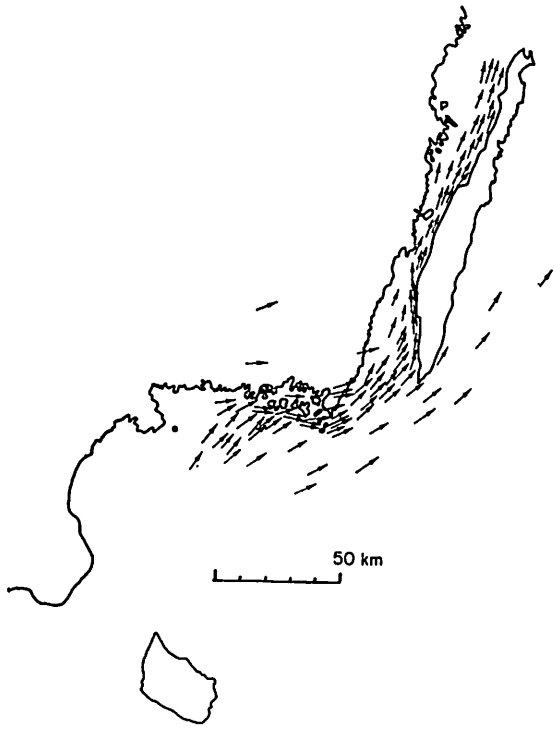

FIGURE 4. General echo pattern identified as Eider migration in eastern Blekinge and around Öland as noted between 06.00 and 18.30 hrs.

Migration from the bays at sites 1 and 2 contributed rather little to the overland passage. From the bay of Lomma (site 4) the observed migration of 35 000 ducks must be regarded as a minimum figure, since the field of view did not cover the whole width of the bay. Ducks from site 4 are included in the radar estimate of 210 000, but it is quite clear that by far the largest proportion of ducks crossing Skåne migrated out of visible range at high altitudes.

After passing Skåne, the Eiders changed their migratory strategy, for the most part descending to fly low over the water surface, and nearly always following the coastline of Blekinge and Öland. The large numbers seen at site 9 confirm that few birds crossed the land in this area. The observation post at site 8 faced the open sea and the watcher could record only 48% of the total migration in the area detected by radar (Alerstam *et al.* in press). Allowing for this and assuming the diurnal distribution of migration to be similar to that at site 9 we arrive at an estimate of 290 000 individuals passing this site. This is in reasonable accordance with the expected figure. Therefore the migration in Skåne, with extensive land crossings, contrasts conspicuously with the concentrated migration along coastlines in Blekinge and around Öland.

TABLE 1

Estimated numbers of total migration of Eiders between 5 *and* 18 *April* 1972

Field observations

Observation site	No. of individuals between[1] 04.00 and 20.00 hrs
3	51 000
4 along the coast	46 000
inland	35 000
5	38 000
6	4 000
7	107 000
8	140 000
9	290 000

Radar observations

Route	No. of echoes between 04.00 and 20.00 hrs	Approx. no. of individuals between[2] 04.00 and 20.00 hrs
Crossing Skåne from the bays at sites 1 and 2	500	50 000
Crossing Skåne from over the Sound or the western Baltic	4 200	210 000
Migrating along the south coast of Skåne	2 200	110 000
	No. of echoes between 20.00 and 04.00 hrs	Approx. no. of individuals between 20.00 and 04.00 hrs
Crossing Skåne from over the Kattegatt, the Sound or the western Baltic	1 800	90 000

Notes: [1] To extrapolate the numbers recorded during the hours of field observation to the hours between 04.00 and 20.00 hrs we have multiplied with a correction factor. For site 9 this factor was 2·4 (Appendix 2). For site 8 the factor used was 2·2, i.e. the same as for site 9 but corrected for 9 hours of observations instead of 8. From radar station R a correction factor of 1·7 was calculated for observation sites 3–8.

[2] 50 was used as mean flock size (cf. Appendix 3), for transforming no. of echoes to no. of individuals. For echoes from the bays at sites 1 and 2, 100 was used as mean flock size.

DISCUSSION

It was previously believed (Svärdson 1953, Mathiasson 1962) that the southward stream along the west coast of Sweden formed the main axis of Eider migration in Skåne. Movement over land was thought to consist of a few ducks deviating inland from the bays along the route. A very large proportion of the Eiders was considered to reach the Falsterbo peninsula.

From our data it is clear that in fact the majority of Eiders cross Zealand, the Sound, the western Baltic Sea and Skåne at high altitudes. During daytime only 15% of all migrating Eiders entered the Sound between Denmark and Sweden from the north. In Skåne only about half of total migration was accessible to visual observation. The situation is quite different off Blekinge and Öland, where about 80% of total daytime migration passed through Kalmar sound and virtually all ducks flew at altitudes within visible limits.

Svärdson also suggested that most Eiders in Denmark depart heading directly towards their breeding areas ('Idealzugrichtung', Schüz 1971), so that those from northern Danish waters reached the Swedish coast at Halland and were then forced southwards. Our evidence, however, indicates that Eider populations in different parts of the wintering range initially depart on different track directions, and only after passing Skåne does a

common preferred track (towards NE) prevail. The birds from northern Denmark actually set out on a course towards SE. For a marine bird there are obvious risks incurred in crossing long distances over land, as in Sweden north of Skåne. The crossing of the Danish islands and Skåne probably involve similar risks, but these are lessened in relation to the reduced distance, and thus outweighed by the advantages of the shorter route.

Eider also migrated during darkness (20.00–04.00 hrs) but to a smaller extent (cf. below and Fig. 3c, d). The overall pattern was identical to that during daylight, but no movements followed coastlines. A similar pattern was found among Common Scoter *Melanitta nigra* and Longtailed Duck *Clangula hyemalis* in southern Finland (Bergman & Donner 1964), where coastal movements occur in daylight with good or medium visibility, while with poor visibility or during the night the ducks cross the coast and head inland. Eiders moving ENE over the western Baltic were deflected along the south coast of Skåne to a varying degree during daytime. Under poor visibility (e.g., on 13 and 14 April, cf. Fig. 3a, b) almost all echoes passed inland. The Eiders crossing Zealand, the Sound and Skåne in an eastward direction seemed to be little influenced by visibility conditions. At night birds flying towards NE across Skåne were sometimes seen to continue over land in Blekinge (Fig. 3d). No confirmatory night-time radar records were obtained at Blekinge or Öland, but these ducks must have travelled almost 250 km over the land of south Sweden.

DIEL PERIODICITY

Migratory activity was recorded on Radar R throughout the 24 h of the day. Darkness prevailed approximately from 20.00 to 04.00 hrs, and during that time about one fifth of the total radar activity was noted. Less than 10% of the total activity was recorded between 22.00 and 04.00 hrs, and on no occasion did any peak of activity occur during this interval. There was, however, considerable day-to-day variation, as illustrated by the half-hourly frequency of Eider echoes passing over eastern Skåne on the two days with most intense migration in Figure 5.

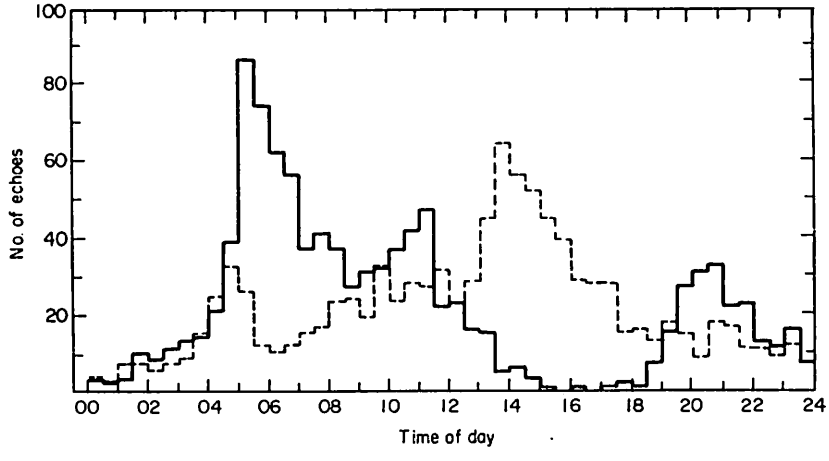

FIGURE 5. Diel distribution of echo passages, identified as Eider migration on 7 April and 13 April (broken line), over Skåne.

In Skåne, activity commenced at about 04.00 hrs, with birds flying inland from sites 1 and 2 (Fig. 6) and from the Sound, mainly site 4. After crossing Skåne, these flocks passed over the east coast or flew along the eastern part of the south coast. The latter rounded Sandhammaren (site 7) where a peak of activity frequently occurred between

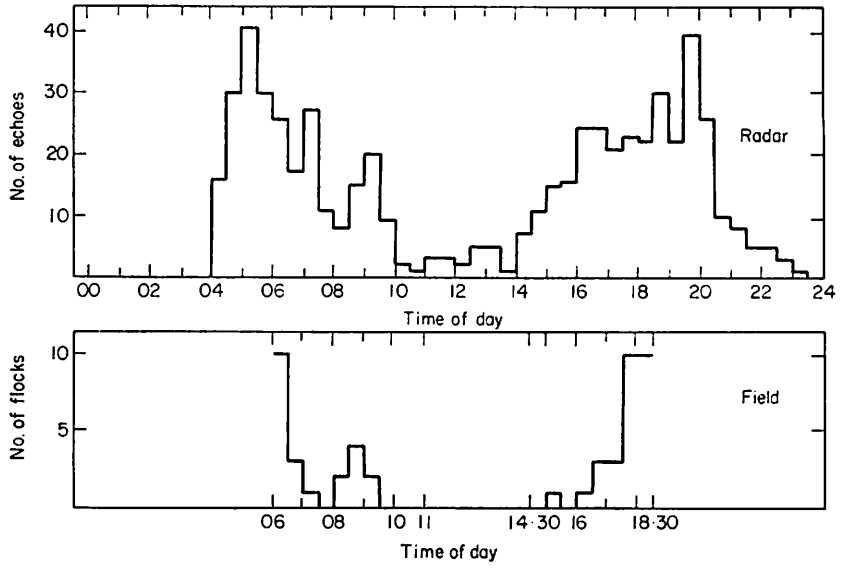

FIGURE 6. Eider migration inland at site 1 and 2, recorded by radar (top diagram) and visually (bottom diagram). Numbers of echoes and flocks are not wholly comparable because 17 April, with incomplete radar records, is excluded from the radar diagram.

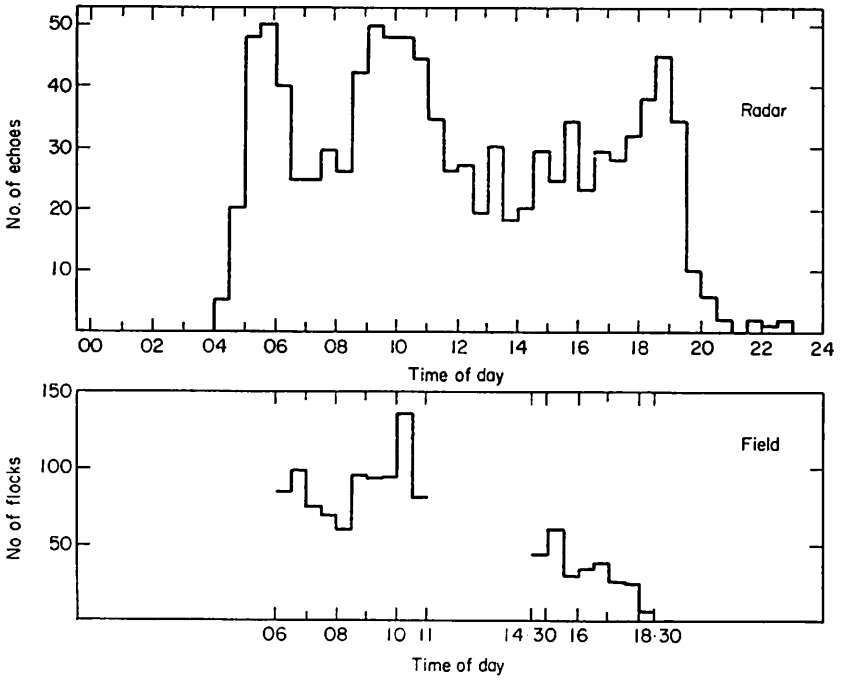

FIGURE 7. Eider migration at site 7, recorded by radar (top diagram) and visually (bottom diagram). Numbers of echoes and flocks are not comparable because 10 and 17 April are excluded from the radar diagram.

05.00 and 06.30 hrs (Fig. 7). On the western part of the south coast (Smygehuk), only a weak intensification of activity was noted in the early morning (04.30–07.00 hrs). This is thus in sharp contrast to the situation at site 7 (Fig. 7), and indicates that few Eiders rested in the southernmost part of the Sound or off the south coast. The intense movements along the south coast further east evidently originated from the Sound, where large numbers obviously rested over night.

The first trans-Zealand migrants reached the region of the Sound around 05.00 hrs. Although migrants from Denmark passed Skåne from 05.00 onwards, no distinct peak occurred in the eastern part of the province until 07.30–11.30 hrs. A peak at this time was often noted for echoes crossing Skåne as well as for echoes moving along the south coast.

Migration inland from sites 1 and 2 reached a second peak about dusk (Fig. 6). Here, as at site 7 (Fig. 7), there was little or no nocturnal activity, and the evening peak terminated rather abruptly after 19.30 hrs. Off the western part of the south coast, numbers also decreased at 19.30 hrs, although migration continued at a reduced rate throughout the night. As already noted, these nocturnal movements did not follow the coastline, but were ENE-orientated probably at high altitude. Migration over land from the Sound increased in the early evening, usually reaching a peak around 18.00–20.00 hrs, but on a few occasions later (20.00–22.00 hrs) during darkness (cf. Fig. 5).

The hours of visual observations were by comparison limited, but records conformed fairly well (Figs 6 and 7). Migration southwards through the Sound noted at sites 3, 4 and 5 did not display large fluctuations, although activity was lower during the afternoon. No apparent correlation existed between the sites—understandably, since the picture was distorted by trans-Zealand migrants joining the visible migration in the Sound. A fairly sharp peak was noted from site 4 at 08.00–10.30 hrs, coinciding with the overall peak and evidently consisting largely of ducks arriving from Zealand.

At sites 8 and 9, both radar and visual observation were restricted to the period 06.00–18.30 hrs; the data are further limited because the two radar stations were used alternately. The migration through Kalmar sound was extraordinarily even, although activity was generally lowered after noon. The pattern was more variable at site 8, where there was intimation of an early morning peak, sharply declining at 06.00 hrs. Another peak was discerned between 07.30 and 09.30 hrs and a third just before noon. Although these three peaks were indistinct, the last two might be related to the peaks observed in Skåne.

DISCUSSION

Although previous records of nocturnal migration of Eider were poor (Edberg 1961), the increase of activity at dusk was widely known and it was not surprising that our records demonstrated the continuation of migration during darkness. The identification of night-time echoes as Eiders is supported by the similarity in speed and overall geographical patterns with echoes recorded during the day, and by the direct connection on many instances of night-time movements with activity before and at dusk.

The peak of arrivals from Denmark fell 3½–5 h after the early morning peak of birds starting from waters off Skåne. At average flight speeds, the interval corresponds to a distance travelled of 250–450 km. The most frequented Danish winter quarters lie immediately east and west of Jutland, 200–300 km west of the Sound. Agreement is sufficiently close to conclude that Eiders of this later peak also depart from their winter quarters in the morning at about 04.00 hrs.

SIZE OF BALTIC EIDER POPULATION

Field observations at site 9 of Eiders passing northwards through Kalmar sound continued throughout the migratory season. Regular counts during five hours in the morning and three in the afternoon in constant relation to sunrise and sunset, tallied 215 000

Eiders (Fig. 8, Appendix 1). Especially when migratory activity was high, the observer frequently extended the period of counting, sometimes to include all the hours of daylight, and thus actually recorded 340 000 Eiders passing northwards. Extrapolating to cover the light hours of all days, with adjustment for the diurnal distribution of migration, gives a figure of 492 000 (Appendix 2). Further compensation is required for the evidence of radar that at least 17% of all flocks passed east of Öland, and that about 20% of migration occurred during the night. This indicates a final figure of about 750 000.

Echo counts from the radar in Skåne, the PPI of which was filmed 24 hours a day for 14 days, gave a total of 8700 echoes that were identified as migrating Eider flocks. Assuming a mean flock size of 50 (Appendix 3), this observation represents a passage of 435 000 Eiders. Assuming that the fraction of the total Eider population passing during this period was the same as at site 9 (cf. Fig. 8, Appendix 1), i.e. 56%, the indicated total population is 775 000.

From records of Danish hunters, and assuming a maximum bag of 15%, Paludan (1962) estimated that the autumn population in Denmark was at least 600 000. On the same basis recent Danish shooting bags of about 120 000 Eiders (Strandgaard 1973) indicate a population of 800 000 individuals. Following Paludan on mortality rates, this figure would decline in late winter to about 600 000, for Danish birds alone (excluding the German wintering population).

A census was taken in January 1969 and 1970 of wintering ducks in Denmark (Joensen *in litt.*). In both winters the number of Eiders was about 500 000. Joensen has stated that practically all important areas were counted, but the figure must still be regarded as a minimum. No figures are obtainable from German waters. Some 5000–10 000 Eiders stay in Sweden each winter (L. Nilsson pers. comm.), but most of these birds probably do not belong to the Baltic population.

The Baltic Eiders are known to breed in Sweden, Finland and to a much smaller extent in Estonia. In the last-mentioned country 5000 pairs are found (Onno 1970) and in Finland G. Bergman (*in litt.*) estimated the present breeding population at about 90 000 pairs. In Sweden, Almkvist & Andersson (1972) estimated the breeding population north of the island of Öland (excluding those of the Gulf of Bothnia, and Gotland) at 80 000 pairs. The total of 175 000 breeding pairs of Eiders in the Baltic Sea is certainly too low, as important breeding grounds were not surveyed.

It is therefore reasonable to accept a spring population of Eiders in the Baltic of 700 000–800 000 birds or, allowing for roughly 20% non-breeders (Paludan 1962), about 300 000 breeding pairs of Eiders. It is encouraging that radar records have given reliable quantitative estimates, indicating that the difficulties in obtaining such information even on a large scale, have been overestimated.

ACKNOWLEDGMENTS

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SUMMARY

Eider migration in southern Scandinavia in spring 1972 was studied simultaneously at three radar stations and ten field observation sites. The Eiders winter in Danish and West German waters, from which they set out on spring migration on courses ranging from SE to NE; those from the

northern part of the wintering area flew SE, those from the south NE, while birds wintering in between these geographical extremes set out on intermediate courses around E.

Radar showed that most Eiders fly over the island of Zealand and the peninsula of Skåne, but only exceptionally further north over Sweden. Few Eiders crossing land were registered by field observers and most evidently passed at high altitudes beyond the range of vision. After having crossed Skåne, on varying tracks both south and north of east, the Eiders descended and changed flight direction towards NE.

Some Eiders from the northern part of the wintering area circumnavigated Skåne, passing south along the Swedish coast of the Sound, crossing the very narrow peninsula of Falsterbo, and subsequently following the south coast of Skåne eastwards. Eiders from southern Denmark and Germany were often deflected eastwards along the south coast.

After having passed Skåne no significant land crossings were made. Upon reaching the province of Blekinge on a course towards NE, the Eiders were deflected E to ESE along the coast and later NNE along the west coast of Öland through Kalmar sound.

Approximately 350 000 ducks migrated during daytime of the study period, 250 000 crossing the land of Skåne while 100 000 passed along the south coast. Almost 300 000 migrated north in Kalmar sound, and 17% of all Eiders passed east of Öland over the open sea.

Three distinct peaks of activity during the day were noted in Skåne. The first, at around sunrise, originated from birds resting in waters off Skåne. The second occurred about four hours later and probably consisted of birds which had departed from the wintering area in the early morning. A final peak at sunset was often recorded. Migration also took place during the night, but involved only one fifth of the total number.

From combined radar and field counts the total Baltic Eider population is estimated to have been 700 000–800 000 in spring 1972, indicating about 300 000 breeding pairs in the Baltic Sea.

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APPENDIX 1

IDENTIFICATION OF ECHOES

Radar characteristics taken into consideration included the size and distinctness of the echo on the PPI, the pattern of echo cohorts in relation to known areas of passage as well as the calculated air speed. Echoes regarded as Eider flocks travelled at speeds of 50–135 km/h; most often ground speeds were noted in the range 70–110 km/h. Knowing the direction and speed of the winds encountered by the birds, the true air speed could be calculated. A major source of inaccuracy was that altitudes could not be determined. By way of approximation, wind data from 600 m over Malmö were used, in some cases somewhat modified by reference to ground wind conditions at weather stations in Skåne. Only one or two wind values (direction/force) have been used for the whole day and throughout the region. The calculated true air speed for the Eider was $74 \pm$s.d. 10 km/h ($n = 315$). Ground speeds of Eiders migrating northwards through the sound between Öland and the mainland (site 9), measured visually (Rydén & Källander 1964), fell in the range 35–110 km/h, corresponding to an air speed of 70 ± 5 km/h ($n = 354$). During the study period extensive migration of Cranes *Grus grus* also took place. Echoes from Crane flocks were, however, easily distinguished as they moved on almost due northerly courses from their resting places around Rügen (Alerstam & Bauer 1973).

Duck migration was recorded from site 9 throughout the spring. Eider counts are shown in Figure 8. The peaks for other common ducks occurred later, e.g., in early May for Common and Velvet Scoters *Melanitta nigra* and *M. fusca*, and confusion is unlikely. At site 9 during the two-week period 5–18 April 93% of all migrating birds were Eiders (Table 2).

TABLE 2

Birds migrating northwards in Kalmar sound 5–18 April 1972

Species or groups	No. of individuals[1]	No. of flocks[1]
Gavia spp.	493	233
Anas platyrhynchos	132	42
Anas penelope	139	31
Other *Anas*	63	24
Aythya spp.	110	29
Clangula hyemalis	108	37
Melanitta fusca	30	12
Melanitta nigra	343	58
Bucephala clangula	531	136
Mergus serrator	749	295
Mergus merganser	121	35
Tadorna tadorna	39	9
Anser anser	51	10
Branta leucopsis	181	7
Cygnus spp.	79	11
Haematopus ostralegus	791	38
Numenius arquata	649	57
Larus canus	2 922	459
Larus ridibundus	946	117
Other *Larus*	112	48
Sterna spp.	44	21
Alcidae	33	21
Subtotal	8 665	1 730
Somateria mollissima	120 748	1 831

Note: [1] Based on visual counts, eight hours per day.

At site 7 echoes were seen following close to the coastline and it was possible directly to compare the field records of Eider flocks moving up the coast with echo counts (Fig. 9). Although the correlation was close, the numbers of flocks were generally somewhat higher than numbers of echoes, indicating either that some of the Eiders migrated too low and out of radar coverage or that resolution on the PPI in such a small area was restricted. On some days there were very few echoes compared to the number of flocks. On these days (10–12 and 15 April) easterly winds prevailed, and it is plausible that many flocks flew extremely low over the water into the headwind and were out of radar coverage. Alternatively, but less probably, their resultant ground speed may have been so low that the MTI system of the radar prevented registration. On other occasions, such as 13 April, when visibility was very poor the numbers of echoes exceeded recorded numbers of flocks.

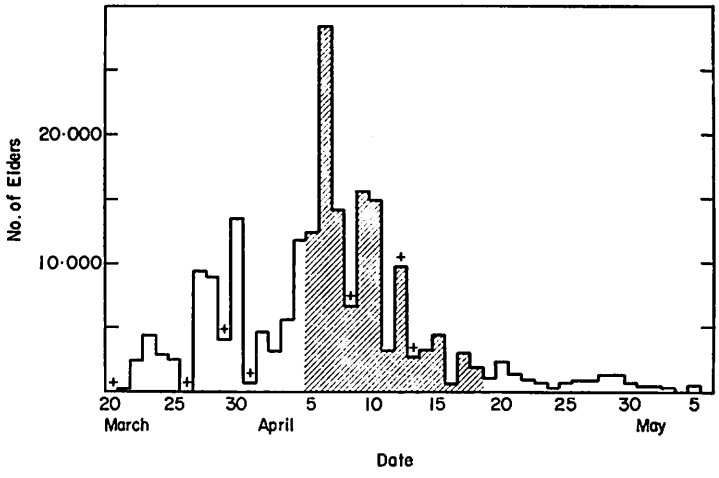

FIGURE 8. The seasonal distribution of northward Eider migration noted at site 9. The number of Eiders passing during eight hours of observation daily is indicated. Hours of observation: 20 Mar.–14 Apr., 05.00–10.00, 16.00–19.00; 15 Apr.–19 Apr., 04.00–09.00, 16.00–19.00; 20 Apr.–4 May, 04.00–09.00, 17.00–20.00. Observations were carried out from 4 March to 20 May. Migration continued to a small extent (up to 2000 a day) to 20 May but is not indicated in the figure. The symbol + indicated that on more than one of the eight hours on that day no observations were made, often due to very poor visibility. The period of the present study 5–18 April is indicated.

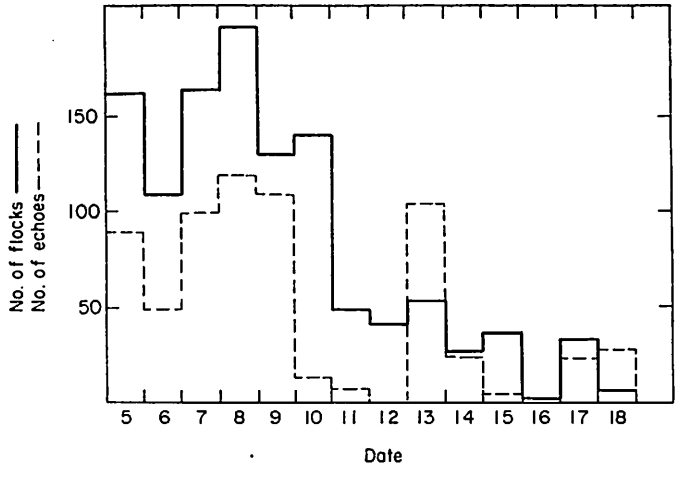

FIGURE 9. Number of flocks noted visually at site 7 (06.00–11.00 and 14.30–18.30 hrs) compared with the number of echoes noted by radar-PPI passing this site (along the coast) during the same time.

APPENDIX 2

Calculation of the total number of Eiders migrating northwards through the sound between Öland and the mainland (site 9) during the hours of daylight in spring 1972 (20 March–20 May). The calculation is based on comparisons of counts during the eight standard hours with counts performed throughout the day on eleven days.

Date	24 Mar.	27 Mar.	30 Mar.	1 Apr.	2 Apr.	3 Apr.	4 Apr.	7 Apr.
Daily total	8 232	19 646	16 400	9 595	15 671	11 162	31 763	43 805
Standard hr. total[1]	2 899	9 429	13 594	4 455	3 123	5 634	11 748	14 164
$\frac{\text{Standard hr. total}}{\text{Daily total}}$ (%)	35·2	48·0	82·9	46·4	19·9	50·5	37·0	32·3
Mean $\frac{\text{Standard hr. total}}{\text{Daily total}}$	20 Mar.–15 Apr. 41·6%							
Correction factor[2]	20 Mar.–15 Apr. 2·4							
Standard hr. total	20 Mar.–15 Apr. 189 000							
Calculated total	20 Mar.–15 Apr. 453 000							

Date	20 Apr.	21 Apr.	22 Apr.
Daily total	3 446	2 085	1 401
Standard hr. total[1]	2 330	1 271	869
$\frac{\text{Standard hr. total}}{\text{Daily total}}$ (%)	67·6	61·0	62·0
Mean $\frac{\text{Standard hr. total}}{\text{Daily total}}$	16 Apr.–20 May 64·5%		
Correction factor[2]	16 Apr.–20 May 1·5		
Standard hr. total	16 Apr.–20 May 26 000		
Calculated total	16 Apr.–20 May 39 000		

Total number of migrating Eiders: 492 000.

Notes: [1] Standard hours of observations: 20 Mar.–14 Apr.: 05.00–10.00, 16.00–19.00
20 Apr.–4 May: 04.00–09.00, 17.00–20.00
[2] Standard hour total × correction factor = daily total.

APPENDIX 3

FLOCK SIZES

Mean Eider flock sizes at different observation sites are shown in Table 3, and the distributions of flocks and individuals on different flock sizes are exemplified in Table 4.

Flocks migrating over the sea were clearly smaller than flocks crossing land. The circling behaviour in the bays did lead to accumulation of Eiders and larger flocks thus finally departed inland. This was most obvious at sites 1 and 2, where flock sizes 100–200 dominated—corresponding to the fusion of three or four normal flocks flying along the coast.

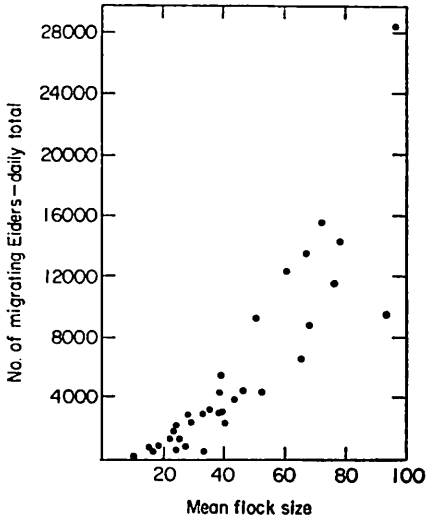

FIGURE 10. Mean flock size of Eiders, recorded at site 9, in relation to magnitude of migration.

Mean flock size at site 9 was larger than at other sites recording sea-bound movements. This was probably due to a concentration effect for ducks migrating through Kalmar Sound. In Figure 10 the mean flock sizes are plotted in relation to the magnitude of passage. The obvious positive correlation probably arise as, with larger numbers and thus higher densities of flocks, the probability for flock fusions as the sound gradually narrows is higher than with small numbers of migrating Eiders.

This cannot be the only explanation as there is still a positive correlation for mean flock sizes smaller than about 40–50, which represent the normal mean flock sizes for seabound movements (Table 4). Obviously smaller flocks are initially formed as migratory activity is low. The migration was also concentrated at site 7, which is reflected by the relatively high mean flock size.

TABLE 3

Eider mean flock sizes at different observation sites, with numbers of flocks in parentheses

Migration over the sea			Migration over land		
Site 3	45	(666)	Site 1	177	(30)
4	38	(763)	2	87	(28)
5	42	(595)	4	59	(353)
7	55	(1 149)	6	76	(30)
8	42	(1 453)			
9	66	(1 831)			

TABLE 4

Frequency of flocks of different sizes, and representation of individual Eiders

Flock size	1–9	10–24	25–49	50–99	100–199	200–499	500–999
Flocks (%)							
Site 1 and 2	—	5·6	14·8	20·4	48·1	11·1	—
Site 5	6·0	21·4	38·5	22·2	4·2	0·5	0·2
Site 9	11·0	17·4	21·5	26·8	17·3	5·9	0·1
Individuals (%)							
Site 1 and 2	—	0·7	4·4	11·8	55·7	27·4	—
Site 5	1·0	11·9	32·2	35·6	12·3	3·7	3·3
Site 9	0·8	3·8	10·6	26·3	34·6	22·9	1·0

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