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Nocturnal Passerine Migration and Cold Front Passages in Autumn – a Combined Radar and Field Study

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Nocturnal passerine migration in S Sweden was studied by radar filming and ceilometer observations during seven weeks in the autumns of 1971 and 1972. Five mass movements occurred, during which the vast majority of all birds involved passed through the area monitored. The weather situation accompanying these events was characterized by NW or NE winds after a cold front passage. Tracks were SSE/SE with NW winds and SW/SSW with NE winds. Movements towards SW/SSW comprised the largest numbers of echoes. Origin and goals of the birds and their reaction to wind, in particular, are discussed.

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INTRODUCTION

During parts of the autumns of 1971 and 1972 we studied the nocturnal passerine migration over the province of Skåne (Scania), southernmost Sweden, with the aid of radar and field observations by ceilometer. In the course of seven weeks' records, much the largest proportion of the nocturnal migration was found to take place during five mass movements. The objective of this report is to describe and discuss the meteorological conditions associated with these events.

MATERIAL AND METHODS

The data at our disposal were gathered during the periods 24 September to 10 October 1971 and 18 September to 19 October 1972.

The radar station used is situated at Romele in Skåne. Its properties have been described by Alerstam & Ulfstrand (1972, p. 101 and Fig. 1). In this report we are only concerned with diffuse echoes representing passerine migration (Sutter 1957, cf. Alerstam 1972). Migratory directions were established according to Nisbet & Drury (1967), and the relative quantities of migratory birds were estimated by measuring the maximal range of echo saturation (r), assuming that the density of birds binoculars (10 × 50) was mounted vertically.

The ceilometer (only available in 1972) was placed at Stensoffa Ecological Station 15 km N of the radar station. The evaluation of the observations in the ceilometer was performed as described by Gauthreaux (1969). We used a lamp of 150 W and a reflector of 30 cm diameter. The angle of the beam was 5°. At a distance of 2 m from the ceilometer a pair of binoculars (10 × 50) was mounted vertically. Observations were commenced as soon as the beam became visible in the binoculars, usually about 50 min after sunset, and continued for 4 hours; this period was chosen because nocturnal passerine migration is usually concentrated to this portion of the night in Skåne

Report No. 54 from Falsterbo Bird Station.

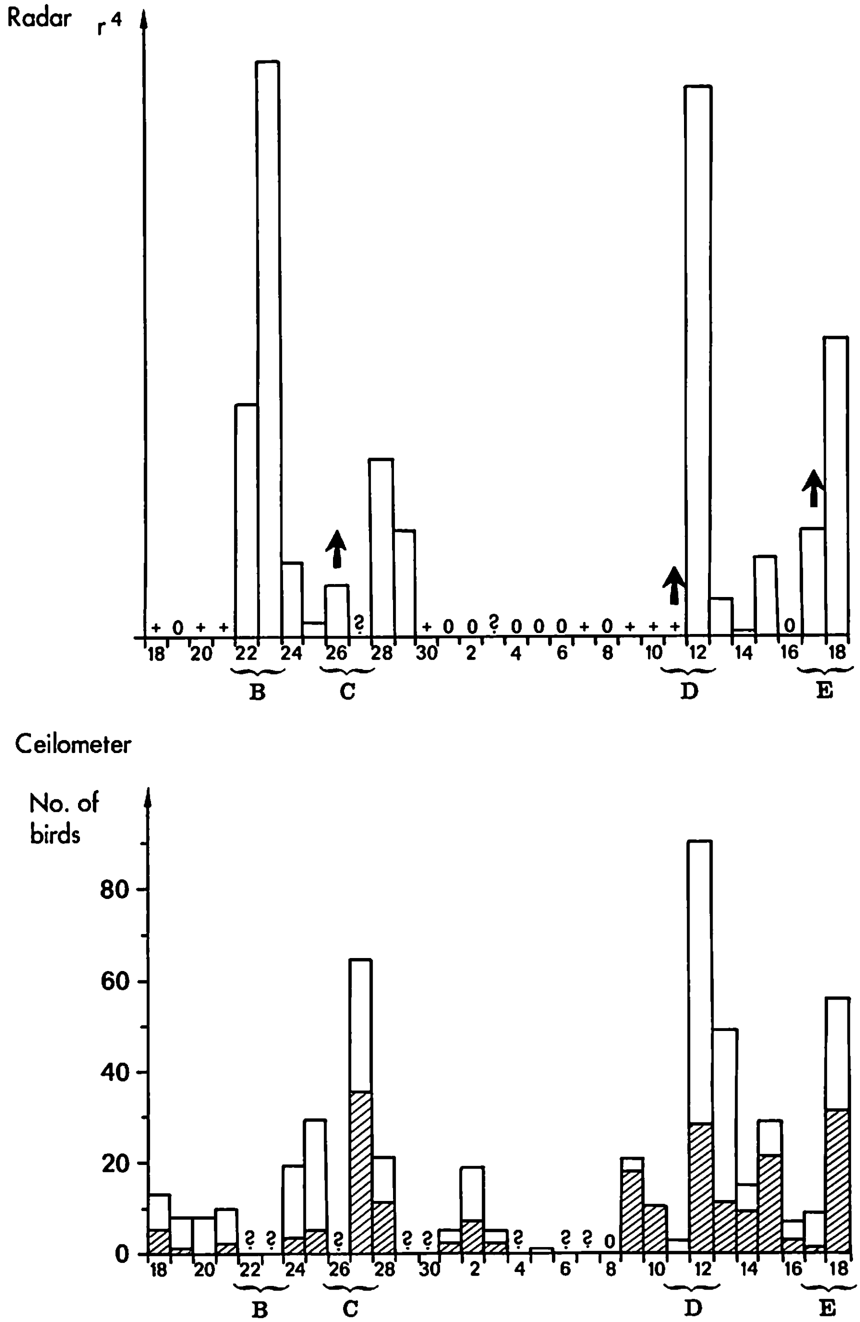

Fig. 1. Nocturnal passerine migratory activity as recorded by radar and ceilometer observations 18 September to 18 October 1972. The observations refer to the situation during 4 hours after the start of migration in the early night. Mass movements B to E are indicated. The vertical arrows in the radar diagram indicate occasions of activity increasing after the first four hours of the night, + indicates very weak activity, and question-mark no observations available. The meaning of r^4 is explained in the text (p. 103). The ceilometer columns refer to numbers of birds seen passing the light beam; the open columns indicate numbers of small passerines, while hatched columns indicate numbers of *Turdus spp.*

Table I. Weather at 1900 hrs in connection with the five cases (A–E) of mass movements. Wind direction and force have been evaluated from synoptic maps. Other weather data are from Lund near the radar and ceilometer stations. Mass movements occurred on the second and third nights of each case

Case A	2/3 Oct.	3/4 Oct.	4/5 Oct.	5/6 Oct.
Wind (km/hr)	WNW 25	NW 55	NNE 35	NW 20
Temperature (°C)	14.2	14.0	7.7	6.0
Cloud (eighths)	6	4	1	4
Visibility (km)	6	5	20	20
Barometric pressure (mb)	1022	1015	1026	1037
Flight direction of migrants	SE	SE/SSE	SSW	S
Case B	**21/22 Sept.**	**22/23 Sept.**	**23/24 Sept.**	**24/25 Sept.**
Wind (km/hr)	W 35	NW 45	NNE 35	NNE/NE 35
Temperature (°C)	13.3	9.6	10.2	8.3
Cloud (eighths)	8	1	3	4
Visibility (km)	5	20	20	25
Barometric pressure (mb)	1023	1016	1015	1016
Flight direction of migrants	E	SE/SSE	SSW	SSE/SSW
Case C	**25/26 Sept.**	**26/27 Sept.**	**27/28 Sept.**	**28/29 Sept.**
Wind (km/hr)	NE 35	NW 20	N 30	N 35
Temperature (°C)	10.8	10.5	7.8	6.8
Cloud (eighths)	3	7	5	1
Visibility (km)	20	20	25	20
Barometric pressure (mb)	1020	1015	1018	1019
Flight direction of migrants	SSW/SW	S/SSW	SSW	S/SSW
Case D	**10/11 Oct.**	**11/12 Oct.**	**12/13 Oct.**	**13/14 Oct.**
Wind (km/hr)	SE 20	WSW 55/NW 40	NW 30	NE 30
Temperature (°C)	10.5	9.7	7.2	9.3
Cloud (eighths)	0	8	1	0
Visibility (km)	6	2	25	10
Barometric pressure (mb)	1015	1004	1008	1017
Flight direction of migrants	W	SE/SSE	SSE	SW
Case E	**16/17 Oct.**	**17/18 Oct.**	**18/19 Oct.**	**19/20 Oct.**
Wind (km/hr)	NW 20	NNW 45	N 55	NW 45
Temperature (°C)	8.2	9.0	3.2	7.9
Cloud (eighths)	0	3	0	3
Visibility (km)	20	20	35	25
Barometric pressure (mb)	1032	1020	1030	1007
Flight direction of migrants	SE/SSE	SE/SSE	SSW/SW	SSE

(Alerstam op. cit.). On two occasions, however, observations were continued until dawn (27/28 September and 12/13 October 1972).

Birds could not be identified to species, but thrushes, initially chiefly *Turdus philomelos*, later also *T. iliacus* and *T. merula*, judging from the calls, could be separated from smaller passerines. Among these *Erithacus rubecula* was presumably dominant; according to ringing records for the periods, *Regulus regulus* and *Troglodytes troglodytes* were also numerous.

Experiments with birds mounted with spread wings indicated that thrushes would be visible in the ceilometer beam up to about 450 m altitude and *E. rubecula* and *R. regulus* to about 300 and 200 m, respectively.

RESULTS

As mentioned above, five mass movements are the subject of the present report. One occurred in 1971; details are given in Alerstam (1972). The rest were studied in 1972, and radar and ceilometer data are presented in Fig. 1. Table I presents information, for each of the five cases A–E, of the concomitant weather changes as registered at Lund near the ceilometer station. It should be pointed out that in the following text and in Table I, wind data have been derived from synoptic maps and thus reflect conditions prevailing above approx. 500 m altitude.

Case A. 2 to 6 October 1971

In the morning of 3 October a low pressure moved SE over Central Sweden. The accompanying cold front extended from that area westwards to Scotland. This front crossed Skåne shortly after 1900 hrs on the same date, and reached N Germany on the following morning. A high pressure simultaneously moved from Iceland to the North Sea.

Moderate migratory activity was recorded in the night preceding the front passage. Just as the front was sweeping across Skåne, birds started departing, but only after 2000 hrs, when the front had moved out over the Baltic, did massive movements originating further north become visible on the radar, to be followed by another large peak about midnight. The direction was SSE/SE; thus birds were flying with the wind. During the night of 4/5 October, still larger quantities were recorded, this time moving SSW but again with tailwinds, for the wind direction had shifted towards NE. In the next night only minor migratory movements occurred.

Case B. 21 to 25 September 1972

A low pressure moved east over N Scandinavia. The accompanying cold front extended from Oslo over NW Jutland to SE England in the evening of 21 September. It travelled across Skåne in the morning of 22 September and proceeded towards E or SE. Britain was covered by a stable high pressure.

In the early night of 21/22 September a minor migratory movement was recorded both on the radar PPI and in the ceilometer beam, with birds flying east; moderate westerly winds prevailed. The first night after the front passage a heavy movement towards SE/SSE was noted under NW winds. The next night still larger quantities, now moving SSW, were recorded under NNE winds. The weather remained similar also on 24/25 September, but movements were much smaller on this night.

Case C. 26 to 29 September 1972

A low pressure moved as in the preceding case. The evening of 26 September the cold front extended in an arc from S Finland just north of Skåne and towards N Scotland. In the early part of the night it swept across Skåne and lay over N Germany in the morning. Little migration started during the actual passage across Skåne, but in the wake of the front a heavy movement was recorded, first detected about 2300 hrs, culminating over Skåne in the late night and continuing until dawn. The direction of the birds was about S. The night of 27/28 September a huge movement towards SSW with N winds was recorded. During the next night, however, in spite of similar weather conditions, much smaller numbers were involved in the movements.

Case D. 10 to 14 October 1972

A low pressure moved SE across N Sweden and Central Finland. The cold front extended from along the Swedish-Norwegian border across the North Sea to England in the morning of 11 October. Travelling SE it crossed Skåne at about 1900 hrs in the same day. In connexion with its passage, wind direction abruptly changed from WSW to NW. A high pressure moved SSE from Iceland to the North Sea on 11 to 12 October.

The night of 10/11 October only negligible bird quantities were recorded; they moved W with following winds. Not until 2000 hrs next evening did echoes appear over the Kattegatt moving SE/SSE and producing two peaks over Skåne at 2030 and 2300 hrs, respectively. Considerable movements continued throughout the night, with the direction changing gradually to SSW. During the next night massive echo cohorts travelling SSE arriving over SW Sweden were recorded. On the night of 13/14 October only moderate SW-bound movements prevailed, but apparently large numbers of birds departed from the island of Gotland in the Baltic, for a compact field of diffuse echoes conforming in shape and size to this island was seen moving SW across the sea E of Skåne in the interval from 2000 to 2200 hrs. A corresponding event is illustrated for the island of Bornholm during case A in Alerstam (1972, Fig. 1), and also occurred during case B on 23/24 September.

Case E. 16 to 19 October 1972

A low pressure moved E across N Scandinavia. The morning of 17 October the cold front stretched from the White Sea across the Finnish Bay and S Norway to Scotland. In the late afternoon it travelled across Skåne towards S and had reached central Germany early next morning. A high pressure remained north of Ireland.

The night of 16/17 October little migration was recorded. Next night larger quantities were noted with a peak between 1800 and 1900 hrs. These birds moved SSE/SE. At 2100 hrs a massive movement appeared from over the Kattegatt. The arc-shaped front of this cohort was exceptionally sharply defined and extended, when first visible on the PPI, from the northern mouth of the Sound westwards over Zealand. These echoes proceeded SE/SSE-wards and produced a peak over central Zealand at 2200 hrs. The night of 18/19 October large-scale SW/SSW-bound movements were recorded.

DISCUSSION

Comparison between ceilometer and radar data

Ceilometer observations are obviously confined to low-flying birds; conversely the radar beam will not catch birds at very low altitudes (cf. Alerstam & Ulfstrand 1972). Although these two techniques are likely to sample partly different categories of migrating birds, quantities of birds as well as their flight directions as measured by the two methods were found to agree (Fig. 1, see also Lindgren & Nilsson 1972). In particular the major movements described above were very prominent both in the ceilometer and on the radar, to the extent that data were available.

This contrasts with previous findings for day-time migration that radical discrepancies are common between low-flying cohorts as seen by field observers and high-flying ones detected on the radar (Alerstam & Ulfstrand op. cit.). At night, birds do not seem to fly as low as is frequently the case for diurnal migrants. This may partly explain the better correspondence between sight and radar records at night and also the fact that topographical leading-lines do not noticeably affect the pattern of nocturnal migration.

We have compared the measurements of the intensity of nocturnal migration with morning counts of resting birds around the ceilometer station and also with the ringing figures from Falsterbo Bird Station in SW Skåne (Lindgren & Nilsson 1972). Alerstam's (1972) conclusion that ringing data do not reflect the magnitude of the nocturnal migration was fully corroborated. The results of the counts of resting birds were difficult to interpret.

It is important to realize that the five cases of mass movements described above comprised by far the majority of all birds moving over S Scandinavia under the entire study periods. Probably more than 90 percent of the nocturnal movements were included in these five movements.

Review of synoptic patterns

During the study period in 1971 a compact high pressure resided over the European continent. This apparently affected the patterns of the low pressure and weather front movements in Scandinavia. Four low pressure passages touching this region have been detected on the synoptic maps. In two cases, owing to the presence of the robust anticyclone over Germany, the cold front stopped and disintegrated over Skåne or the Baltic. Consequently the shift to northerly winds usually occurring after a cold front passage did not happen. In a third case a cold front moved eastwards across Skåne, but again the northerly winds did not penetrate as far south as this province, apparently because of the high pressure prevailing over the northern part of the continent. The fourth cold front passage during the 1971 study period has been described above as case A. On this occasion the continental high pressure centre had temporarily receded as far south as the Balkans, and another had built up over the Norwegian Sea. The cold front attached to this low pressure could consequently advance as far south as the Mediterranean and was followed by strong northerly winds. This was the only cold front passage during the period that was accompanied by really large-scale nocturnal bird migration.

Four cold front passages across S Scandinavia were recorded in the 1972 study period. All have been described above (cases B to E). Their pattern closely resembles that described as case A in 1971, i.e. they were followed by northerly winds. During this study period the overall distribution of anticyclonic centres differed from 1971. A high pressure area covered the British Isles and the surrounding seas, extending over Scandinavia between the cyclones, and permitting the southwards advance of northerly winds in the wake of the cold front passages. With a high pressure over Germany and Poland, as was the case in 1971, the front passages are instead followed by westerly winds. All the four cold front passages in 1972 were accompanied by heavy migration movements representing by far the majority of the birds departing over Skåne during the four weeks the process was monitored.

Weather changes and migration

Meteorological factors may affect bird migration in two fundamentally different respects (cf. Ulfstrand 1960). They may act as releasers of the migratory flight, and they may influence the geographical pattern of the migrating birds.

In all five cases of cold front passages accompanied by northerly winds, heavy migration was observed. Important attributes are the presence of an anticyclone west of S Scandinavia and the eastwards passage of a cyclone across N Scandinavia. Typically, after the front passage across S Scandinavia, strong winds develop and shift via NW to N/NE. Shortly after the front passage, under NW winds, considerable SSE/SE-bound migration takes place. Subsequently, after the further shift of wind direction, still heavier migratory movements, and now directed towards SSW/SW, occur.

This brief description based on data in Table I emphasizes one of the most patent features accompanying a cold front passage: the predictable change in wind force and direction. Other meteorological changes associated with front passages include falling temperature and improving visibility. Cloudiness and barometric pressure also tend to change in connection with front passages, but data are too few to reveal a consistent pattern.

Little or no bird migration was recorded before the front passage across the study area. After the passage heavy migration usually took place during two nights, but on the third night in spite of seemingly favourable conditions, migratory activity dropped markedly, possibly owing to scarcity of birds in *Zugdisposition* (Schüz 1971).

Interpretations of the pattern of migration

When the massive migratory movements took place, the front had already passed the entire Scandinavia. In case C birds were migrating very closely behind the front; whether they started as a prompt reaction to the front passage or had departed from further north and were about to overtake the front is impossible to decide.

Part of the SE-bound movements recorded shortly after a front passage demonstrably consisted of birds departing in the early night from Skåne and surrounding areas. In four of the five cases large quantities arrived later in the night from over the Kattegatt and SW Sweden. In cases A and D these birds formed two distinct peaks passing at about 2.5 and 5 hrs, respectively, after the peak consisting of the locally departing bird cohort. In case E only the later peak was recognized, and in case B birds from the northwest and hence partly from over the Kattegatt were obviously joining the locally departing birds, as demonstrated by the long duration of the migratory activity (until past midnight), but not as distinct cohorts. Case C differed somewhat from the rest, since the birds following the front were flying due S.

The cohorts arriving fairly late in the evening almost certainly had departed from N Denmark (the earlier peak) and Norway (the later peak). The temporal pattern conforms with what is to be expected, assuming that the birds depart approx. 45 min after sunset and travel with an air speed of about 40 km/hr. The birds from these areas come within reach of our radar only when winds are northwesterly over the whole of the Scandinavian peninsula. In two cases, viz. C and D, aberrations were noted. The first occurred on 26/27 September, when winds were NE over Norway but N over S Scandinavia. As earlier pointed out, this passage was followed by S-bound movements from the inland of Sweden. The second took place on 12/13 October when winds over Skåne remained NW on the second night after the front passage but had at that time already changed to NE over Norway. Birds moved, as expected, towards SSE over Skåne on this night, but no echoes were seen arriving over the Kattegatt. The activity ceased early on this occasion.

Hence, in these two cases no birds seemed to reach Skåne departing from Norway.

Although the SE-bound movements were often of considerable magnitude, still larger quantities were involved in the SW-flying cohorts. These movements showed one fairly early peak, and the activity as seen on the radar was low after midnight. This decrease of the echo density has been interpreted as due to lower flight altitude of the migrating birds after midnight (Evans 1966). On two occasions with low radar activity after midnight, ceilometer observations were carried out throughout the night without providing any evidence of low-altitude migration in the later part of the night. The timing of the peak of the SW-bound movements shows that the departure area was not too remote from the observation sites, presumably comprising S and SE Sweden. As mentioned before, we could on one occasion identify a large cohort departing from the island of Gotland in the Baltic.

Final remarks

We have demonstrated that, with NW winds, birds partly from Norway cross S Sweden on an approx. SE course and that, with NE winds, birds departing from SE Sweden travel SW across the same area. Do birds depart from Norway also with NE winds and from SE Sweden with NW winds? Observations from the Shetlands in the north to the English Channel in the south have revealed regular SSW-bound movements attributed to cohorts recruited from Norway chiefly during NE winds (Lack 1963, Myres 1964, Evans 1966, Parslow 1969). These observations suggest that the question posed may be answered in the affirmative as far as Norwegian birds are concerned. For S Sweden the situation is less well documented. Birds were seen to depart from Skåne towards SE, but they may originally derive from W Scandinavian regions; whether other than these W Scandinavian bird populations also take part in these movements is unknown.

The separation of two quite well defined categories of preferred directions among nocturnal migrants, viz. one towards SW/SSW and another towards SSE/SE, as indicated in our data, has also been established by Raböl et al. (1971) in Denmark and by Steidinger (1968, 1972) in Switzerland.

Thus, a division of the movements into two distinct categories seems to be a recurrent feature among nocturnal migrants over much of Europe. It may be interpreted in a number of different ways, as discussed by e.g. Evans and Steidinger. On present evidence it does not seem possible to decide which interpretation comes closest to the truth.

As mentioned before, the nocturnal migration during our study periods is largely made up of *Turdus spp.* and *Erithacus rubecula*, with *Regulus regulus* and *Troglodytes troglodytes* probably also important. For the turdines a large body of ringing recoveries demonstrates that the winter-quarters of Scandinavian birds are situated in western Europe (Ashmole 1962, Rendahl 1965, Högstedt & Persson 1971). A small minority of the *E. rubecula* ringed at Ottenby in SE Sweden seems, however, to move in a more southerly or even south-east-erly direction. Although we are aware of the difficulty of evaluating recovery frequencies from different areas with different shooting practices and so on, we cannot help thinking that there is a remarkable discrepancy between the large quantities of echoes travelling about SE over Skåne and the low proportion of the Scandinavian populations, including birds in transit, of all the above-mentioned species known to winter in that direction.

Svärdson (1953) correlated what he called 'avalanches' of diurnal migrants with synoptic weather patterns partly resembling those we have described above. He regarded temperature changes as the chief factor releasing bird migration. Lack (1963), on the other hand, concluded that wind direction was the paramount factor, as far as autumnal migration is concerned. Lowery & Newman (1966) found by means of moon-watching that maximum passerine migration in autumn took place immediately after cold front passages, partly under heavy following winds. In Louisiana, Able (1972) found that cold front passages associated with an anticyclone to the west and followed by about northerly winds were correlated with the largest mass movements of nocturnal migrants travelling towards the south over the Gulf of Mexico. Richardson & Gunn (1971) recorded heavy nocturnal migratory movements towards SE in Canada under N/NW winds after cold front passages. Thus the general pattern of synoptic situations and bird movements resembles that found in the present study.

Evidence is accumulating that bird migration frequently culminates under tail-wind conditions. In the present study, peak nocturnal migration was invariably correlated with strong following winds. According to our data birds migrated under such wind conditions that they were able to travel twice as fast as under calm conditions.

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