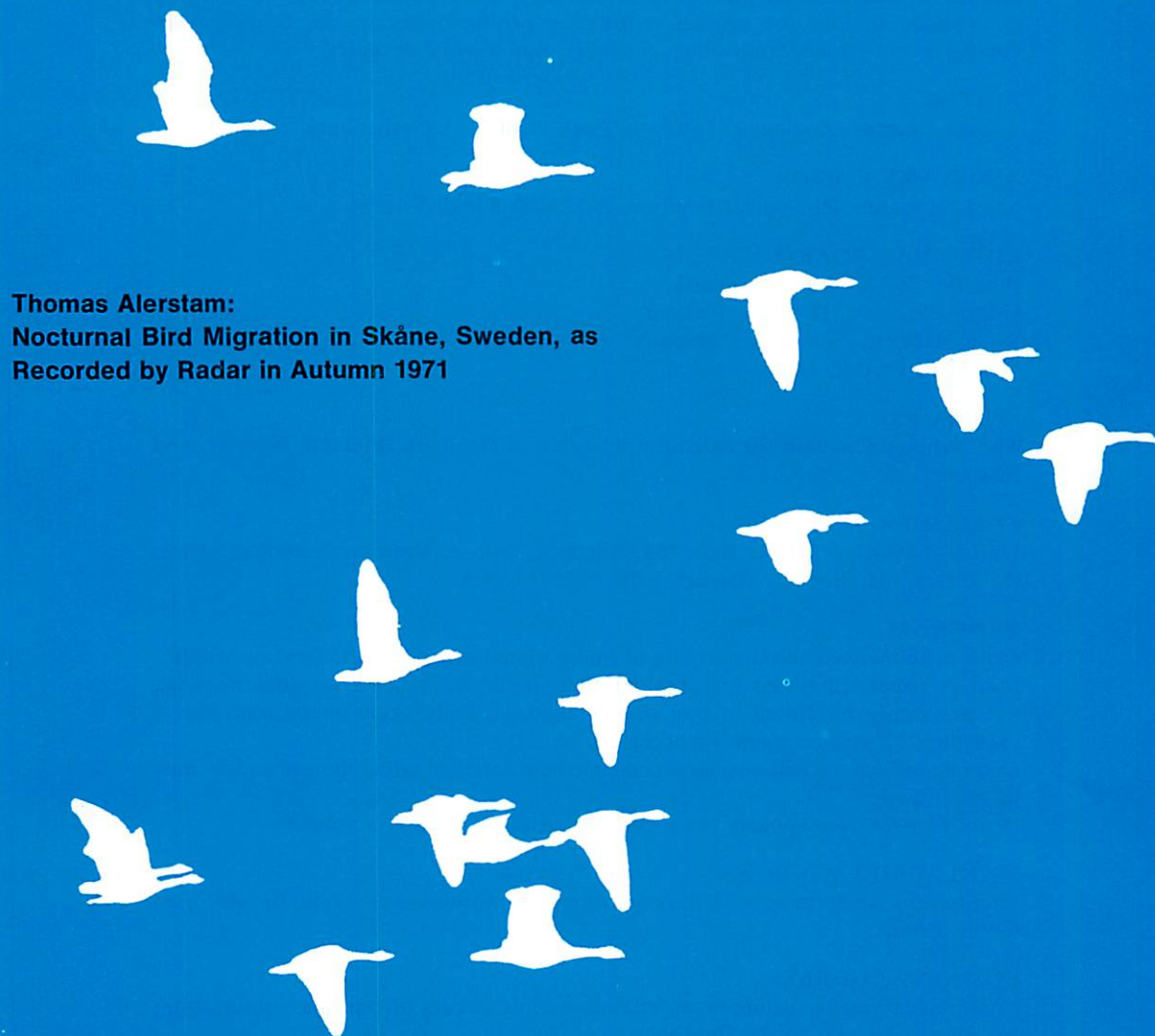


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Thomas Alerstam:
Nocturnal Bird Migration in Skåne, Sweden, as
Recorded by Radar in Autumn 1971



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Nocturnal Bird Migration in Skåne, Sweden, as Recorded by Radar in Autumn 1971

THOMAS ALERSTAM

Alerstam, T. Nocturnal Bird Migration in Skåne, Sweden, as Recorded by Radar in Autumn 1971. *Ornis Scand.* 3, 141–151, 1972.

Radar films were obtained from a high power, 23 cm, MTI-equipped station at Romeleåsen, 21 Sept.–10 Oct. Fast, distinct echoes (probably ducks and/or waders) and slow, diffuse echoes (probably small passerines, mainly *Erithacus rubecula*) were differentiated. Distinct echoes (76 % registered in 4 nights) travelled predominantly W-WSW with following winds, and diffuse echoes SE, probably displaced by W winds, and, in one night with following wind and half of total diffuse activity, SSW. Peaks of activity were recorded in early night and, for diffuse echoes only, also after midnight. Morning trapping results at Falsterbo did not correlate with the amount of echoes the previous night. This can probably be explained by the effect of local weather factors on the trapping figures.

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INTRODUCTION

During a three-week period in autumn 1971 (24 September–10 October) the Civil Aviation Board of Sweden, the Swedish Air Force, and the Ornithological Society of Skåne cooperated in a study of bird migration in southernmost Sweden. Diurnal migration was recorded by simultaneous field and radar observations (Alerstam & Ulfstrand 1972). Radar observations were also carried out during the night, and the present report is a description and short interpretation of these results. This is the first study in Sweden of nocturnal migration as recorded by radar.

Radar has been used to a considerable extent for studies of nocturnal bird migration, but a number of other methods of studying nocturnal migration have also been tried. For instance, nocturnal migration has been studied by observations from aircraft with lightbeams

(Bellrose 1971), by telescopic moon-watching technique (Lowery 1951, Nisbet 1963, Gauthreaux 1970, 1971), telescopic watches with the aid of a ceilometer (Gauthreaux 1969, 1971), aural records (Graber & Cochran 1959, Graber 1968), and radiotelemetry (Cochran et al. 1967). Data from bird kills at television towers or lighthouses, the morning fall of night migrants, and the subsequent captures at bird ringing stations are often used in studies of nocturnal migration. Few comparisons between methods are available. In the present paper, captures of night migrants at Falsterbo Bird Station are compared with the radar records. A review of radar studies on nocturnal migration is given by Eastwood (1967).

Compared with the other methods, radar appears to be the most valuable tool for studying nocturnal migration, although the difficulties of specific identification and quantification must be appreciated.

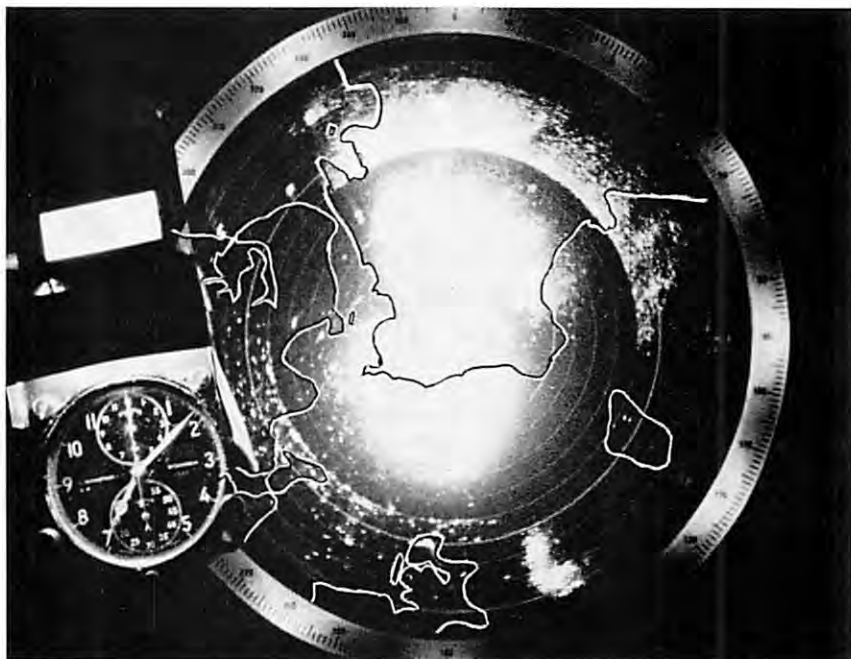


Fig. 1. Movements of diffuse echoes towards SSW Oct. 4 at 19.09 hrs. The effect of the MTI (moving target indicator) is clearly seen. Note the diffuse bird echoes originating from Bornholm, showing an area of echoes nicely conforming with the size and shape of the island moving SW towards the German coast.

MATERIAL AND METHODS

Radar stations and film equipment

During the investigation period echoes from two radar stations were filmed with time-lapse technique. One station was situated at Romele in southern Skåne and was a high-power, 23-centimetre station fitted with an MTI (moving target indicator) -system. This system prevents stationary and slow, weak echoes from being registered on the PPI (plan position indicator). The station was used with a maximum range setting of 135 km.

The other station was situated at Bulltofta, Malmö, and consisted of a medium-power, 10-centimetre radar without MTI-system. The range used was 65 km.

Although data from both stations were important and in part mutually complementary as regards the analysis of diurnal migration (Alerstam & Ulfstrand 1972), it was decided to use only the data from Romele station in

the present study because no echoes nor echo systems remained entirely undetected on Romele radar. Echoes of phenomena other than migrant birds were recorded on Bulltofta radar and interfered with the analysis, and the possibility of assessing directions of movements, speeds, and quantities of small and diffuse echoes was greatly reduced at Bulltofta station at high echo density.

The PPI of Romele station was filmed with 2 frames/min, and the films were analysed with respect to echo type, echo speed, and geographical and temporal patterns. The material consists of films from 15 nights.

Nocturnal migration

Nocturnal migration is here defined as movements between approx. 18.15 and 05.15 hrs. These hours mark the end and the beginning, respectively, of local bird movements at sunset and dawn to and from roosts. The time of

sunset during the period changed from 18.00 (24/9) to 17.21 (9/10), and that of sunrise from 05.59 (25/9) to 06.28 (10/10) hrs.

Different types of echoes

Two different types of echoes were easily distinguishable. One consisted of large, distinct dot-like echoes, often moving with high speed. These echoes were practically unaffected by the MTI-system of the radar (cf. below). They were quantified by measurements of echo densities on the radar-PPI's, and after calculating the ground speed the number of echoes passing during a certain time or the whole night could be estimated. It should be noted that when the film is stopped and echoes are counted from areas within a certain frame, an unknown proportion of echoes is missed. This proportion of echoes shows up on the moving film. Although the figures presented below are underestimated, they certainly are in the correct order of magnitude. The true air speed was calculated on the basis of the ground speed and the wind speed at 600 m altitude (Malmö). For this type of echoes, true air speed was usually found to be 65 to 75 km/hr.

The second category of echoes consisted of a more diffuse type, and individual echoes often intergraded, creating extensive layers of echoes. It was sometimes difficult to assess visually the direction of the movement. But the MTI effect on the echo distribution was a good aid in this case. The diffuse echoes were greatly affected by the MTI system of the radar. This happens because the basis of MTI reduction is the radial velocity of the target. When this component is too low, the echo is not registered on the PPI. This happens as echoes move on a tangential track with respect to the radar. As could be seen from Fig. 1, on either side of the radar station there is a MTI-wedge where the echo density is zero. These sectors are thus found perpendicular to the mean direction of movement, which accordingly was rather easy to estimate.

Speed was hard to measure, but true air speed was often calculated to 50–55 km/hr. Probably

this figure is slightly too high, as the more distinct echoes, which are perhaps faster than most, were predominant in the speed calculations.

RESULTS

Distinct echoes

Fig. 2 shows quantities and directions of distinct echoes during the 15 nights. The echo movements in each direction were classified into 6 classes:

Class 1: very few	0–20	echoes
2: sparse and irregular	20–100	"
3: rather sparse but regular	100–250	"
4: moderate	250–500	"
5: heavy	500–1500	"
6: very heavy	>1500	"

These figures refer to whole nights.

It was possible, by means of actual counting of the echoes in different sectors, as described above, to obtain detailed quantitative estimates of these classes. The reason for not using precise figures of echoes in discrete directions was that movements in close-lying directions could not be separated in the quantification method used.

For further calculations the following values for the different classes were used: 1:10, 2:50, 3:150, 4:350, 5: 1000, 6: 1750.

The total activity for the different nights is shown in Fig. 3.

Diffuse echoes

Direction and estimated relative quantity of diffuse echoes are shown in Figs. 2 and 3. Actual densities could not be measured. Instead the figures are relative scores based on the distance from the radar station in the direction of movement at which echoes become extinguished assuming that doubling of the distance indicates a sixteenfold increase of the bird density (cf. below). Large errors, however, must arise because of the different speed of the echoes, and, more important, because of the altitude of the birds and the

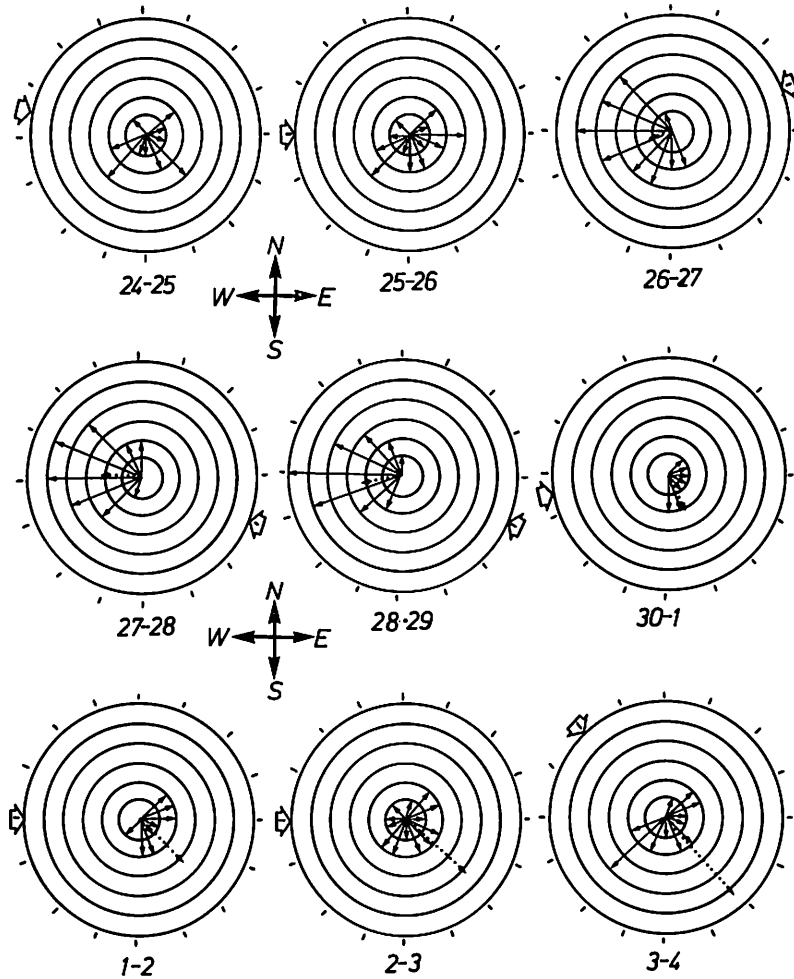


Fig. 2. For explanation, see next page.

altitude coverage of the radar at different distances. During the two most intensive nights diffuse echoes reached outside the 90 km range, but were invisible within the 70–90 km range. This phenomenon could be due to the fact that the radar, at ranges exceeding 90 km, is operated with a lowbeam with better coverage at lower altitudes than the mixed beam just inside the 90 km range. Possibly more important is the deliberate reduction of echo intensity at ranges within 90 km to avoid extensive clutter on the PPI (swept gain). The estimations of echo densities were based on the echo distribution within 90 km range, and densities are probably underestimated at large

intensities; in fact the quantification at such intensities must be regarded as not much more than a very rough approximation. For a broad quantitative discussion the seven density classes were transformed to a relative constant-interval scale. Other things being equal, the echoing area (A) of a target is related to the maximum range of detection (R_{\max}) as $A = \text{const.} \times R_{\max}^4$ according to the radar equation (Eastwood 1967, p. 19). Assuming that the echoing area is proportionate to the density of migrating birds, information on the distribution of activity on different directions for the whole study period (cf. Table I, Discussion p. 147) can be attained.

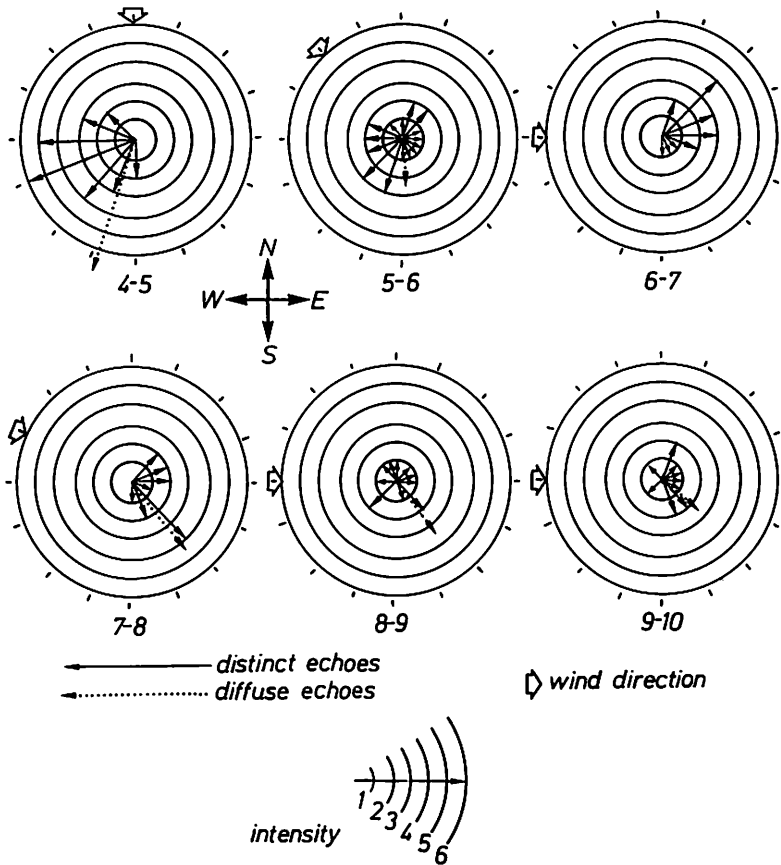


Fig. 2. Direction and quantities of echo movements on 15 nights from 24/25 September to 9/10 October. The intensity scales differ for the two types of echoes as described in the text.

It should be pointed out that the following broad discussion is scarcely affected and definitely not invalidated by the approximations inherent in these intensity estimates, which in fact, tend to reduce the amplitude between different densities.

DISCUSSION

Distribution of echo movements in different directions

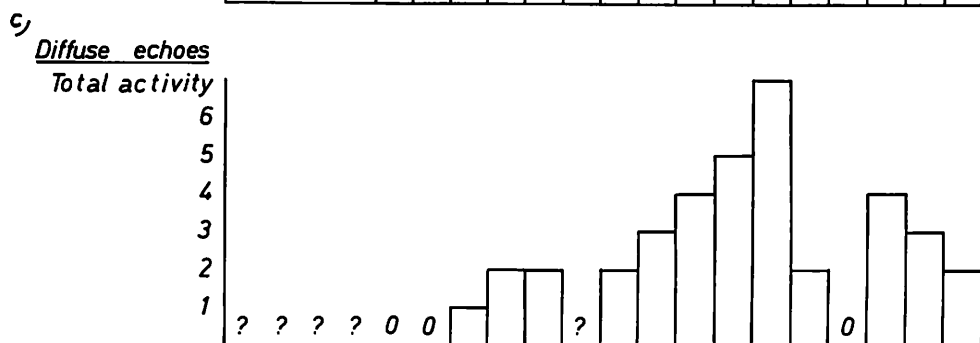
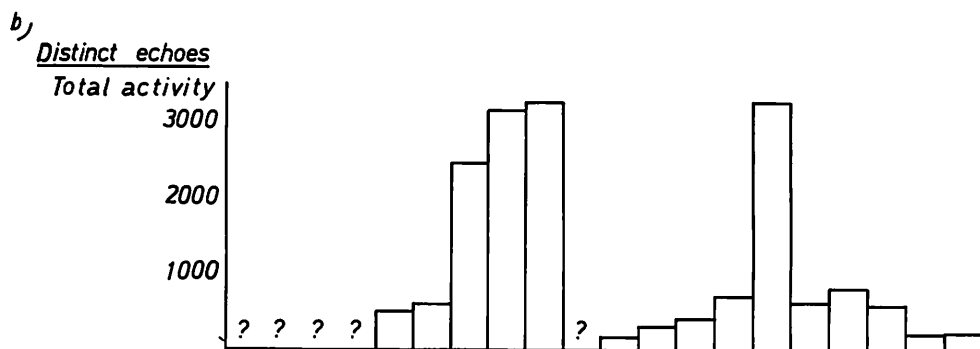
The total number of distinct echoes travelling in different directions during the entire period is shown in Table I. The number of nights with

movements in each direction is also shown. There is a marked predominance of W-ly or WSW-ly directions and 74 % of the activity falls in the sector NW/SW.

Similar data concerning the diffuse echoes are also presented in Table I (cf. p. 147). It is clearly seen that two directions, SSW, and SE, dominate. The same pattern was noted in autumn for night migrants over Denmark from a radar study by Rabøl et al. (1971).

Within each night (Fig. 2) it is interesting to note the much larger scatter of directions for the distinct echoes. The diffuse echoes tend to move rather close to the mean direction.

	sept										oct										
	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10
a) Wind direction	→	→	↗	↗	→	↘	↘	↘	↘	↘	↘	↘	↘	↘	↓	↘	↘	↘	↘	↘	↘
Wind speed (ms)	7	10	7	7	15	15	7	10	7	5	8	12	10	12	12	10	15	15	13	10	
Cloud cover	2	1	5	4H	2	8	5H	1H	0	4	7	5	6	4H	0	0	3	2	7	5	
Rain (00-06hrs)	+		+	+			+			+	+		(+)						+		
Visibility (km)	8	7	0,2	2	30	35	20	20	10	0,2	1	3	4	25	70	50	10	20	3	20	
Temp (°C)	12	12	9	11	11	11	11	10	12	8	14	15	13	12	6	3	12	12	11	12	



d) No. of trapped passerine migrants

<u>Net hours</u>	35	32	48	56	10	49	104	56	69	90	70	80	40	56	75	32	30	17	77	45
<i>T. troglodytes</i>	2							7	2	3	7	2		3	1	7				3
<i>Turdus philomelos</i>				2		2	5	1	7	8	2	1	1	2	10	1				3
<i>P. phoenicurus</i>	6	8				4	4	1	2		1	1								
<i>Erithacus rub.</i>	44	10	71	8		11	232	12	23	70	18	4	26	8	11	4			14	4
<i>Sylvia spp.</i>	1		1	1		1	12	4	2	4	3	1		1						1
<i>Phylloscopus spp.</i>	2	2	2				11			1	3	1		1						5
<i>R. regulus</i>							17	1	1	1		2			4					
All species	53	20	75	16	0	19	293	21	38	91	29	10	31	13	36	5	0	0	27	5

20 21 22 23 24 25 26 27 28 29 30 1 2 3 4 5 6 7 8 9 10
sept oct

Table I. Distribution of activity on directions and numbers of nights. Activity figures for distinct echoes show estimated number of echoes passing during the 15 nights. Number of nights with movements (>20 echoes) recorded in each direction are shown to the right. The figures for total activity of diffuse echoes are relative and derived from estimations of the maximum range of echo-detection of the single nights (Fig. 3) assuming that migrating bird density is proportional to the fourth power of maximum range (cf. p. 144).

Direction of movement	Total activity		Number of nights	
	Distinct echoes	Diffuse echoes	Distinct echoes	Diffuse echoes
N	80		1	
NNE	170		3	
NE	730		8	
ENE	410		5	
E	460		4	
ESE	220		3	
SE	750	80	6	6
SSE	480	1	9	1
S	310	1	5	1
SSW	630	150	6	1
SW	1720		10	
WSW	3660	1	8	2
W	4830	1	5	1
WNW	1900		5	
NW	960		4	
NNW	120		2	

Distribution of activity on different nights

As may be seen from Table I, the vast majority of distinct echoes moving towards W/NW were recorded during a few nights; also movements frequently seen in certain other directions such as SW, SSE, or NE comprised

only a small portion of the total number of echoes. The four nights with highest activities were responsible for 76 % of all echoes.

The same tendency is still more marked for diffuse echoes (Table I). One night (4/5 Oct.) possibly contributed more than half the total number of these echoes recorded during the whole period and thus made SSW the predominant direction, in spite of frequent SE-movements, often with considerable numbers involved.

Peaks of activity within nights

The activity of distinct echoes, even if often noted throughout the night, was invariably much higher before midnight. Maximal intensity was usually noted between 18.45 and 21.00 and only exceptionally were peaks recorded after midnight.

Diffuse echoes showed a quite different picture. Disregarding the three nights in September with easterly winds and very low activity, which was concentrated to the earliest hours of the night, the following pattern emerges. Of the remaining nine nights with movements of diffuse echoes, four showed two peaks, one in the early night and the other after midnight. Three nights only showed one peak after midnight and two nights only one peak before midnight. The first peak was normally noted between 18.45–19.00 and must have comprised birds mainly from Skåne. In the two nights with highest intensity the peak was somewhat delayed and on Oct. 3/4 a smaller first peak could in fact be separated from the

Fig. 3. Weather, migration intensity as registered by radar, and trapping figures at Falsterbo.

a. Weather as recorded at Malmö 01.00 hrs. Cloud cover given in eights. The figures show the mean of records at 19.00, 21.00, 23.00, 01.00 and 03.00 hrs. H = ceiling mainly at above 1500 m.

b. Total activities on the different nights of distinct echoes. Activity figures show estimated total numbers of passing echoes in all directions (cf. p. 143).

c. Total activities on the different nights of diffuse echoes. Activity figures denote the distance in Swedish miles (= 10 km) from the radar station in the direction of movement at which echoes are visible (cf. p. 143).

d. Trapping figures of nocturnal passerine migrants at Falsterbo Bird Station. Net hours = No. of nets × mean no. of hours per net. Species with less than 5 trapped individuals have not been listed separately, but are included in the total figure of all species. Three species have been combined with their genus *Sylvia*, two species with the genus *Phylloscopus*. It should be noted that the number of net hours is influenced by the number of birds available; plenty of birds results in capture work for a greater number of hours. This bias, however, does not affect the conclusions.

major peak at 20.15. During these two nights (Oct. 3/4 and 4/5) one could expect the temporal pattern to be influenced by migrants from more distant recruiting areas.

The commencement of nocturnal migration has been shown to have a fixed relation to sunset. Lack (1963a) noted the start of small passerine migration in autumn one half to one hour after sunset, while water-birds started approx. two hours before sunset. Parslow (1969) gives a mean of 39 min. after sunset for passerine autumn migration from southern England.

Over Skåne the appearance of diffuse echoes occurred approx. 45 min. after sunset. Main departures of distinct echoes occurred about the same time, but small numbers of echoes were recorded well before sunset.

The late peak with one exception occurred 02.15–03.15. The divergence occurred on 3/4 Oct., when the peak was noted as early as midnight. It should also be noted that on 4/5 Oct. there was only a relatively weak intensification at 03.15. This second peak may be a result of different hours of start of migration and/or widely separated recruiting areas.

In numerous radar studies of small passerine nocturnal migrants, activity peaks during the late night have been recorded. They have all been attributed to bird cohorts originating from a distant area. Off Norfolk in England, Lack (1963a) often recorded peaks in autumn typically around sunrise, which were attributed to migrants usually leaving from Norway but also sometimes from Scotland or Denmark and continental Europe in the early night.

In spring, density peaks early and late in the night were recorded in coastal New England (Nisbet & Drury 1967). The intervening density minimum was correlated with a shift in mean directions, which again was obviously correlated with different recruiting areas during the night.

Nocturnal migrants leaving the land areas south of the Gulf of Mexico in spring reached southern Louisiana during daytime, typically at noon, but with unfavourable wind conditions, trans-Gulf migrants were delayed and did not reach southern Louisiana until nightfall the

day after start of migration (Gauthreaux 1971). In no case have different peaks during the night been attributed to different hours of start of migration or to a tendency for birds to settle in the middle of the night.

It is a common occurrence, however, that the mean altitude of the migrants reaches its maximum value early in the night, continuously sinking during the night. In extreme cases the birds are lost from the radar PPI during the late night, reappearing with the light around dawn. This was shown for thrushes migrating from Norway towards Scotland (Myres 1964). This phenomenon could not be involved in the late peak over Skåne.

A large number of diurnal and nocturnal animal species exhibit two major activity peaks, namely one at the beginning and the other towards the end of the activity period (e.g. Aschoff 1967). The cycle is basically determined by internal physiological processes which are adjusted by external stimuli, usually light changes at dawn and dusk. However, it is not clear from the present evidence whether the double peak of nocturnally migrating small birds depends on a double activity peak as such or if other factors, such as different starting areas for different cohorts, play a more important role. It may be mentioned that provided that the morning peak birds started at the same time as those making up the early night peak, they would have travelled approximately 400 km before appearing on the PPI. As they often travelled SE (except 4/5 Oct.), they might have departed from S Norway.

Influence of weather factors

It should be stressed that the present data are much too scarce to allow more than general indications of the influence of weather factors.

The marked influence of wind direction on the direction of movements of distinct echoes is clearly seen from Fig. 2. The echoes tend to move with a tailwind, although with certain deviations.

The quantity of distinct echoes also seems correlated with wind direction. The four nights specially marked in this respect had easterly

or northerly winds. Interestingly enough, these wind directions do not normally occur a great deal during the autumn in southern Sweden, where westerly winds prevail. As seen from Fig. 3, nights with heavy cloudiness and rain show low activity.

As regards diffuse echoes, Fig. 3 clearly shows that their distribution on different nights markedly differs from that of distinct echoes. The most active night was characterized by northerly winds, low temperature, no clouds and very good visibility and the main direction was SSW. Good activity was noted on several other nights, when the main direction was SE. As the winds on these nights were westerly, the direction of migration seems to be influenced by wind.

The influence of wind on small passerine night migration is extensively discussed in the literature. One view is that migrants normally compensate for the direction of the wind, and travel on constant tracks. The small differences of mean track directions could be explained by the assumption that the various species or populations prefer different tracks and selectively migrate under different wind conditions (Evans 1966, Nisbet & Drury 1967). Other authors claim that the birds migrate with a constant heading and, not allowing for the wind, travel on a track resulting from the direct influence of wind on heading direction (Lack 1959, 1963a, 1963b, Steidinger 1968, Parslow 1969). Lack later concluded from his studies over the North Sea that migrants normally compensate for the wind by flying with either light or more or less following winds. Birds meeting strong crosswinds, however, seem unable to maintain their preferred track directions. Under these conditions the tracks markedly deviate from headings, obviously as a result of wind displacement (Lack 1969).

Other workers again have shown that small passerine nocturnal migrants tend to fly downwind, irrespective of wind direction. Large numbers of migrants were noted those nights when wind direction ran parallel to the birds' primary direction (Gauthreaux & Able 1970). Different views probably in part reflect different adaptive migratory patterns in different

areas, for example in USA and England (Nisbet & Drury 1967).

Although no detailed analysis of the present data is possible, owing to lack of exact ground-speed (and air-speed) data, it seems not unreasonable to assume that the diffuse echoes of the different nights reflected birds which constantly headed S-SW but were displaced by westerly winds to SE directions, with easterly winds to W-WSW direction. The large migration on 4/5 Oct. would mean that the birds tended to migrate when the track direction could approximately follow the heading direction.

The tendency to migrate with following or light winds has been stressed by all authors cited above.

The possibility remains that birds do compensate for the wind, but that movements SSW and SE are completely unrelated. This, however, seems to be a highly improbable alternative.

Evans' (1966) opinion that Scandinavian nocturnal migrants tend to maintain a fixed SSW track with moderate or light winds, but allow themselves to be carried off from a fixed heading (SSW) by strong crosswinds, could not be examined owing to the absence of nights with low wind speed throughout the study period.

Larger nocturnal migrants, as, for example, ducks, which give rise to distinct echoes, have been shown to move on a constant heading without drift compensation (Bergman & Donner 1971).

Concerning the weather effects on nocturnal migration, Nisbet & Drury (1968) argued with the aid of multiple regression analysis that migratory activity during spring in north-east USA is adapted to precise phases in the succession of weather systems. The primary selective force seemed to be the weather (and probably food) conditions at the destination which could be predicted by observing the sequence of changes of weather at the point of take-off. They also noted that certain specific weather factors with strong simple correlations with migration density did not show significant partial correlations. Such spurious correlations

appeared because these particular weather factors were correlated with other factors, with significant partial correlation with migration and would disappear if these other factors were kept constant. One of the factors with spurious correlations was tailwind. It was in fact shown that only a weak tendency of response to tailwinds would be disastrous to the birds. Small-bird echoes and distinct echoes (from waterbirds) showed a very similar response to weather factors.

Species and species groups involved

The distinct echoes probably consisted of Anseriformes and/or Charadriiformes, probably mainly ducks. This is supported by the distinctness and consistency of the echoes and also by their rather high true air speed. Further support is provided by the behaviour of the echoes. During the nights with easterly winds they were first recorded over or around Hanö Bay and Köge Bay. This suggests that the birds might have rested on or near the water or eventually flew at low altitude over sea areas, rising when they reached land.

The diffuse type of echoes, with slow speed, were probably migrating passerines with diffuse flock structure. Information about the numbers of night migrants trapped at Falsterbo bird station (Fig. 3) shows that the Robin *Erithacus rubecula* widely predominated, but warblers of the genera *Sylvia* and *Phylloscopus* as well as thrushes of the genus *Turdus*, the Wren *Troglodytes troglodytes*, and the Goldcrest *Regulus regulus* were also numerous.

No relationships between the quantity of the nocturnal radar movements and of the morning trapping results at Falsterbo were found. Indeed the morning of 5 Oct. showed the greatest trapping figure in October, but was far surpassed by the morning of 27 Sept., when only little activity at night was shown by the radar. Rather special weather conditions prevailed during this morning, heavy rain falling from 03.30–10.00 hrs at Malmö.

Earlier investigations have shown that falls of night migrants improve if rain, fog or heavy headwind occur during migration. These

phenomena evidently interrupt the migration (Parslow 1962, Lack & Parslow 1962, Lack 1963a). Consistent with these views, great differences between falls of night migrants are sometimes recorded at bird stations situated very close to each other.

Thus at Falsterbo high trapping figures were expected after those nights when rain and/or fog were noted between 00.00–06.00 hrs, meaning good capture mornings on 21/9, 23/9, 24/9, 27/9, 30/9, 1/10, (3/10) and 9/10. The close agreement between the prediction and the actual trapping figures prove that the latter are more dependent on the local weather factors than on the overall quantity of migrating birds during the night. These facts restrict or prevent the use of the night migrant falls in studies of many important aspects of nocturnal migration.

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