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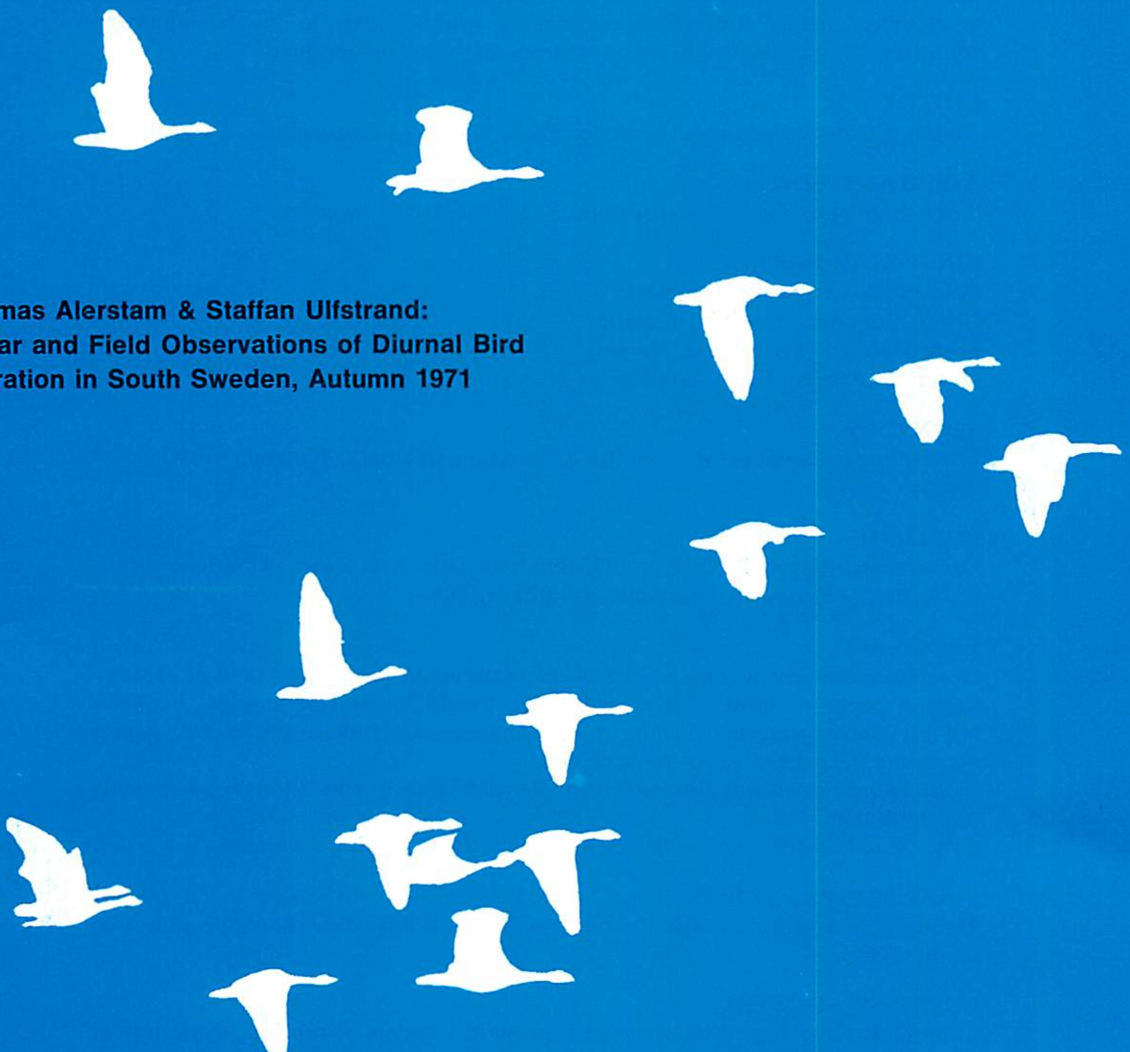

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Radar and Field Observations of Diurnal Bird Migration in South Sweden, Autumn 1971

THOMAS ALERSTAM & STAFFAN ULFSTRAND

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Two radar stations and five field observers recorded bird migration in S Sweden during autumn 1971. Large echoes chiefly comprised *Columba palumbus* flocks. A new pattern of anseriform migration across Skåne from E to W was discovered. Echoes, presumably reflecting *Fringilla coelebs* migration, showed little correlation in time and space with visible migration of the same species. High-flying passerines did not compensate for cross-winds and were unaffected by leading lines, whilst low-flying passerines compensated for cross-winds and were strongly affected by leading lines. The vast majority of all echoes recorded during the whole period passed in a few days with following winds. Visible migration was most intense under head-wind conditions. Reversed movements occurred regularly.

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INTRODUCTION

The rapidly rising frequency of collisions between birds and aircraft has attracted a great deal of attention to the problem of spatial and temporal bird density fluctuations in the air and to the factors governing these fluctuations. The study of bird migration, therefore, has turned into a subject of great applied significance. In the province of Skåne (Scania) in S Sweden a new civil airport is being constructed in the middle of an area known to harbour a very rich breeding avifauna and, more important from the view-point of air traffic safety, an exceptional abundance of birds during autumn passage migration. Therefore, ornithologists were called upon to examine the pattern of bird migration across and around the province of Skåne. Both military (Royal Swedish Air Force) and civil (Civil Aviation Board of Sweden) authorities have realized the importance of this work and have worked closely with the Ornithological Society of Skåne, which incorporates Falsterbo Bird Station.

In autumn 1971 the PPI's of two radar stations were filmed continuously during three weeks while five field observers recorded the visible migration (September 21 to October 10). As already mentioned, this region is blessed with an extraordinary abundance of migratory birds, and this allowed a very extensive material to be gathered in the course of this brief study period. The present report is devoted solely to the echoes recorded in daytime, and to the simultaneous field observations. The results concerning the nocturnal migration are given in Alerstam (1972). The chief aims of the present report were to identify the echoes in terms of bird species involved, describe major systems of diurnal bird

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migration, compare the results of radar registrations with field observations and interpret some of the numerous differences established, and briefly to comment upon the influence of wind and topography on the diurnal bird migration in the area. For reasons later to be explained, our study is primarily concerned with Chaffinch *Fringilla coelebs,* Common Buzzard *Buteo buteo,* Wood Pigeon *Columba palumbus,* and Eider *Somateria mollissima.*

Thanks to the pioneer studies of Rudebeck (1950) and later activities at Falsterbo Bird Station, we are familiar with the main features of the visible bird migration in Skåne. Of course it was early realized that this is only part of the story. Many birds were assumed to move at altitudes beyond visibility by conventional methods. Obviously the development of radar techniques and their application to ornithological research meant tremendous progress in this research area (Sutter 1957, Lack 1959, and later papers). Although the significance of radar is particularly great for our understanding of the process of nocturnal migration, the radar technique has also opened up entirely new vistas for the study of diurnal migration. Enthusiasm for this new tool has, however, in some cases led to a serious underestimation of the continued importance of careful and systematic field observations, and regrettably few attempts have been made to compare the results of radar studies with those acquired from field studies. It may be added that the comparisons that do exist (Mascher et al. 1962, Gehring 1963, Wilcock 1964) have been carried out under circumstances not likely to yield a large body of data about visible migration.

In recent years a larger number of radar studies have been carried out in the United States, Britain, Germany, Switzerland, Canada, Finland, Denmark, and elsewhere. Eastwood (1967) and Myres (1970) have supplied useful summaries of the information available.

STUDY AREA

The chief geographical features of the region of S Scandinavia within which the present study was carried out, and all place names mentioned in the text and tables, are summarized in Fig. 1. The approximately rectangular shape of the peninsula of Skåne and the straight course of its coast lines are significant features from the view-point of bird migration. It is also worth mentioning that the distance from W and SW Skåne to Denmark (Zealand) is so short that birds are able to see across the sea even when flying at a low altitude.

Much of SW Skåne consists of open agricultural land, but there are also extensive tracts of managed woodlands, the SW-most of which is situated around the new airfield (Sup on Fig. 1) at a distance of approx. 40 km NE of Falsterbo (Fbo). Malmberg (1955) and other local ornithologists believe that the migration routes of those species which for some reason prefer tree-covered landscapes, for example pigeons, finches and many birds of prey, are concentrated over these woodland areas.

Rudebeck (1950) has concluded that the main factors explaining the extraordinary autumn concentration of migrating birds in Skåne and, particularly, at Falsterbo are 1) their primary direction being approximately SW, and 2) their reluctance to move across the open sea, resulting in the coasts serving as leading lines.

For discussions of the terminology of bird migration we refer to Rudebeck (op. cit.), Geyr (1945), Mueller & Berger (1967), and Schüz (1971).

METHODS

Radar

During the investigation period two radar stations (Romele, R, and Malmö-Bulltofta, B) were filmed with time-lapse technique (2 and 10 frames/min, respectively). These stations (see Fig. 1) record bird echoes in mutually complementary ways. Thus, station B has a short wave length (10 cm), no MTI-system, and a limited range (60 km) within which, however, small echoes are well recorded. In contrast, station R has a longer wave length (23 cm), is equipped with an MTI-system, and has a wider range (135 km), in addition to which it has a better coverage of objects at low altitudes (see below). Station R, therefore, will miss quite a large proportion of small and slow objects whilst having an excellent coverage of large and fast echoes, and the opposite is true for station B, where large echoes tend to become obscured by the abundant small echoes.

The films obtained have been analysed with respect to types of echo, echo speed, and echo density. The ground speed of the echoes was estimated through plotting on maps and calculating the average distances per time unit

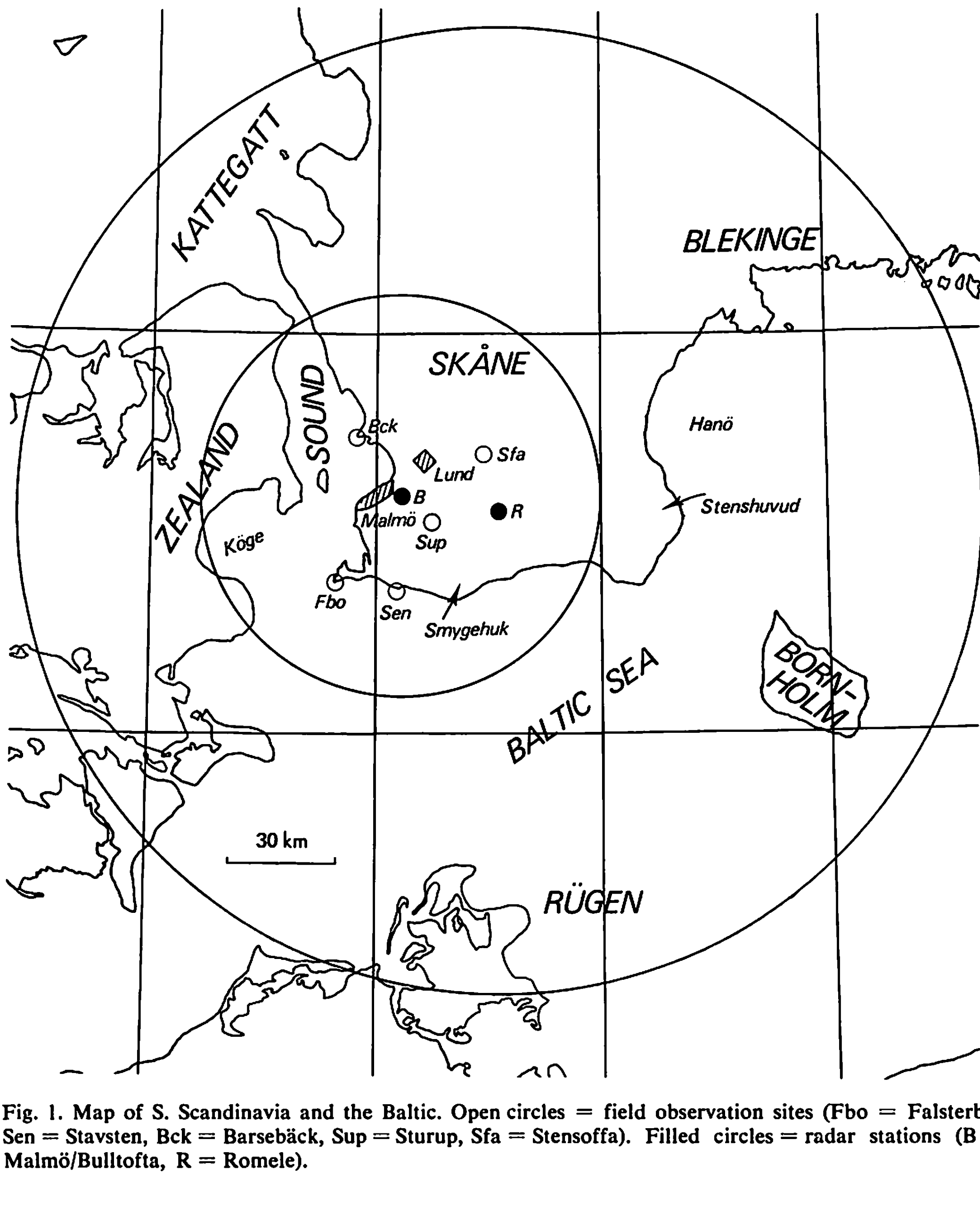


Fig. 1. Map of S. Scandinavia and the Baltic. Open circles = field observation sites (Fbo = Falsterbo, Sen = Stavsten, Bck = Barsebäck, Sup = Sturup, Sfa = Stensoffa). Filled circles = radar stations (B = Malmö/Bulltofta, R = Romele).

for 5 to 15 echoes. True air speed (TAS) and true heading were estimated using information of wind conditions from Malmö-Bulltofta at 600 m a.s.l. However, in many cases the reports of wind directions and velocities were imperfect, or ground speed estimations too inaccurate, so that in the following tables TAS information is wanting for a number of echo cohorts. Generally speaking we regard our TAS values as only approximate.

Through measurements of echo densities and velocities the magnitude of different echo cohorts could be quantified. For large echoes the records from station R were used. It was usually possible to count accurately the number of echoes passing over a certain front width during a given time period, so that the figures given in the tables are direct counts of echoes. Since some echoes moved outside the periphery of the zones within which we counted, our figures throughout are conservative. The question of the number of birds involved is briefly discussed on p. 136.

For the cohorts of small echoes the counting operation produced much less accurate figures, and we therefore had to transform the actual figures into a logarithmic scale as follows:

100– 300	echoes	= 2–
300– 800	"	= 2
800– 1000	"	= 2+
1000– 3000	"	= 3–
3000– 8000	"	= 3
8000–10,000	"	= 3+
10,000–30,000	"	= 4–
30,000–80,000	"	= 4

For the interpretation of radar records of bird migration, the altitudinal coverage of the radar beams is extremely important. The lowest altitude at which a certain target may be recorded by the radar primarily depends on its distance, its reflecting area, and the atmospheric temperature distribution which affects the propagation of the beams. Also the vertical azimuth of the beam lobe is important, and elevated land tracts may screen large areas from the reach of the radar beams (so-called radar shadow). Considering the variability of all these parameters it is obvious that one cannot define rigidly the lowest level at which a bird or bird flock may be recorded.

As a general rule, birds moving at tree-top height are invariably missed, and only seldom would birds moving at $<$ 100 m above ground be recorded. At wider distances, this level is of course, much higher. Thus, for example, the lowest height of a bird flock at 130 km from radar station R to be recorded would be in the order of 1000 m. However, the relationship between lowest level and distance from radar station is not linear. Thus, birds at a distance of, say, 70 km from station R are likely to produce echoes even if flying at a height of only a few hundred metres.

The analysis of the radar films from the present study revealed that radar station B is much more influenced by radar shadow phenomena and other disturbances causing incomplete coverage at low altitudes.

Field

The field observers were instructed to count as accurately as possible all birds flying through their field of vision from 0600 to 1400 hrs with a pause between 1030 and 1100 hrs. Figures were added up for each 30 min and for the whole day.

Particularly at Falsterbo, numbers of individuals and species are sometimes so immense that a single observer is unable to identify and count in such detail as is possible with lesser quantities involved. Naturally the observers' notes often contain entries such as 'unidentified passerines', 'probably finches', and so forth. We have decided that the best procedure is to lump all passerines except Starling *Sturnus vulgaris* under one heading. (Corvids hardly migrated during the study period.) Now it is a well-known fact, amply supported by the observers' records, that the vast majority of passerines seen on visible migration during autumn in Skåne are Chaffinches, in late autumn occasionally also Bramblings *Fringilla montifringilla*. Therefore we feel justified in using Chaffinch as a designation for the small passerines recorded by the observers. Among them are included a number of Skylarks *Alauda arvensis*, Linnets *Carduelis cannabina*, Reed Buntings *Emberiza schoeniclus*, Thrushes *Turdus* sp., Swallows *Hirundo rustica* and others. But we wish to point that all these other species rarely exceed 10 per cent of the total number of passerines, and often very much less. In some cases we shall mention separately migratory movements of certain passerines other than Chaffinch and Starling (see main tables).

The pigeons are labelled as Wood Pigeons disregarding the fact that a small proportion, probably in the order of one or two per cent, may in fact have been Stock Doves *Columba oenas*. Likewise, a small proportion of the birds of prey here called Common Buzzards may have been Honey Buzzards *Pernis apivorus* or Rough-legged Buzzards *Buteo lagopus*. In all these cases, however, the vast majority of the migratory cohorts are made up of the species whose name we use as a label for the whole cohort.

One must remember that field observers' notes about direction of migrating birds are often inaccurate. It is very difficult to determine the course of a bird flock travelling tangentially in relation to the observer. However, since there were topographical features to which the observers could relate their observations, the inaccuracy of their direction notes should not be overemphasized. There is, for example, no doubt about the recognition of so-called reversed migration (see p. 135).

Individual differences in terms of visual acuity and capability of estimating flock numbers are another source of error, as demonstrated by Enemar (1964) and Källander et al. (1970). Such differences between observers may lead to widely divergent results. We have to appreciate that the figures in the observers' records only show the order of magnitude of the visible migration. The errors are likely to be especially large when the birds move in a highly complicated way, turning back and/or passing over the observer in several directions simultaneously. Such behaviour occurs frequently, particularly when the birds approach the coast line (Rudebeck 1950).

It is self-evident that birds flying at low height are more likely to be seen by a field observer than those moving at high altitude. There are good reasons to assume that small passerines at $>$ 100 m altitude become under-represented in the records. On the other hand, a large pigeon flock or troup of migrating buzzards may be clearly visible at an altitude around 1000 m. For small birds, then, one might expect that the radar PPI's and field observers record almost totally separate bird cohorts, whereas for larger birds and birds which prefer travelling in large conspicuous flocks this is presumably not true, at least not to the same extent.

We wish to reiterate that although we have been forced to lump a number of species under a few headings, our study is in fact concerned with the four dominant diurnal migrants in Skåne during the season in question, viz. Chaffinch, Wood Pigeon, Common Buzzard, and Eider.

The observation sites were selected so as to yield information about the spatial pattern of migratory movements and to allow a comparison between coastal and inland stations. One observer was placed at Falsterbo (Fbo), a rather obvious choice. Another was placed at the S coast of Skåne to allow a comparison between numbers of birds following this leading line with those recorded to Fbo. Similarly, the W coast was studied by an observer at the Barsebäck peninsula. Two observers were posted inland, one of the sites being close to the future airfield (Sturup, Sup), and the other near the lake of Krankesjön (Stensoffa, Sfa). The location of these sites is shown on Fig. 1. The observers were B. Brodéhn, R. Edberg, G. Högstedt, G. Rudebeck and D. Wooldridge. In addition, G. Roos carried out observations at Fbo every second day from 1500 hrs to sunset.

EXPLANATION OF MAIN TABLES

Weather

Temperature: in°C, as recorded at Fbo at 0700 hrs.

Visibility: in km as recorded at Fbo at 0700 hrs.

Cloud cover: in eighths. The figure given is a mean of records from Malmö at 0700, 0900, 1100, 1300 and 1500 hrs. *Low* means cloud ceiling (base) mainly at 〈 300 m altitude, *high* means cloud ceiling mainly at 〉 1500 m.
Rain: Information from six meteorological stations in Skåne summarized.
Wind: in m/sec.

Radar observations

The quantification of radar cohorts and the calculation of true air speed was carried out as explained on p. 102. The information is tabulated as follows:
Cohort No. – Duration of movement – Main direction – Quantity of echoes – True air speed – Peak area(s) – Peak duration.

We have omitted from the tables echo cohorts obviously representing purely local movements, such as flights of larids and Starlings to and from roosting places.

Field observations

The field observers were posted at five sites as described above and shown in Fig. 1. Three localities are situated at the coast, and two inland. The information about visible migration is tabulated as follows:
Observation place – Species or group – Duration of movement – Direction – Quantity of birds – Peak duration.

Field observations commenced on September 21, but since neither of the radar stations were in operation on that date, it has been completely omitted.

MAIN TABLES WITH COMMENTS

September 22

Weather

Temperature: 13.0	Cloud cover: 5.2 (low)	Wind:	0700	1300
Visibility: 7	Rain: nil	Fbo	SW 7	W 2
		Lund	SW 1	WSW 1
		Malmö	WSW 10 (at 600 m)	

Radar observations
Radar station R out of operation

Large echoes: None

Small echoes:

I	0540–0930	SE	2+	55	Throughout	0745
II	0630–0915	ENE	2–	–	–	–
III	1045–1500	SE	2+	55	Köge Bay	1200
IV	1545–1815	SSE	2–	–	Throughout	1700

Field observations

Fbo	Chaffinch	0600–0800	W/SW	700	–
	Starling	0600–0900	W/SW	1500	–
Sen	Swallow	0630–1200	W	900	–
Bck	Chaffinch	0600–1130	W	300	–
Sup	Very little				
Sfa	Swallow	0630–1300	SW	1100	–

Comments

Field observers noted considerable Swallow activity. We suggest that the radar in fact recorded high altitude Swallow movements. Generally, this day was characterized by low migratory activity.

September 23

Weather

Temperature: 11.8	Cloud cover: 5.8 (low)	Wind:	0700	1300
Visibility: 0.3	Rain: nil	Fbo	E 5	E 10
		Lund	0	SE 3
		Malmö	variable 3 (at 600 m)	

Radar observations

Radar station R out of operation and B closed until 0800.

Large echoes: None

Small echoes:

I	0800[1]–1300	SSW/SW	3	–	–	–
II	0800[1]–0930	NE	2	–	Throughout	0845

Field observations

Fbo	Chaffinch	0700–1100	W/SW	2200	0800
	Swallow	0700–1100	W/SW	450	1030–1100
	Starling	0700–1030	W/SW	1000	0730–0800
Sen	Chaffinch	0700–1030	SE	5000	0800–1000
Bck	"	0730–1030	S	2500	0830–0930
	Starling	0630–0700	W	1500	–
	Chaffinch	0600–1200	S	160	–
Sup	"	0600–1000	NE	250	–
	Swallow	0600–1400	SE	300	–
Sfa	Chaffinch	0600–1200	S/E	2200	0600–0700, 1000–1200
	Swallow	0700–1200	S/E	250	0700–0800, 1145

[1] From the start of radar station B.

Comments

The main radar movement had a strong westerly component and probably reflected finch migration (cf. Fbo and Bck). The extensive E-bound movements seen by the field observers at Sen and at the inland stations were almost entirely missed on the radar.

September 24

Weather

Temperature: 14.3	Cloud cover: 6.6	Wind:	0700	1300
Visibility: 1.5	Rain: heavy and extensive	Fbo	S 5	SSW 10
		Lund	E 3	SSW 4
		Malmö	S 5 (at 600 m)	

Radar observations

Large echoes: None

Small echoes:

I	0550–1000	N	3	–	–	–
II	0700–1000	S[1]	2	–	–	–
III	0800–1000	ESE	2	–	S Sound	0815
IV	1630–1800	ESE	2	–	S coast	1700

Field observations					
Fbo	Chaffinch	0630–1230	W/SW	5500	0900–1030
	Swallow	0700–1300	W/SW	1200	0730–0930
Sen	Very little				
Bck	Chaffinch	0700–1030	S (W)	1800	0700–0830
Sup	Very little				
Sfa	"				

[1] Highly variable direction, but with some preponderance towards S.

Comments

Rapidly changing weather situations made the migratory pattern complicated. A rain front moved due N and passed the S coast at 0500 hrs. At 0550 hrs the extensive rain area was followed by showers, the last of which invaded the S coast at 0715 hrs. In the wake of these showers radar echoes appeared over the Baltic moving NW to NE in over Skåne. From around 0700 hrs the echo tracks over the sea became disoriented, some proceeding northwards, others moving back over the sea, and still further ones with no distinct direction. Echoes decreased from 0800 hrs, and none were seen after 1000 hrs. These movements are labelled as Nos. I and II. Cohort No. III was completely distinct from I and II. Very low daily totals were reported by all field observers, suggesting that the bird movements seen on the radar were largely invisible from the ground.

September 25

Weather				
Temperature: 11.4	Cloud cover: 6.2	Wind:	0700	1300
Visibility: 30	Rain: small amounts but widespread	Fbo	W 14	W 13
		Lund	WSW 5	WSW 4
		Malmö	WNW 15 (at 600 m)	

Radar observations						
Large echoes:						
I	0700–0730	ESE	10	–	–	–
II	1100–1300	SSE	10	–	–	–
Small echoes:						
III	0540–0830	E	3–	–	Sound	0630
IV	0930–1430	SE/ESE	3	45	N Sound	1045
					S Sound	1015, 1130
					S coast	1200
V	1730–2000	S/SSE	2–	65	–	–

Field observations					
Fbo	Chaffinch	0600–0930	W/SW	1100	–
Sen	Very little				
Bck	"				
Sup	"				
Sfa	"				

Comments

Cohort I departed from SE Skåne, and similar echoes arrived from the Kattegatt around noon. The latter echoes moved along the W coast of Skåne, and some turned inland near Malmö. Like these large echoes, small echoes had a E/SE direction. Many of them crossed the Sound from Zealand. Later a new cohort appeared (IV) from Zealand and Skåne probably consisting of two sub-groups, viz. one crossing the Sound in its northern part with a SE direction and its main peak around 1045 hrs and leaving the S coast around noon, and another crossing the Sound in its middle and southern parts, keeping a more ESE-ly direction and showing a double peak at 1015 and 1130 hrs. Both these movements abruptly ceased at 1430 hrs. The field observers noted practically no visible migration during this day.

September 26

Weather

Temperature: 11.1	Cloud cover: 4.6 (high)	Wind:	0700	1300
Visibility: 30	Rain: nil	Fbo	W 10	WNW 8
		Lund	WSW 1	W 1
		Malmö	WNW 5 (at 600 m)	

Radar observations

Station B had incomplete coverage before noon.

Large echoes:

I	0615–1500	S	100	65	–	–	
II	0530–1700	WSW/SW	150	65	Stenshuvud	1115	1245
					Fbo	1245	1415
III	0600–1800	S	20	–	–	–	
IV	1100–1600	W	40	80	–	–	

Small echoes:

V	0615–1000	S	4	45	Bck	0630–0730, 0830–1000
VI	1100–1200	ENE/E	2+	–	S coast	1115–1200
VII	1600–1845	S/SW	3–	55–60	Sound	1700

Field observations

Fbo	Wood Pigeon	1030–1400	W/SW	1200	1230–1300
	Chaffinch	0600–1400	W/SW	56,000	0830–1030
Sen	Common Buzzard	1230–1330	W	40	–
	Chaffinch	0600–1330	W	150,000	0700–0930
Bck	Wood Pigeon	0900–1330	W	800	–
	Chaffinch	0700–1030	W	5000	0900–1000
Sup	Wood Pigeon	0600–1030	SW	350	–
	Chaffinch	0600–0930	SSW	6000	0600–0830
	"	0800–1330	NE	1500	0900–1030
Sfa	"	0600–0930	SW	8000	0630–0800
	Siskin	0600–1000	SW	600	–

Comments

This was the first day with a relatively high number of large echoes (Fig. 2). Cohort I mainly moved over the Sound, while No. II echoes moved more or less due W over much of Skåne and the Sound. No. III was confined to a more restricted corridor over Central Skåne. Many of the No. II echoes appeared over the NE-most part of Skåne or over Hanö Bay, and some followed the E coast for a distance until they turned SW in over land just north of Stenshuvud. They could be followed until they departed over the S or W coast. Cohorts II and III differed radically with respect to their direction.

Small echoes were detected in two compact waves moving S over the Sound, and the peaks recorded for cohort V were extremely well delimited and conspicuous. These waves appeared as congestions in a steady S-bound movement for much of the forenoon. The

S coast caused many echoes to deviate and follow it due W for some distance, but later they resumed their S-bound course. E-going echoes were numerous before and around noon moving over or off the S coast.

A peak of large echoes over the Fbo peninsula nicely coincided in time with observations of Wood Pigeon flocks. Large echoes in the Bck area may also be safely associated with migrating Wood Pigeons. Cohort IV probably consisted of Eider, Wigeon *Anas penelope* and Brent Goose *Branta bernicla* flocks according to observations at Falsterbo in the afternoon.

The second peak of No. V coincided with field observations of finch migration at Bck, but the first peak has no counterpart in the field records. There seems to be a good connection between the heavy finch passage observed at Fbo and Sen and dense small echo concentrations over and around SW Skåne.

E-bound small echoes were particularly prominent this day. Corresponding movements were noted in the inland at Sup, but the still more distinct passage along or off the S coast remained unnoticed by the field observers.

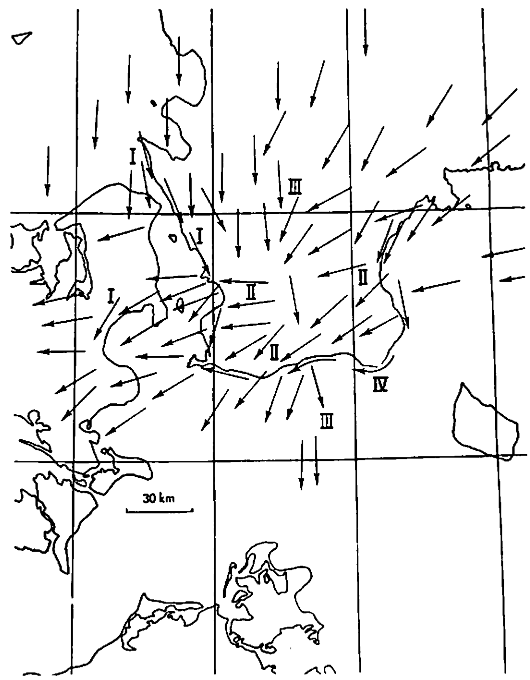


Fig. 2. Movements of large echoes, cohorts I to IV. September 26.

September 27

Weather

Temperature: 10.8	Cloud cover: 6.0	Wind:	0700	1300
Visibility: 15	Rain: moderate quantity,	Fbo	ENE 8	E 12
	restricted area	Lund	ESE 6	SE 5
		Malmö	E 5 (at 600 m)	

Radar observations

Large echoes						
I	0600–1800	SW	900	65	Central Skåne Fbo	0630–0800 0745–0815
II	1000–1730	W/WSW	350	65	Stenshuvud Malmö	1200–1400 1430–1600
III	0600–1730	W/WSW	250	75	–	1330–1430
Small echoes						
IV	0530–1030	W/NW	4–	40	W Skåne N Sound Smygehuk Fbo Smygehuk[1]	0545–0615 0615–0715 0715 0745 0845
V	1630–1830	W	2			–

Field observations					
Fbo	Eider	0600–1400	W	7100	0800–0900
	Buzzards[2]	0830–1400	W	65	–
	Wood Pigeon	0830–1230	W	21,000	0830–0930, 1015, 1145
	Chaffinch[3]	0630–1100	–	(20,000)	0730–1030
Sen	Eider	0700–1030	W	9500	–
	Chaffinch	0600–0730	W	3000	–
	"	0730–1030	E	24,000	–
Bck	"	0600–1030	W	5000	–
	"	0600–1000	SE	4500	–
Sup	Wood Pigeon	0600–1400	SW	700	0615
	Chaffinch	0600–0900	S	1400	0600–0730
	"	0700–1230	NE	1000	0730–1000
Sfa	Wood Pigeon	0630–1100	SW	1900	0630–0730, 0800–0900, 1015
	Chaffinch	0730–0900	SW	150	–
	"	0800–1400	NE/SE	1900	–
	Siskin	1200–1400	NE	500	–

[1] Direction SSW. [2] 43 Honey Buzzards, 15 Common Buzzards. [3] Complex behaviour, see under Comments.

Comments

Large echoes (I) appeared over NE Skåne and moved SW with most of the activity before 1000 hrs (Fig. 3). Cohort II took over from that hour but did not culminate until around noon and later. These echoes were detected NE of Stenshuvud and crossed Skåne with an almost due westerly direction, departing over the Sound towards Denmark mainly between Fbo and Malmö. Cohort III consisted of echoes moving far off the coast over the Baltic.

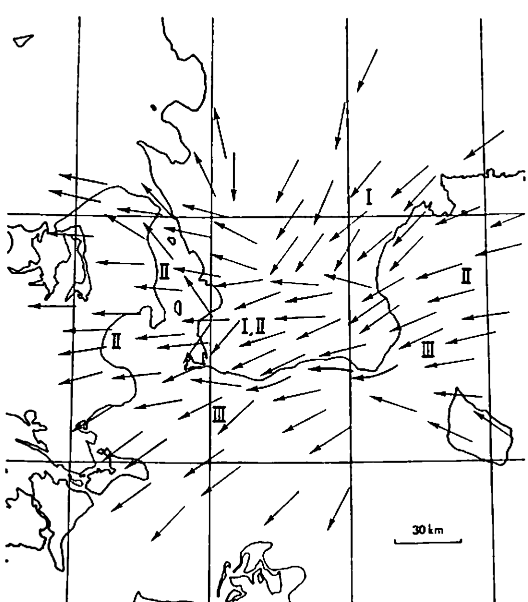


Fig. 3 Movements of large echoes, cohorts I to III. September 27.

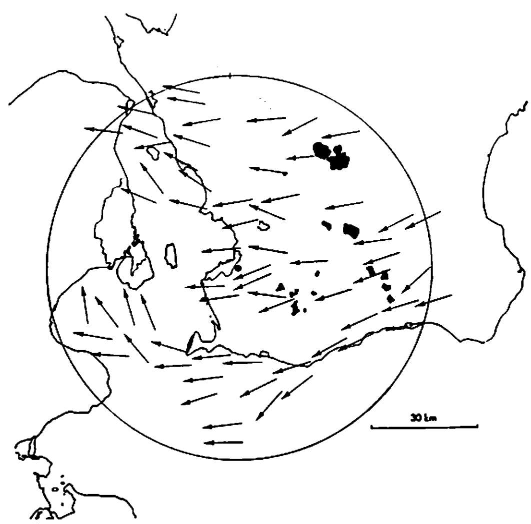


Fig. 4. Movements of small echoes, cohort IV. September 27.

Small echoes (Fig. 4) departed from Skåne chiefly in two zones, viz. over the northernmost Sound and over the Fbo peninsula, later to some extent also over the western third of the S coast.

The visible migration at Fbo was characterized by a heavy passage of Wood Pigeons with three more or less distinct peaks which, however, are not possible to associate with any of the large echo movements over Skåne. Yet we regard it as almost certain that the large echoes did reflect Wood Pigeon migration. There were also a small number of buzzards over Falsterbo which may have contributed to producing large echoes, but we consider it unlikely that buzzards made up a significant portion of the large echoes; first, because their numbers were fairly low, and second, because echo behaviour did not agree with buzzard behaviour (cf. September 29).

The very heavy Eider passage off the S coast was reflected in a number of echoes (III).

Finches behaved at Fbo in a highly complex way. Fairly large numbers were active, but almost all turned back over Fbo. According to the observer, Chaffinch flocks could be seen moving in almost all directions most of the time, and it is very doubtful if any of them in fact departed from Sweden. At Sen and the inland stations, return movements with easterly directions were very conspicuous, and quantities involved were often larger than in the W-going movements. At Bck, on the other hand, some of the Chaffinches seemed to depart over the Sound. It is to be noted that the radar showed no trace of the very heavy E-going movements of passerine birds.

As a matter of fact, the 'hesitating' behaviour exhibited by the finches also occurred among the buzzards and pigeons at Falsterbo, although in these cases it was possible to estimate how many eventually managed to cross the Sound.

September 28

Weather

Temperature: 11.2	Cloud cover: 6.0	Wind:	0700	1300
Visibility: 25	Rain: small amounts, restricted area	Fbo	ENE 8	ESE 11
		Lund	E 6	SE 5
		Malmö	E 10 (at 600 m)	

Radar observations

Large echoes:							
I	0600–1800	WSW/SW	350	60–70	Smygehuk	0645–0715	
					Fbo	0645–0900	
					Central Skåne	0645	
					Central Skåne[1]	1700	
II	0600–1800	WNW/WSW	350	65	Stenshuvud	{1015–1145	{1345–1445
					Zealand	{1130–1300	{1530–1645
Small echoes:							
III	0510–0900	W/WSW	4–	35	Sound, Central Skåne	0545	
					Fbo, Smygehuk	0600–0730	

Field observations

Fbo	Buzzards[2]	0600–1200	W	250	–
	Wood Pigeon	0630–1100	W	14,000	0630–0800, 1045
	Chaffinch	0600–1100	W	5000	0600–0800
	"	0600–0730	E	1000	–
Sen	Wood Pigeon	0600–0700	W	800	–
	Chaffinch	0630–1130	E	24,000	0600–0730

Bck	Common Buzzard	0730–1030	SW	110	–
	"	0830–1000	SE	35	–
	Chaffinch	0630–0830	W	3000	–
Sup	Wood Pigeon	0600–1400	S	3000	0930–1200, 1315
	"	1100–1230	SE/E	900	–
	Chaffinch	0600–0800	S	200	–
	"	0600–1300	NE	700	–
	Siskin	0600–1400	SE	200	–
Sfa	Very little migration				

[1] Direction SW.
[2] 225 Common Buzzards, 15 Rough-legged Buzzards and 10 Honey Buzzards.

Comments

Qualitatively as well as quantitatively the radar picture closely resembled yesterday. The large echoes during their peak period in the early morning were gathered in an extremely narrow corridor (width less than 5 km) over the S part of the Fbo peninsula, the Sound and Zealand. Like yesterday, this SW-bound cohort (I) sharply differed from a more due W-going one (II). Echoes belonging to the latter never passed over Falsterbo but departed over the W coast towards Zealand. Echoes frequently deflected from their main direction over coast lines.

Small echoes moved over a broad front in the morning. Many left for Zealand with a due W direction.

The field observers reported generally less migration than yesterday. In contrast to the preceding day, pigeons culminated at Fbo quite early. Over the inland stations small numbers of Wood Pigeons were recorded without distinct activity peaks.

Buzzard migration at Fbo started at an uncommonly early time in the morning and proceeded with a low and even intensity up to noon. At Bck Common Buzzards were comparatively numerous and were divided into two groups, one departing over the Sound and the other following the coast line towards SE.

Finches, as the previous day, exhibited a strong inclination for reversed movements at all stations apart from Bck. Except at Sen, quantities involved were modest.

The correlation in time between large echoes (I) and Wood Pigeon passage at Fbo is quite close. The E-bound passerine movements were not detected on the radar PPI's.

September 29

Weather

Temperature: 10.5	Cloud cover: 4.2 (high)	Wind:	0700	1300
Visibility: 6	Rain: nil	Fbo	ENE 4	ESE 9
		Lund	ENE 7	E 8
		Malmö	SE 5 (at 600 m)	

Radar observations

Radar station B out of operation until 1000 hrs.

Large echoes:

I	0630–0745	SSW/SW	15	–	–		–		
II	0530–1800	W/SW	1500	60–70	E. Skåne	0515	0745	1000	1215
					Smygehuk	0715			1215
					Fbo	0630–0845			1015
					Zealand	0645	0830		1700
III	1000[1]–1700	SW/S	100	60	Off Smygehuk		1000	1215	1500

Small echoes:						
IV		1000[1]–1130 WSW/SSW		3	50	–	–
V		1700–1830 SW		2+	50–55	–	–
Field observations						
Fbo	Common Buzzard	0800–1400	W	580	0930–1030, 1100–1130	
	Wood Pigeon	0630–1300	W	5000	0700–0800	
	Starling	0600–1000	W	1800	-	
	Chaffinch	0600–1000	W	1300	-	
Sen	Wood Pigeon	0600–0830	W/SW	2000	0630–0700	
	Chaffinch	0600–0800	SW	13,000	-	
	"	0630–1030	E/SE	29,000	-	
Bck	Wood Pigeon	0630–0730	W	800	-	
	Chaffinch	0600–0830	W	8500	-	
Sup	Wood Pigeon	0600–1400	SW	800	-	
	Chaffinch	0630–0730	NW	150	-	
	"	0600–1030	E	1000	-	
	Swallow	0730–1400	S	500	0930–1200	
Sfa	Chaffinch	0630–0800	SW/SSE	400	-	

[1] These cohorts were mainly visible on the B radar which was out of function until 1000 hrs.

Comments

The pattern of large echo movements again closely resembled that of the preceding two days with one cohort moving in a broad front towards SW, another, starting somewhat later in the morning, crossing Skåne with an almost due W-ly course. However, these two cohorts were not so sharply differentiated as on the two preceding days and have therefore been combined in the above table (II). Cohort I is made up of a small number of fairly large echoes following the W coast towards SSW.

When the B radar came in operation, it showed a number of echoes of remarkable behaviour (Fig. 5). They moved SW over land, but when reaching the S coast they turned and followed it for shorter or longer

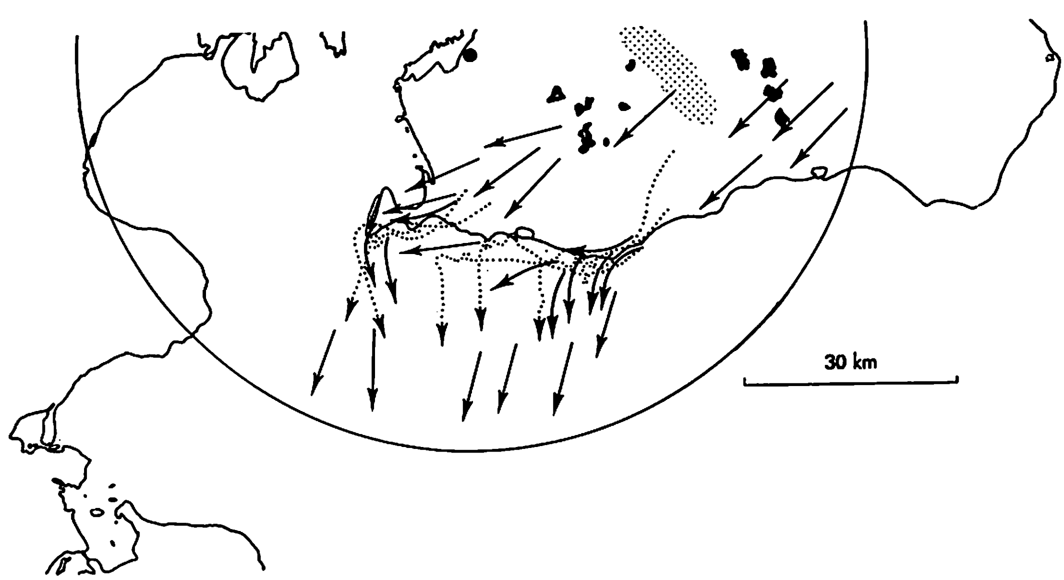


Fig. 5. Echoes of Common Buzzards *Buteo buteo* on passage migration. September 29.

distances, frequently changing speed and course, in some cases conspicuously circling, before, suddenly, they turned almost 90° and proceeded over the Baltic with an almost due S course. During and just after this very conspicuous turn, they appeared to move faster than otherwise. This is our clearest observation of buzzard migration on the radar screen.

Small echoes were numerous in the early morning and again displayed an evening peak with echoes departing towards SW.

The observer at Fbo noted the second highest daily total of migrating Common Buzzards during the investigation period. They exhibited two rather distinct peaks. There was much hesitation and soaring before they departed. Scattered pigeon flocks were also seen, while passerine migration was very weak. Elsewhere pigeons and finches were recorded in moderate quantities, the latter showing a strong inclination for reversed migration.

Buzzard migration was fairly well covered by radar and the observer at Fbo, but it is remarkable that the observer at Sen, in particular, only saw a very small number of buzzards. Also the pigeon flocks were nicely correlated between radar and field observers. The radar indicated a fairly heavy SW-going movement of passerines which was largely invisible to the observers while, by contrast, the observers but not the radars recorded considerable reversed movements.

September 30

Weather						
Temperature: 12.6		Cloud cover: 7.2 (low)		Wind:	0700	1300
Visibility: 7		Rain: rather heavy and extensive		Fbo	SW 5	SSW 8
				Lund	SE 1	S 1
				Malmö	SSW 5 (at 600 m)	
Radar observations						
Large echoes: None						
Small echoes:						
I	0530–0800	(SSE)	+	–	–	–
Field observations						
Fbo	Chaffinch	0600–1230	W	7000	–	
	Starling	0600–1000	W	1400	–	
Sen	Chaffinch	0630–0730	W	200	–	
	Swallow	0600–0700	W	200	–	
Bck	Very little migration					
Sup	Chaffinch	0700–1030	W	300	–	
Sfa	Very little migration					

Comments

The only echoes recorded behaved differently from any other occasion. At around 0530 hrs a flush of small echoes appeared in the Malmö area moving in all directions with a slight preponderance for SSE. In part of the area these echoes encountered heavy rain. A new rain front moved in from the W around 0700 hrs, and simultaneously all the echoes disappeared. For the rest of the day the PPI's were exceptionally devoid of bird echoes.

Very little visible migration was recorded by the observers. Adverse weather probably explains the low activity and the aberrant behaviour of the early morning echoes.

October 1

Weather

Temperature: 14.0	Cloud cover: 6.4	Wind:	0700	1300
Visibility: 3.5	Rain: nil	Fbo	W 7	W 7
		Lund	W 3	WSW 5
		Malmö	W 7 (at 600 m)	

Radar observations
Radar station B out of operation.

Large echoes:						
I	0800–1000	SW	15	–	–	–
II	1600–1830	ESE	+	–	SE Skåne	1800
Small echoes:						
III	0545–1030	SSE	3+	–	Smygehuk	0545–0630, 0800
IV	0600–1200	E	+	–	Sound	0600–0630

Field observations

Fbo	Chaffinch	0600–1400	W	40,000	0930–1200
Sen	"	0930–1230	W	7500	1100–1200
Bck	"	0800–1130	W	13,000	–
Sup	Wood Pigeon	0630–1400	SW/NW	1100	0600–0730
	Chaffinch	0600–1400	SW/NW	1900	–
	"	0830–1030	NE	300	–
Sfa	Very little migration				

Comments

While large echoes were few, small echoes were rather numerous. Particularly the second peak of cohort III reflected massive movements. The echoes of No. IV emerged over W Skåne, partly also from Zealand. It is noteworthy that all small echoes moved E or SE. The scarcity of large echoes is in agreement with the findings of the observers, who did not report any significant numbers of pigeons or buzzards. The high density of small echoes also agrees with large numbers of small birds, chiefly Chaffinch, recorded on migration, but it is important to realize that while the echoes moved about SE, the passerines seen by the observers held a SW-ly course.

The evening movement (No. II) consisted of echoes moving somewhat faster than typical small bird echoes and continued without interruption into nocturnal migration. We cannot decide what species were involved in this movement, although thrushes may seem a reasonable guess.

October 2

Weather

Temperature: 14.2	Cloud cover: 5.8	Wind:	0700	1300
Visibility: 3	Rain: nil	Fbo	WSW 8	W 9
		Lund	W 3	WSW 6
		Malmö	WNW 13 (at 600 m)	

Radar observations

Radar station B out of operation until 1230.

Large echoes: None

Small echoes:

I	0530–1000	SSE/SE	3	–	SE Skåne E of Smygehuk	0645 0730
II	0545–0930	E/ESE	2	–	Sound	0620
III	1500–1900	SSE/SE	3–	65	S coast	0620

Field observations

Fbo	Chaffinch	0600–1400	W	225,000	0800–1300
Sen	"	0630–1300	W	105,000	0730–1100
Bck	"	0600–0930	W	14,000	0730–0800
Sup	Wood Pigeon	0900–0930	S	1000	–
	Chaffinch	0600–0830	SW	2500	–
	"	0730–1400	N	1800	–
	Siskin	0600–0830	S	400	–
	"	0830–1130	N	500	–
Sfa	Chaffinch	0630–0830	SW	3500	–
	Siskin	0630–0700	SW	300	–

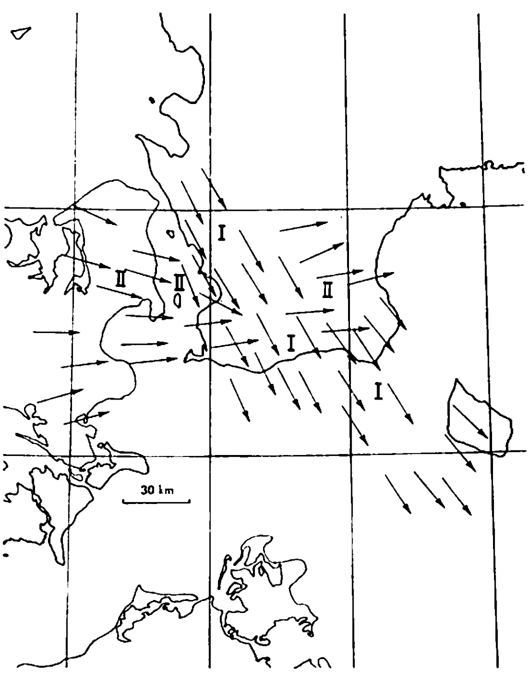


Fig. 6. Movements of small echoes, cohorts I and II. October 2.

Comments

Small echoes occurred in moderate quantity (Fig. 6). Many were first seen following the W coast towards SSE. Later they crossed over Skåne and departed, early in the morning, from around Stenshuvud and the SE corner of Skåne, later chiefly over the E third of the S coast. A few echoes (No. II) kept a more due E-ly course, arriving from over the Sound. The SW corner of Skåne remained remarkably empty of radar echoes throughout the day.

The field observers at all three coastal stations unanimously reported one of the season's heaviest finch passages, the birds moving more or less due W. Thus this day represents an outstanding case of almost diametrically opposed versions of bird migration as studied by radar and by field observers, respectively. Little migratory activity was noted by the observers apart from the finches.

October 3

Weather

Temperature: 13.2	Cloud cover: 6.4	Wind:	0700	1300
Visibility: 2	Rain: small quantity, restricted area	Fbo	SW 5	WNW 7
		Lund	W 1	W 2
		Malmö	W 12 (at 600 m)	

Radar observations

Large echoes:						
I	1045–1300	SSE/SSW	45	70	NW Skåne	1045
					Fbo	1200
Small echoes:						
II	0515–0730	SE	3	40	throughout	0545
					E of Smygehuk	0645
III	0630–0745	SSE	3–	40	Sen	0645
					E of Smygehuk	0745
IV	0730–1100	S/SSE	3	50	N Sound	0745
					Malmö	0845
					Sen	0915
					Smygehuk	0945
V	0930–1430	S/SSE	3	45	N Sound	1045
					Malmö	1100
					Smygehuk	1145
					Sen	1215
VI	1500–1900	S/SSE	2	55	Smygehuk	1700

Field observations

Fbo	Wood Pigeon	1130–1330	W	1400	–
	Chaffinch	0600–1400	W	39,000	0700–0900
Sen	"	0600–1100	W	20,000	0830–1000
Bck	"	0600–1200	W	14,000	0800–0830
Sup	Wood Pigeon	0630–0900	SW	900	–
	Chaffinch	0600–1230	SW	5000	0600–1000
Sfa	"	0630–0830	SW	1000	–

Comments

While this day featured only a limited number of large echoes, most of which were recorded over the W coast, small echoes appeared in large numbers and in several highly distinctive systems (Figs. 7 and 8). No. II consisted of a broad front wave originating in part from Zealand, in part from NW and N Skåne. In its early phase, this movement led to departures over the Stenshuvud area, later over the E third of the S coast. Echoes could frequently be traced moving in the area around Bornholm. While this movement was still in progress, a clearly separable one (III) originated near the S coast. These echoes departed in a narrow corridor, which gradually transferred towards E like No. III. No. IV was most clearly

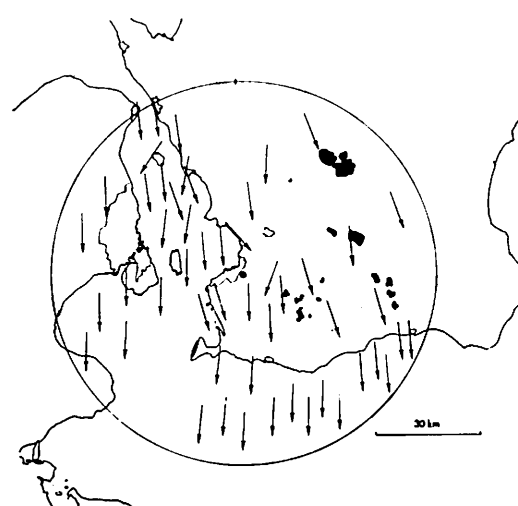
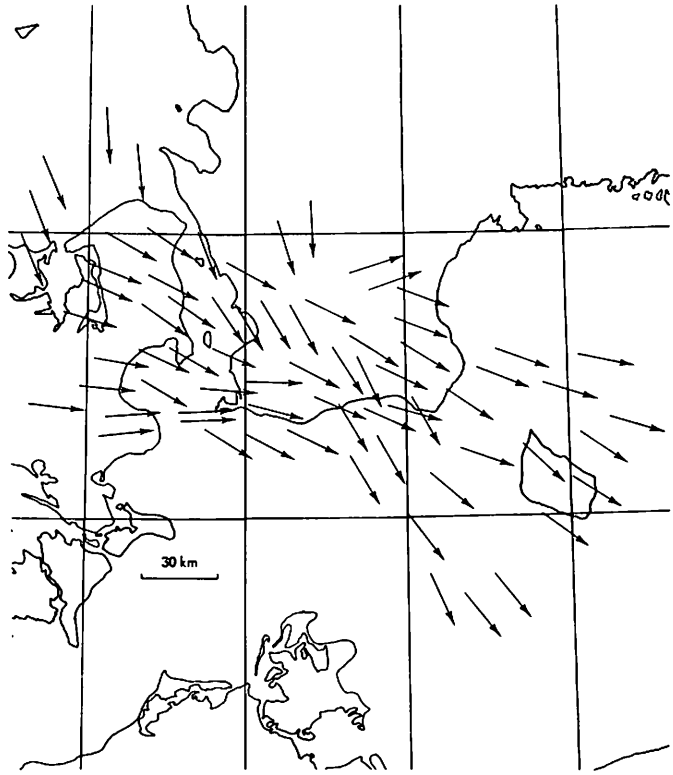


Fig. 7. Movements of small echoes, cohort IV, according to radar station B. October 3.

Fig. 8. Same as Fig. 7 but based on radar station R.



seen over the sea. At least a considerable portion of the last-mentioned cohort consisted of echoes invading Zealand and NW Skåne from the Kattegatt. Again, a highly distinctive cohort (V) built up first over NW, later over the whole N part of Skåne, and developed into a massive broad front passage over the entire width of Skåne. Finally it may be pointed out that the evening movement consisted of echoes having a slightly but distinctly higher speed.

Small numbers of Wood Pigeons were noted at Fbo during a period which fitted in with large echoes No. I. The Wood Pigeons recorded at Sup, however, did not fit in with the radar picture. As regards the small echoes, they do not agree with the observers' records at all, either in time or in direction. One is justified in assuming that radars and field observers were recording totally different migratory systems.

October 4

Weather

Temperature: 10.2	Cloud cover: 1.0	Wind:	0700	1300
Visibility: 30	Rain: nil	Fbo	NW 15	NW 17
		Lund	NW 3	NW 7
		Malmö	N 15 (at 600 m)	

Radar observations
Radar station B out of operation until 0800 hrs.

Large echoes:							
I	0630–1300	S/SSW	425	75	NW Skåne	0700	
					S Sound	0745	
					NW Skåne	0900	
					Bck	1015	
II	0600–1300	SW	800	65	Central Skåne	0615	0915
					S coast	0715	1045
					Central Skåne	0745	
					S coast	1145	
III	0600–1300	SW	350	65	Stenshuvud	0830	
					"	1015	
					E of Smygehuk	1115	
Small echoes:							
IV	0800–1200	S	4	45	–		
V	1500–)1830	S	4–	50	Throughout	1700–1800	

Field observations

Fbo	Common Buzzard	0630–1300	W	470	0900–1200
	Wood Pigeon	0630–1330	W	13,000	0630–0830, 0945, 1045,
Sen	Common Buzzard	0700–1230	W	220	0900–1030
	Wood Pigeon	0600–1400	W	24,000	0600–0730, 1130–1230
	Chaffinch	0600–0930	W	39,000	0700–0830
Bck	Wood Pigeon	0630–1200	W	6000	0645, 1000–1130
Sup	Common Buzzard	0630–1400	SW	140	1015
	Wood Pigeon	0600–1400	SW	9000	0700–0800, 0930–1200
	Chaffinch	0600–0900	SW	1200	–
	"	0600–1400	N	300	–
Sfa	Wood Pigeon	0600–1200	SW	8200	0600–0700, 0930–1130

Comments

One of the chief characteristics of this day was the extremely great number of large echoes (Fig. 9). Cohort I was restricted to the NW part of Skåne and the Sound region. Many echoes appearing over the NW promontories followed the W coast towards SSE, turning SW over the Bck area and disappearing over Zealand. No. II was a massive broad front movement over the entire width of Skåne, while No. III was restricted to the E and SE parts of the province, echoes deriving from over the Hanö Bay and departing over the E half of the S coast. Not mentioned above is a minor number of echoes travelling SSW over the Baltic E of Bornholm.

As the B radar came into function at 0800 hrs, vast quantities of small echoes were seen on the PPI. The frequency was already decreasing and reached a low level at noon. These echoes moved S/SSW over a broad front and did not display any reaction in terms of direction change when reaching the S coast. A new peak built up in the afternoon and reached almost the same magnitude as the morning peak. This means that this afternoon movement was the fourth strongest small echo activity recorded during this study, only surpassed by the morning movements of September 26, and October 4 and 5.

The most important field observations concern a heavy movement of Wood Pigeons. It seems safe to conclude that most of the large echoes in fact represented pigeon flocks. Also Common Buzzards were moving in fair num-

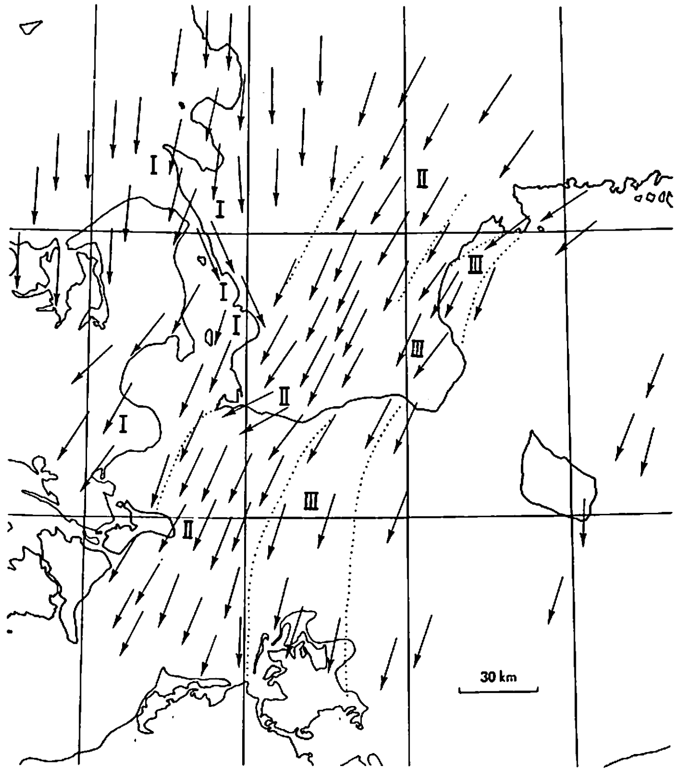


Fig. 9. Movements of large echoes, cohorts I to III. October 4.

bers over Fbo and Sen. No typical 'buzzard echoes' were seen today, presumably because other types of large as well as the immense density of small echoes hid them from view. Only at Sen and, to a lesser extent, at Sup were small birds seen migrating. Reverse movements were distinctly scarce this day.

There is a good agreement between the passage of Wood Pigeon flocks as recorded by the observers and the temporal and spatial distribution of Cohorts I and II. On the other hand, the extraordinarily strong passerine movement revealed by radar was almost completely invisible to the observers.

October 5

Weather

Temperature: 5.0	Cloud cover: nil	Wind:	0700	1300
Visibility: 30	Rain: nil	Fbo	NNE 4	N 7
		Lund	N 1	NNW 1
		Malmö	N 9 (at 600 m)	

Radar observations						
Large echoes:						
I	0630–1200	S/SW	250	60	NW Skåne S Sound	0715, 0900 0830
II	0600–1200	SW	1550	60	Central Skåne S Sound Fbo, Smygehuk	0645 0830 0945 0715 1015 0745 0915 1015
III	0630–1200	SW	200	60–75	E of Smygehuk Hanö Bay	0645, 0745 0945
IV	0700–1400	W	10	–	S of Bck	1245
V	0645–0715	WSW	–	70	–	
Small echoes:						
VI	0530–0900	S/SSW	4	45	Throughout	0615
VII	1615–1815	S	3–	50	Throughout	1700

Field observations					
Fbo	Eider	0630–0800	W	1000	–
	Common Buzzard	0600–1400	W	1400	0800–1200
	Wood Pigeon	0600–1400	W	12,000	0540–0800, 0930–1230
Sen	Common Buzzard	0800–1300	W	370	0900–1030
	Wood Pigeon	0600–1300	W	31,000	0600–0700, 0930–1030
	Starling	0630–0930	W	4100	0630–0730
	Chaffinch	0600–0830	W	13,000	–
Bck	Wood Pigeon	0600–1230	W	12,000	0600–0700, 0945, 1100–1200
Sup	Common Buzzard	0730–1330	SW	70	–
	Wood Pigeon	0600–1400	SW	5100	0730–0930, 1130–1230
	Chaffinch	0600–1000	SW	1500	–
	"	0730–1200	N	400	–
Sfa	Wood Pigeon	0600–1200	SW	11,000	0600–0730, 0900–1030
	Redwing	0600–0830	NW	350	–

Comments

Large echoes behaved in a way strongly resembling the pattern of the previous day. Cohort I consisted of echoes moving over the Sound off the W coast of Skåne. The quantitatively dominant feature this day was No. II, a movement over the whole width of Skåne except the SE part. In fact, there was a sharp demarcation line between a zone of dense echoes to the west and one of almost none to the east running from the NE coast to Smygehuk on the S coast. Generally speaking the movement had a more W-ly centre of gravity today than the previous day, and a number of echoes reached the W coast around Bck from where a good many left for Zealand. In the SW part of Skåne echoes deriving from cohorts I and II blended, making the picture less clear. The echoes appearing over the Hanö Bay were fewer than yesterday (III). Cohort IV, although comprising a comparatively small number of echoes, is highly distinctive because of the W or even WNW direction of the echoes. The echoes classed as No. V had a unique shape. When first seen on the PPI over the Baltic they looked like large waves with their long axis perpendicular to their course of movement. The biggest echo had a width of at least 15 km. After a while these remarkable echoes disintegrated into normal dot-like ones.

The density of small echoes moving SSW in the morning was higher than on any other occasion during the present study. The duration of this immense movement, however, only covered some hours.

The field observers noted above all a very heavy passage of Wood Pigeons with an unusually early morning peak before 0715 hrs. The temporal pattern was remarkably different between the two inland stations. This also applies to their records of Common Buzzards which, like the Wood Pigeons, were exceptionally early on the move at Fbo, where the season's highest daily total (although not high compared with daily totals recorded on many other occasions at Fbo) was noted. A number of large Eider flocks were recorded at Fbo, but no duck migration could be seen at Sen. Passerine movements were of very modest extent. A distinct activity of Redwings was noted at the inland stations, particularly at Sfa.

As on October 4, there is no doubt that the vast majority of large echoes represented Wood Pigeon flocks. It is interesting to note, however, that there is only a partial agreement between the timing of radar peaks and culminations of visible migration. Thus, the early morning peak recorded more or less clearly by all the field observers does not show up as a distinct peak on the radar PPI's. Both radar and field observations show a more westerly concentration of the pigeon migration in comparison with the previous day. Another feature worthy of attention is that, again like October 4, radar echoes representing pigeon flocks moved out from the Fbo peninsula in an almost due W course but soon changed their direction 30 to 60° towards the S. And yet one similarity to the day before is that the echoes deriving from buzzards were apparently hidden by the multitude of pigeon echoes. The remarkable echoes over the sea (V) are probably associated with the duck flocks passing at Fbo. Finally, the tremendous quantity of small echoes moving in the morning has no counterpart in the observers' notes of passerine migration.

October 6

Weather

Temperature: 9.6	Cloud cover: nil	Wind:	0700	1300
Visibility: 25	Rain: nil	Fbo	W 10	SW 14
		Lund	WSW 2	NW 3
		Malmö	W 11 (at 600 m)	

Radar observations

Large echoes: None

Small echoes:

I	0530–0830	SE	2	–	SE corner	0615
II	0615–1000	SSE	3–	45	Smygehuk	0645, 0745
III	0845–1000	E/NE	2–	–	"	0930

Field observations

Fbo	Eider	0600–0800	W	1900	–
	Finches	0600–1130	W	4100	0730–1030
Sen	Starling	0630–0800	W	3200	–
	Finches	0600–0900	W	13,000	0630–0800
Bck	Starling	0800–0930	W	800	–
Sup	Very little migration				
Sfa	Starling	0600–0630	W	1200	–

Comments

A day with low echo densities. No. I was composed mainly of echoes appearing over Skåne, but a certain portion arrived from over the Sound and Zealand. E/NE-going echoes were unusually prominent on the radar PPI's.

Field observers recorded only small or moderately small quantities of migrating birds, all of which were approx. W-going.

There is a relatively good agreement between the timing of small echo culminations and passerine migration peaks, but directions differ, frequently by more than 90°.

October 7

Weather

Temperature: 12.0	Cloud cover: 7.0	Wind:	0700	1300
Visibility: 5	Rain: extensive and heavy	Fbo	WSW 16	WSW 15
		Lund	WSW 4	W 7
		Malmö	WNW 20 (at 600 m)	

Radar observations
Practically no echoes.

Field observations
No visible migration recorded.

Comments

The very low migration activity is hardly surprising under the highly adverse meteorological conditions prevailing.

October 8

Weather

Temperature: 12.0	Cloud cover: 6.2 (high)	Wind:	0700	1300
Visibility: 25	Rain: restricted areas	Fbo	W 13	W 9
		Lund	W 6	NNW 6
		Malmö	NW 15 (at 600 m)	

Radar observations

Large echoes:						
I	1100–1500	SSE/SSW	45		NW Skåne	1145
Small echoes:						
II	0530–1000	SE	3−	75	Central Skåne	0645
				–	SE corner	0730
III	0700–1000	SSE	2+	–	–	
IV	0730	SSE	2−	–	Köge Bay	

Field observations

Fbo	Chaffinch	0700–1330	W	9500	0830–1130
Sen	"	0700–1030	W	13,000	0830–1030
Bck	Very little migration				
Sup	Chaffinch	0600–1000	SW	1200	–
	"	0730–1230	N/E	1100	–
Sfa	Very little migration				

Comments

The only large echoes seen (I) appeared over S Kattegatt and NW Skåne and later disappeared over Zealand and W Skåne.

Among the small echoes, cohort II was mainly seen over the inland, while No. III was limited to two rather nicely demarcated corridors, one over the W coast of Skåne N of Malmö, the other, parallell to the first one, at roughly 15 km inland from the coast. No. IV consisted of a brief but comparatively intense departure from E and SE Zealand.

At about 1300 hrs a rain front invaded Skåne, and echo activity ceased.

Field observers recorded only finch migration in moderate or small quantities. In time, visible migration coincided with radar peak activity, but directions differed sharply, the radar showing SE/SSE movements, but the observers seeing W-going movements.

October 9

Weather

Temperature: 11.6	Cloud cover: 6.0 (low)	Wind:	0700	1300
Visibility: 18	Rain: extensive	Fbo	W 3	SW 7
		Lund	W 1	SW 2
		Malmö	W 10 (at 600 m)	

Radar observations

Large echoes: None

Small echoes:

I	0630–0930	SE	2	–	SE corner	0715
					E of Smygehuk	0745
II	0630–0930	SSE	3	40–50	N Sound	0745
					Malmö	0815
					off Smygehuk	0845
III	0800–1030	SSE	3–	40–50	N Sound	0845
					Malmö	0915
					Fbo	0945
IV	0930–1130	SSE	3–	40–50	N Sound	1045
					Malmö	1115

Field observations

Fbo	Eider	0700–1230	W	3800	0830–1100
	Chaffinch	0600–1400	W	68,000	0830–1130
Sen	Eider	0730–1200	W	2500	–
	Chaffinch	0630–1200	W	150,000	0900–1100
Bck	Starling	0700–1400	W	4700	–
	Chaffinch	0600–1400	W	4300	–
Sup	Common Buzzard	1000–1030	SW	180	–
	Chaffinch	0730–1330	SW	3000	0800–1030
	"	0800–1400	N	500	–
Sfa	"	0800–1000	SW	3200	0800–0900

Comments

Cohort I differed from the rest in showing up on the radar PPI's over land as well as over the sea, while the other cohorts were visible almost exclusively over the sea. Cohorts II, III, and IV were similar to each other in terms of spatial pattern and differed only in their timing, behaving like a succession of sharply distinct waves.

A heavy Eider passage was noted at Fbo and Sen. At Sup a locally restricted movement of Common Buzzards was recorded. It is doubtful if such a movement will lead to more extensive travels and sea departures. All stations recorded one of the period's largest passerine movements with Chaffinch, Brambling, and to a lesser degree thrushes, as dominants.

Radar stations did not record the large Eider movement over the Baltic. The very heavy passerine migration recorded by the field observers was only very incompletely covered by radar, although there is a general agreement in timing between the radar and visible peaks. As so often, the radar stations and the field observers differed in respect to the direction indicated for the bird movements.

October 10

Weather

Temperature: 12.4	Cloud cover: 4.6	Wind:	0700	1300
Visibility: 25	Rain: restricted	Fbo	WSW 10	SW 12
		Lund	W 2	WSW 7
		Malmö	W 10 (at 600 m)	

Radar observations

Large echoes: None

Small echoes:

I	0515–1000	S/SSE	3	45	–	0730–0800

Field observations

Fbo	Starling	0630–1100	W	7000	0730–0830
	Chaffinch	0600–1300	W	37,000	0630–0930
Sen	"	0600–1000	W	30,000	0700–0800
Bck	Starling	0630–1030	W	7000	0645
	Chaffinch	0600–1030	W	6000	0645, 0745, 0830–0930
Sup	"	0600–1000	SW	500	–
	"	0600–1400	N/NE	300	–
Sfa	"	0630–1000	SW	1000	0630–0800

Comments

Quantities of small echoes were lower this day than the previous day, but their behaviour was about the same.

Field observers saw very little migration apart from finches and Starlings which moved in moderate or fairly large quantities at all coastal stations and in small numbers at the inland stations.

Peaks as recorded by the radar stations and the field observers tended to agree reasonably well. But as so often, directions differed, the former revealing mainly SE-going movements and the latter recording W-going birds.

LARGE ECHOES AND THE MIGRATION OF WOOD PIGEONS, COMMON BUZZARDS AND EIDERS

Synopsis of main echo systems

Cohorts of large echoes as viewed on the radar PPI's may be classified in five major systems, as illustrated in Fig. 10 A to D. The quantitative importance of the different systems appears in Table I.

System A consisted of echoes emerging over the Swedish W coast N of Skåne or over the Kattegatt. Over the N-most part of the Sound these echoes often proceeded along two separate paths: one across Zealand with a SSW bearing, later somewhat deflected by the coast

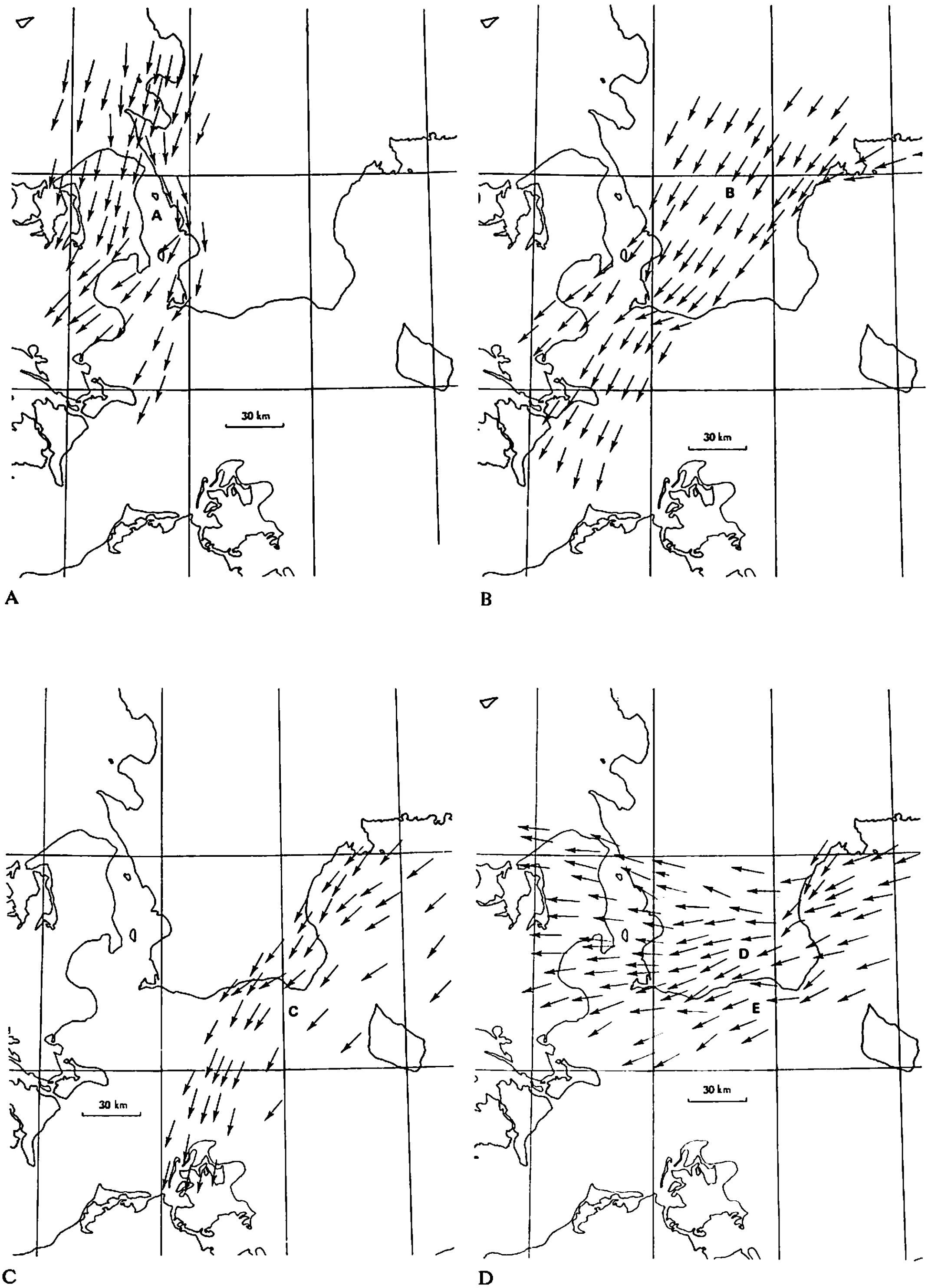
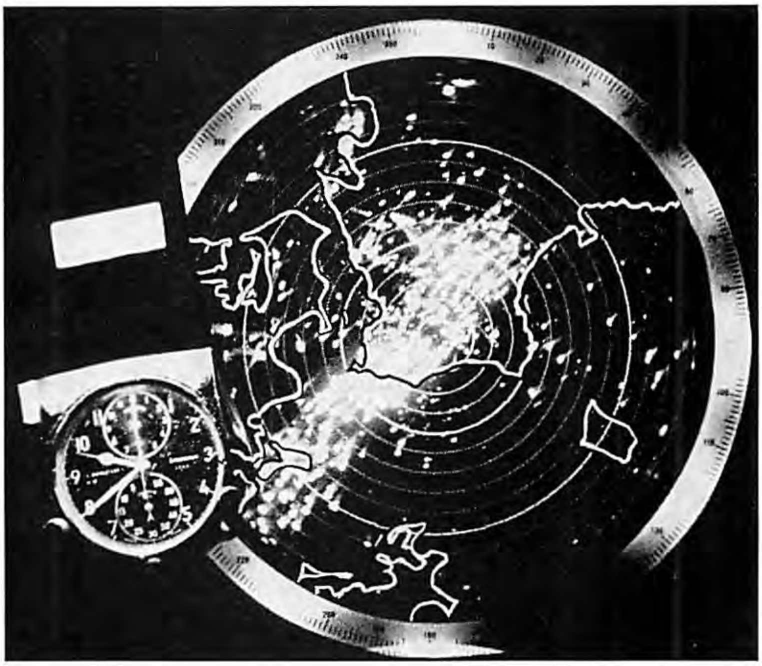


Fig. 10. Diagrammatic maps showing the patterns of migratory systems of large echoes. A = System A, B = System B, C = System C, D = Systems D + E.

Fig. 11A



line of Köge Bay (see Fig. 1), and another towards SSE along the W coast of Skåne, later turning SW above Bck and departing from there towards Zealand. A small portion of the last-mentioned sub-cohort eventually may reach Fbo and depart from there or from other places in the SW corner of the province. Generally, however, much the largest proportion of System A echoes took the route described first.

On October 3 and 8 all System A echoes kept SSE directions over Zealand, the Sound and W Skåne. On the former date this led to a higher proportion than usual of the cohort passing over Fbo. Over the sea to the S and W of the Fbo peninsula, these echoes switched

Table I. Distribution of major movements of large echoes on different migration systems (cf. Fig. 10)

System	A	B	C	D	E	Other
Sept. 25	10	—	—	—	—	10
26	100	+[1]	—	⟨150[1]	40	20
27	—	900	—	350	250	—
28	—	350	—	350	—	—
29	15	+[1]	—	⟨1500[1]	—	100
Oct. 1	—	—	15	—	—	10
3	45	—	—	—	—	—
4	425	800	350	—	—	—
5	250	1550	200	10	+[2]	—
8	45	—	—	—	—	—
Totals	890	⟩3600	565	⟨2360	⟩290	140

[1] On these particular occasions it was difficult to separate between Systems B and D. We estimate that the former made upp approx. 15 per cent of the total number of echoes. This percentage has been used in Table II.

[2] Large band-formed echoes as described on p. 120 and impossible to quantify in a comparable way.

Fig. 11B

Fig. 11. Photos of radar PPI's. A = Radar station R on October 4, large echoes cohort II, System B, mainly involving migrating flocks of *Columba palumbus*. B = Radar station B on October 2, small echoes, cohort I, showing *Fringilla coelebs* migration under heavy deflection due to W winds.

from SSE to SSW/SW. On October 8 the echoes to a large extent disappeared over Skåne possibly owing to weather deterioration causing discontinuation of the migratory flight.

System B (Figs. 10 B, 11 A) most closely resembled the migratory pattern generally regarded as 'normal' in Skåne. Echoes moved with SW bearing over the whole width of Skåne except the SE corner. As seen on Fig. 10 B some echoes moved due W off the coast of the province of Blekinge, but when over land in NE Skåne they changed to SW. At the S coast of Skåne there was again a temporary deflection. The position of the migration corridor sometimes fluctuated, so that on October 5, for example, a portion of the echoes belonging to System B departed from Bck where usually echoes from System A prevailed.

A characteristic property of cohorts of System B was that frequently very large numbers of echoes were involved. Also, there were temporal and spatial differences of echo density, so that the stream of echoes progressed as a sequence of irregular pulses.

System C (Fig. 10 C) consisted of echoes which, for example on October 4, were very clearly concentrated over a promontory in the W part of Blekinge but on the following day appeared more scattered over the Hanö Bay. System C echoes kept a SW/SSW bearing and only crossed over the SE corner of Skåne. Over the Baltic they moved in a narrow zone well separated from System B, taking land at the island of Rügen in DDR.

System D (Fig. 10 D) differed sharply from the other systems owing to the WNW/WSW bearings of the echoes involved and to the late time of the day for most of the activity peaks (around noon). When the echoes approached the E coast of Skåne in the Hanö Bay area, distinct deviations southwards over the sea were noted. A major portion of the echoes turned inland just N of Stenshuvud (see Fig. 1) after which they kept an approximately W-ly course. In some cases these echoes could be followed crossing the Sound and proceeding westwards over Zealand.

Finally System E only comprised echoes travelling W over the open sea.

A few echo cohorts are not easily grouped with any of the five systems described above, which, as a matter of fact, included the vast majority of all cohorts recognized in the course of this study. As seen on Fig. 5, there were echoes on September 29, cohort III, on B radar whose behaviour precludes their being grouped within System B. On September 25 and October 1, a few echoes were seen departing from the SE corner of Skåne with an ESE bearing, and on September 26 a few echoes were moving almost due S over central Skåne.

Identification of echoes

As repeatedly pointed out in the comments under the main presentation of each day's observations, there was a very good correlation between echo cohorts of Systems A and B, on the one hand, and field observations of migrating flocks of Wood Pigeon, on the other (Table II). A few exceptions to this rule call for brief comments. As seen in Table II, the visible migration of Wood Pigeons at Bck was considerably higher on October 5 than on the preceding day, although System A echoes reached the W coast in particularly large numbers on October 4. Furthermore, no pigeons were recorded at Bck on October 3 and 8, although System A was quite active on these days. This is probably explained by a somewhat different behaviour and origin of the majority of the echoes on these days. Interestingly enough, on October 3, System A echoes could be followed as far south as Fbo from where they departed over the sea. In most days, echoes in the Fbo region almost exclusively belonged to System B, which was not active on this particular day.

System C was only recorded on October 4 and 5. It consisted of echoes moving with the same speed as those belonging to Systems A and B which, as just mentioned, could be as-

Table II. Comparison between large echo cohorts and Wood Pigeon daily totals as recorded at five field observation sites

Date	No. of echoes System A	No. of Wood Pigeons at Bck	No. of echoes System B	No. of Wood Pigeons at Fbo	Sen	Sup	Sfa
Sept. 22	–	–	–	–	–	–	–
23	–	–	–	–	–	–	–
24	–	–	–	–	–	–	–
25	10	–	–	–	–	–	–
26	100	800	25	1200	–	350	–
27	–	–	900	21,000	–	700	1900
28	–	–	350	14,000	800	3000	–
29	15	800	250	5000	2000	800	–
30	–	–	–	–	–	–	–
Oct. 1	–	–	–	–	–	1100	–
2	–	–	–	–	–	1000	–
3	45	–	–	1400	–	900	–
4	425	6000	800	13,000	24,000	9000	8200
5	250	12,000	1550	12,000	31,000	5100	11,000
6	–	–	–	–	–	–	–
7	–	–	–	–	–	–	–
8	45	–	–	–	–	–	–
9	–	–	–	–	–	–	–
10	–	–	–	–	–	–	–

sociated with Wood Pigeon flocks. The concentration of System C echoes over a S-wards projecting peninsula in W Blekinge and their deflection W-wards when approaching the S coast of Skåne are facts proving that the birds involved were land birds. No field observations were carried out in the region covered by System C. Therefore we cannot be quite sure that these echoes in fact reflected pigeon migration, but wish to point out that there is nothing arguing against this assumption.

In contrast to Systems A to C, System D did not consist of land birds, as witnessed by their behaviour at the E coast of Skåne. Closely similar movements were seen at night as well as by day. We suggest that ducks and/or geese were responsible for these echoes which were too fast to represent, for example, larids. Almost all wader species have left Sweden at the season in question. There are no field observations aiding the identification of these echoes. At coastal sites, the dominant anseriform species at this time of the year is the Eider, but this species is known to cross over Skåne during autumn on diurnal migration in extremely rare cases only (Edberg 1972). Other possible species are *Anas* ducks, *Branta*, and *Anser* geese (see p. 133).

System E represents birds moving off the coast of Skåne. This system was active only on three days at which coastal observers recorded considerable Eider migration. We therefore do not doubt that System E echoes largely reflected Eider migration. It is worth pointing out that on October 6 and 9 the field observers saw considerable Eider migration, without any comparable echoes discernible on the PPI's.

Table III. Daily totals of migrating Common Buzzards. At Sfa no significant migration of Common Buzzards was seen

Date	Fbo	Sen	Bck	Sup
Sept. 26	–	40	–	–
27	65	–	–	–
28	250	–	145	–
29	580	–	–	–
Oct. 4	470	220	–	140
5	1400	370	–	70

In Table III we have compiled the field observations of migrating Common Buzzards. Only on September 29 have we been able to distinguish echoes obviously associated with buzzard migration (Fig. 5). These echoes were only seen on radar station B (cf. p. 112). On September 28, the radar PPI's revealed heavy concentrations of large echoes departing towards W at Fbo and Bck. At the former site, the echoes behaved according to the pattern of System B and at the latter site according to System D. At Fbo there was at the same time an early morning peak of both Wood Pigeons and Common Buzzards, and this was the day of the most intense Common Buzzard passage at Bck. Probably a certain proportion of the echoes seen this morning in fact represented migrating Common Buzzards. However, no echoes displayed the peculiar behaviour described for September 29.

Comparatively large numbers of Common Buzzards were reported, especially from Fbo, on October 4 and 5. The immense number of echoes clearly associated with Wood Pigeons on these two days probably prevented buzzard echoes from being distinguishable on the PPI's. Finally, it may be added that echoes of System C might have represented Common Buzzard migration, at least in part.

SMALL ECHOES AND THE CHAFFINCH MIGRATION

General pattern

In contrast to the large echoes and the migration with which these were associated, small echoes and passerine migration were recorded on all days except September 30 and October 7 (cf. pp. 113 and 122). Thus we have data from a larger number of days for small birds.

Effects of wind

Eleven out of 19 days had winds prevailing between SW and WNW. On none of these occasions did the small echoes move W of S, but movements were restricted to the sector between S and E.

The usual pattern of small echo movements under W-wind conditions consisted of an early morning cohort emerging over Central Skåne, moving SE and departing primarily over the SE corner of Skåne. Somewhat later, still heavier movements over the Sound and W Skåne towards approx. SSE led to departures from the S coast (Fig. 11 B), chiefly E of Smygehuk (see map, Fig. 1). In certain cases echo density was higher over the sea than over the land, probably as a result of increasing altitude of the migratory birds over the sea. Significantly, this was noted mainly on the B radar which has an inferior coverage at low altitudes. In other cases, particularly during really large-scale movements, echoes were more or less equally dense over land and sea. Except during the very largest movements, the SW corner (SW of a line from Malmö to Smygehuk) usually remained relatively devoid of echoes.

Yet another typical feature of days with W winds were movements towards due E, i.e. with more or less following winds. These E-bound movements were of two kinds. Some echo cohorts departed from Zealand and crossed the Sound and Skåne, often early in the morning. Another category is made up of localized groups of echoes which, mainly along the S coast, moved E fairly late in the day, at a stage when other movements had ceased or decreased.

On September 25 the main small echo movement was directed more to the E than on any other occasion. These echoes moved with due following winds.

September 26 differed from other W-wind days but showed similarities to the N-wind days (see below). In terms of numbers of small echoes this was the third largest day during the study period. The main direction was towards S, but there was a wide scatter of echo bearings. This day differed from all others with respect to the impact of topography on echo tracks. At the S coast many echoes deviated towards W, while at the W coast they turned SSE for some distance. On this day, movements across the Sound were mainly from Skåne to Zealand, not the opposite, as was the case on all other west-wind days.

S-winds (2 days) were combined with generally adverse weather and only insignificant bird movements.

Echo movements under winds from the E (4 days) sharply differed from those recorded under W-wind conditions. Bearings were invariably between SW and WNW.

N-winds prevailed on October 4 and 5. The largest echo movements for the whole period were witnessed on these days. The main bearings were S and SSW on the two days, respectively. Echoes moved on a very broad front, without reacting to topographical features and with similar densities over land and sea.

Evening movements

On ten out of 19 days a distinct peak of echo movements occurred after 1500 hrs and up to sunset. These echoes behaved as described in the preceding paragraph in relation to wind but differed from most small echo cohorts with respect to TAS (50 to 65 km/hr as compared to 40 to 50 km/hr for echoes earlier in the day). On some days the evening peak was followed by similar echo movements during the dark hours.

On October 3 and 4 the evening peaks were extremely large, especially on the latter day, and consisted of echoes closely resembling those seen earlier in the day. Hence these afternoon to evening movements probably consisted of finches.

Identification of echoes

The observers recorded the Chaffinch as making up the vast majority of the migrating passerines. Nothing contradicts the assumption that the small echoes also consisted of Chaffinches. We cannot conceive that other species might occur in large quantities on diurnal migration at the time of the year when this study was carried out.

DISCUSSION

Primary, secondary, and reversed directions

Many factors are known or suspected to influence the track of migrating birds (e.g. Rudebeck 1950, Lack 1963, Evans 1966a, Rabøl 1967, Schüz 1971). Some terminological questions need to be clarified before the discussion of the present results.

At a given stage of its autumn migration, a bird will move in a direction basically determined by its inborn reaction to certain orientation clues. This is known as its primary direction (Schüz op. cit.). It is important to realize that this may change several times between the starting point (usually the breeding area) and the end of the migratory journey (e.g. Rabøl 1972).

The track of a migrating bird is, however, obviously affected by a number of environmental features, notably wind conditions and topography. A great deal has been written about the relationships between these factor complexes and the pattern of bird migration, most of which is excellently summarized by Schüz (op. cit.). The direction of the bird under the influence of these and other analogous factors constitutes its secondary direction. (We would prefer the term 'track direction' as being a good deal more informative.) Although different species react differently, a few rules seem to be widely valid, namely that a) birds tend to fly higher with a following wind, and b) when flying higher, they become less dependent on topographical leading lines and, generally speaking, on the features of the landscape below them.

Autumn migration generally leads to the winter quarters of the bird populations involved. The majority of Scandinavian birds move towards SW, less often S, in autumn (Rudebeck op. cit.). The fact that a minority takes a different course need not bother us here. However, under certain circumstances, birds may move in more or less exactly the opposite direction in relation to their normal course at a given time and place. This is known as reversed migration. In this kind of migratory movement the same distinction between primary and secondary (or track) directions may be made as described above for the normal direction.

To what extent birds react to the force of lateral wind is a much debated problem (e.g. Bergmann & Donner 1964, 1971, Drury & Nisbet 1964, Evans 1966b, Nisbet & Drury 1967, Lack 1969, Parslow 1969). Birds do not necessarily drift with the wind like inanimate particles, but, on the contrary, are able actively to influence their own speed and direction in relation to wind and ground. Thus, the secondary direction of a bird is by no means governed wholly by the wind (assuming for the moment that topographical features are inoperative), but reflects the interplay of the bird's heading (the direction of the bird's long axis) and the wind forces. Evidently the bird may adjust its heading as a response to various environmental stimuli. Although Schnitzler's (1972) experimental set-up was so artificial that the results may illustrate birds' extraordinary powers of manoeuvring rather than their reactions to wind under sustained flight, his paper emphasizes the significance of the aerodynamic properties and flight capability of birds, a research field where only a beginning has been made (see Pennycuick 1969). Bellrose (1967) and Bruderer (1971) recorded different true air speeds during migration at different wind conditions.

It may be pointed out that the heading of a bird conforms with its primary direction as well as with its track bearing in the absence of deflecting forces. Such forces may, however, stimulate the bird to change its heading, which is neither constant nor a concept synonymous with primary direction.

Migration goals, wind effects, and directions of echoes

The winter quarters of the species with which we are chiefly concerned are known fairly well owing to a large number of ringing recoveries and other evidence.

Rendahl (1965) and Olsson (1958) have compiled the recoveries of Wood Pigeons and Common Buzzards, respectively, deriving from Fenno-Scandia. The Wood Pigeon mainly winters in SW France, and the Common Buzzard in N and Central France, Belgium, Holland, and NW Germany. Thus their winter quarters are situated SW from Scandinavia. In fact, in much smaller numbers they winter north of the regions just described, including S Scandinavia.

According to B.O.U. (1971) only very small numbers of Common Buzzards from the Continent irregularly reach the British Isles, and no recoveries of birds ringed abroad have so far been reported. The same source considers that small numbers of Wood Pigeons regularly invade S England across the Channel. It is therefore clear that the British Isles are a relatively unimportant migration goal for Scandinavian Wood Pigeons and Common Buzzards.

Salomonsen (1967) and Joensen (1968) have shown that Baltic Eiders chiefly winter in SE and Central Danish waters. They do not appear to cross or circumnavigate Jutland to any significant extent.

The Chaffinch offers a much more complicated migratory pattern than the other species. Rendahl (1968) has summarized the recoveries of Fenno-Scandian birds. North European Chaffinches winter in W-most Europe, from Holland to Portugal. Different shooting practices and laws render the interpretation difficult, and one cannot say for certain where the majority of the Chaffinches stay. To a limited extent Continental Chaffinches cross the Channel and winter in England, particularly its S and central parts. The distribution of the recoveries strongly suggests that only a small proportion of the Chaffinches have travelled to Britain over the North Sea, but rather that they have arrived from over the Channel. And already long ago their departure from Holland towards Britain was described by Deelder (1949) and other Dutch ornithologists. It therefore seems clear that the primary direction of N European Chaffinches has to change strongly in the course of the autumn migration (Tinbergen 1949, van Dobben 1953, Lack 1960, Gruys-Casimir 1965). As far as we know there is no evidence to indicate that significant numbers of Chaffinches ever cross the North Sea, as assumed by Snow (1953), and Perdeck (1970) claims that they depart from S Norway with a SSE course.

As mentioned before, the higher birds fly, the less dependent do they become of topographical features. Tracks of high-flying birds, therefore, are chiefly the outcome of the interplay of two components, viz. the birds' heading, which may or may not conform with their primary direction, and the wind conditions. Given the tracks and the wind conditions, headings may be calculated. It is of obvious interest to examine whether the tracks of birds as recorded on the radar PPI's and their calculated headings agree with the direction pointing towards their migratory goals.

Echoes belonging to Systems A and B reflected migrating Wood Pigeon flocks (p. 128). Most of these echoes held a SW course. Since most movements took place with following winds, there was no lateral displacement. Generally speaking, then, the Wood Pigeons were flying in a direction pointing to their winter quarters in SW France.

However, it is important to note that this SW-dominated pattern was not always prevailing throughout the whole area monitored by the radars. In its NW parts, for example NW Skåne and S Kattegatt, pigeon echoes were frequently moving S or even SSE (System A). We interpret this as a result of the leading line effect of the Swedish W coast which runs approximately NNW/SSE. More interesting is the fact that the direction of the Wood Pigeons did not change until some distance and time after they had escaped the leading line itself. At Bck (see Fig. 1) a change often took place, so that the Wood Pigeon flocks switched from their entrained SSE direction to the more 'correct' one towards SW. A persistent effect of a leading line was also discernible at the Fbo peninsula. The direction of the S coast is approximately E/W, and the temporarily induced W-ly bearing of the pigeons did not switch back to SW until some distance to the W of the peninsula. A third example is provided by the coast of Blekinge, the effects of which persisted after the birds had entered NE Skåne.

A fairly good parallelism exists between the Wood Pigeon migration at the five field observation sites, but some exceptions are noteworthy. On September 27 and 28, with E-ly winds, Wood Pigeons were recorded on migration at Fbo but not at Sen, whilst with N-ly winds the passage was of about the same magnitude at these two places. This suggests that E-ly winds will transfer the centre of the migration towards W. Conversely, the pattern of System A on October 2 and 8 suggests that W-ly winds were accompanied by an E-ward transfer of the main migration, as compared with conditions with following winds.

Thus, whilst Wood Pigeon tracks pointed in the direction of their migratory goals, these birds were affected by limited lateral deflections as a result of the wind conditions prevailing.

We have previously justified our conclusion that the large echoes classified under Systems A and B did not to any appreciable extent reflect Common Buzzard migration. Only on one occasion did we record echoes that without hesitation must be ascribed to buzzard migration. The relationship involved between patterns of Common Buzzard migration and wind conditions has been analysed in detail by Rudebeck (1950), who concluded that wind conditions caused considerable deviations and thus affected the number of birds recorded at Fbo (cf. Ulfstrand 1958, 1960). The few data we have obtained do not contradict this notion of deviations caused by wind but restricted by topography.

System D has been assumed to comprise mainly anseriform birds. Since we do not know what species are involved, we obviously cannot identify their winter quarters. One might speculate, however, that a W-ly course across Skåne may be anticipated in *Anas* ducks and *Branta* geese on their way to the S shores of the North Sea and the British Isles. Another possible species is the Common Scoter *Melanitta nigra* known to winter in large numbers to the W of Jutland. Eiders only rarely fly over land during autumn migration in Skåne (cf. Edberg 1972).

Finally, the Eiders included in System E were moving straight towards their presumed winter quarters.

Tracks and headings of small echoes in relation to Chaffinch winter quarters

If Chaffinches were to reach their winter quarters in the most direct possible way, then they would have to depart from S Scandinavia on SW or WSW bearings. As demonstrated in Table IV, small echoes, presumably representing chiefly migrating Chaffinches, on nine days out of seventeen showed SE/SSE-directed tracks, but in fact these cohorts represented only about one quarter of all small echoes recorded during the study period. Movements towards S/SSW were only indicated on the PPI's on three or four occasions, but still represented no less than about 55 per cent of all small echoes. Under both conditions, the birds were travelling E of the direction pointing straight towards their migratory goal area (Idealzugrichtung, Schüz 1971). Further, there are virtually no ringing recoveries of Scandinavian Chaffinches from the area where these birds will invade the Continent. There is, thus, much to support the assumption that these Chaffinches were obliged to change their primary direction soon after having crossed the Baltic. Perdeck (1970) from field observations has shown the primary direction of the Chaffinch in autumn to gradually shift from about SSW in Scandinavia to W by N in Northwest France.

Table IV. Bearings of movements of small echoes in relation to wind direction

Bearings	Percentage of total echo quantity	Dominating bearing, No. of days	Wind direction
N	3	1	S
NE-ESE	3	–	W (one day E)
SE-SSE	23	9	W
S-SSW	55	3 (4)[1]	N-(NW)
SW-WNW	16	3 (4)[1]	E

[1] On Sept. 23 the dominating bearings were SW/SSW.

As discussed above, Chaffinch tracks were in the sector SE/SSE with W winds and in SW/W with E winds. The calculated headings in both cases remained in the sector SW/S with an average around 200° (= SSW). With N winds, tracks and headings coincided, and under these wind conditions by far the largest echo densities were recorded.

Thus, it seems legitimate to conclude that Chaffinches flying at a comparatively high altitude and therefore only recorded by radar did not compensate for the effects of lateral winds (cf. p. 133). The birds were constantly heading towards approx. SSW, and this is probably close to their primary direction in the present area. Significantly, the largest numbers were recorded with following winds, when tracks, heading and primary direction are parallel. We shall later compare this situation with that found in the low-flying Chaffinches.

Nisbet & Drury (1967) postulated that, in passerine nocturnal migrants, what was supposed to be drift effects might be explained by different populations or species being differently stimulated (or de-stimulated) by different wind directions. They argue that in a given area birds with different primary directions are present and that, with no or following winds, a corresponding scatter of echo tracks will be found. With cross-winds, populations and species which, because of their primary direction, face particularly strong head-wind components, are supposed not to depart, while those having, for the same reason, a particularly strong tail-wind component will depart in large numbers.

For nocturnal migrants, Drury & Nisbet (1964) and Nisbet & Drury (1967) in America, and Evans (1966b) and Lack (1969) in Europe, have assumed complete compensation for the deflective effects of lateral wind components. In contrast, for the same kind of migration, Parslow (1969) did not find any compensation over the English Channel, nor did Bergman & Donner (1964, 1971) for diving ducks over S Finland. Evans and Lack, however, consider that under strong cross-winds compensation does not occur.

If compensation does not occur, then Nisbet & Drury's apparent 'drift-effect' of selective cohort migration, as described above, would be added to the directly wind-caused change of flight directions. Since there are no indications in our observations of the existence of compensation, we should have to except considerable effects of selective cohort departure. However, with following winds, such as, above all, on October 5, the scatter of echo tracks was quite small, suggesting comparative homogeneity among the migrating birds in terms of primary direction. However, within the scatter that is to be found among the calculated headings (<40°), a subsidiary effect of selective cohort departure cannot be entirely ruled out. To decide this, one would have to analyse whether headings are slightly more to the E with W winds and vice versa, but our data are too scarce for that purpose.

As often in autumn in this region, winds were strong most of the time. The relationship between tracks and light winds could therefore not be studied. We would like to add that also in nocturnal migrants, among which the Robin *Erithacus rubecula* was most numerous, we found no trace of wind compensation (Alerstam 1972).

We conclude that Chaffinches above Skåne generally move in a direction not pointing directly towards their winter quarters and that, as far as the high-flying cohorts are concerned, they are subjected to considerable lateral displacement as a result of the wind conditions. The radar PPI's scarcely indicated at all that the movements of high-flying Chaffinches are affected by topographical leading lines, such as the coast lines. Thus, Chaffinches under these circumstances seem to be liable to more extensive deflections than the larger birds, such as Wood Pigeons and Common Buzzards, where deviations seemed to be restricted by the coastal leading lines.

Directions of visibly migrating Chaffinches

Small echoes and visibly migrating Chaffinches neither agree in time nor in space/bearings (cf. p. 130). Fig. 12 sets forth the most frequently recorded directions of visibly migrating Chaffinches at the five field observation sites.

At Fbo Chaffinches (and other passerines) moved towards W/SW in 97 per cent of all movements recorded. On a few days, namely September 27 and 28, a certain portion turned back near the coast, so that the migration pattern became highly confused.

At Sen about 85 per cent of the Chaffinches were recorded moving W along the shore, while the major part of the rest moved in the opposite direction. E-bound movements dominated on four days, viz. September 23, 27, 28, and 29. These four days were the only ones during the whole study period with prevailing E-winds.

Chaffinches at Bck moved W, departing across the Sound towards Denmark (90 per cent). Coasting movements were largely restricted to one single day, viz. September 27.

Inland, Chaffinches chiefly moved SW (Sup 50 per cent, Sfa 80 per cent). Significantly, most of those not moving SW were flying towards NE. Thus the low percentage figure for Sup of SW-bound birds does not indicate a particularly large scatter, but rather that a high proportion of all birds recorded were engaged in reversed movements (see below). Such movements were particularly conspicuous on days with E-winds but occurred on most days regardless of wind conditions. As may be seen in the Main Tables, reversed movements usually took place later in the day than the normal movements.

Fig. 12 Diagrammatic map indicating main directions of visible migration of *Fringilla coelebs* at five field observation localities.

The remarkable constancy of the direction of visibly migrating Chaffinches under variable wind conditions demonstrates that these low-flying birds compensated for the effects of cross-wind. This is in contrast to the conclusion reached for the high-flying cohorts (p. 134). As far as visible migration is concerned, our results agree with those reported from Holland by Gruys-Casimir (1965). A glance at the main tables suffices to show that particularly large daily totals were recorded on days with winds about W/SW, i.e. due head-winds causing no lateral deflection.

Whilst being able to maintain their direction in spite of lateral wind forces, the low-flying Chaffinches were strongly affected by topographical leading lines, as witnessed by the high numbers counted at Fbo and Sen in comparison with the other localities.

Bergman (1964) proposed that these low-altitude movements had the function of compensating for the wind displacement met with at high-altitude migration.

E-bound movements

E-moving echoes may be divided into two categories. One consists of echoes departing early in the morning from Zealand and crossing the Sound and Skåne in almost due E-ly direction (see main tables for September 22, 24, 25 and October 1, 2, 3; Figs. 6 and 8). They appeared somewhat more distinct than most small echoes and cannot with certainty be classified as finches. These movements were only seen on days with more or less W-ly winds.

A different pattern is represented by echoes chiefly moving E along the S coast of Skåne (see September 23 and 26, October 6). They usually occurred fairly late in the morning. On September 23 they moved against the wind and thus represent one of only two cases (the other being on the following day) of echo movements directly against the wind noted during the entire study. The movements on

September 26 and October 6, on the other hand, took place with W-ly winds.

E-bound echoes without exception made up a small minority (10 per cent) of all echoes recorded during a given day.

E-bound visible migration was, strictly speaking, restricted to Sen and the two inland sites. At Sen, Chaffinches were coasting E-wards, rather than W-wards, on September 23, 27, 28 and 29, that is, days with E-ly winds. On the second and fourth of these days Chaffinches moved W in the early morning but later switched to the opposite direction. The change was often quite sudden. On the other two occasions, only E-bound movements were seen. The radar PPI's displayed cohorts of small echoes moving W on all these days and did not show any changes such as seen by the field observer. There was a shift in wind direction from ENE to E/ESE on the two days, when the main direction of the visibly migrating Chaffinches was noted to change at Sen, but we do not suggest any connection between these two phenomena.

At the inland stations, the daily pattern usually consisted of SW-bound movements starting early and continuing for a variable period. Reversed movements started and ended later. At Sfa, but not so clearly at Sup, there is close correlation between E-ly winds and NE/E-bound Chaffinch migration.

It seems worth pointing out that E-bound movements are of two fundamentally different types. The birds seen moving E along the S coast were following a secondary direction which, probably because of the interplay of wind and topographical factors, deviated extraordinarily much from the normal direction (approx. SSW). The E- or NE-bound birds inland presumably followed a secondary direction which was derived from a reversed primary direction. The correlation between E-ly winds and strong reversed migration is to be expected on the assumption that head-winds bring the birds closer to the ground and hence render them visible to field observers. Reversed migration at high altitude should have shown up on the radar PPI's, but we did not find any evidence for this kind of migratory movement.

CONCLUSIONS

Owing to the combination of radar stations and several field observers simultaneously recording the bird movements, a number of new facts and ideas about the magnitude and pattern of bird migration in S Sweden have emerged.

Close correlation between radar echoes and visibly migrating Wood Pigeon cohorts allows a detailed description of the geographical distribution of movements of this species under a variety of meteorological conditions. As a rule Wood Pigeons were moving SW, although leading line effects temporarily caused deviations from this bearing. Cross-winds led to lateral displacement of the migrating cohorts. The amount of this deflection, however, was checked by the effects of the coast lines. Apparently, these factors neatly interacted in determining the course of the Wood Pigeon migration.

We have previously justified our claim that the great majority of echoes belonging to Systems A and B reflected Wood Pigeon flocks. These systems comprised a total of 5000 large echoes during the whole study period. Assuming that all these echoes represented Wood Pigeon flocks and further that the average flock size was 200 birds (as seems entirely reasonable considering that high-flying pigeon flocks are seldom small but frequently consist of more than 1000 birds), these systems would have comprised about 10^6 Wood Pigeons. Since this species is very abundant in much of Scandinavia, we believe this figure to be quite credible and without doubt in the right order of size. It may be compared with the totals of Wood Pigeons reported at Fbo (70,000), Sen (60,000), and the three remaining observation sites (20,000 each) during the same period. The relation between the figure estimated on the basis of the radar information and those provided by the field observers gives an idea about the leading line effects and also about the proportions of the bird populations travelling through Skåne in autumn that are actually recorded by a field observer. It may be added that the study period included much the most important part of the migration period of the Wood Pigeon.

Common Buzzard numbers were unexpectedly low throughout the study period, and very little was seen of them on the radar PPI's.

Anseriform birds played a prominent role among the large echoes (Systems D and E, Fig. 10). Off the S coast Eiders and other ducks and geese moved W, a familiar pattern. But System D represents a pattern of anseriform migration hitherto largely overlooked in S Scandinavia (cf. Edberg 1972), and the identification of the species involved is awaited with great interest. The fact that echoes behaving in the same way as those classified under System D continued moving well into the night (Alerstam 1972) is further support for the assumption that these echoes mainly consisted of anseriform species.

However, we believe that the most interesting results of the present study refer to the migration of passerines, chiefly Chaffinches. The radar PPI's almost every day revealed echo movements representing passerines flying at a considerable altitude and almost completely invisible to the field observers. The tracks of these high-flying cohorts were strongly affected by wind directions. Cross-winds produced predictable changes of track directions assuming no compensation on the part of the birds. It is probably significant that the largest number of echoes was recorded under tail-wind conditions. The fixed heading and presumably the primary direction was SSW, and it follows that the Chaffinches will have to change their direction during later stages of their autumn migration in order to reach their migratory goals (cf. Rabøl 1972). It is also extremely interesting that these high-flying birds did not pay any attention at all to coast lines and other major topographical features, as far as we can judge from the echo behaviour.

The visible Chaffinch migration proceeded in a very different manner. The low-flying cohorts stayed almost entirely undetected by radar. They were moving in a fixed direction suggesting wind compensation. Particularly large numbers were recorded during head-wind conditions. It is impossible to decide whether this depends on high activity per se, or on increased conspicuousness connected with the low flight altitude (or both). Still it would seem reasonable that selection should favour migratory activity under conditions when lateral deflection is least likely, on the assumption that any deviation from a straight course between starting point and goal area is disadvantageous. However, under certain circumstances, the importance of reaching any suitable landing area may be so overriding that selection has provided a mechanism whereby birds give up their 'normal' heading and allow themselves to be drifted with the wind with no attempt at compensation (Evans 1966b). Further studies are required to examine the question how echoes behave under head-wind conditions combined with generally favourable conditions.

In contrast to the small echoes, the low-flying Chaffinches were strongly influenced by the coast lines. In particular the S coast of Skåne caused considerable concentrations of migrating Chaffinches, as witnessed by the high numbers counted at Fbo and Sen. The W coast of Skåne seems to have little effect in this respect.

The Chaffinch migration across Skåne proceeds in two quite different ways. Certain birds fly at a considerable altitude, become strongly deflected by cross-winds and are almost entirely unaffected by topographical leading lines. Other birds fly at a very low altitude, compensate for lateral wind forces and tend to follow topographical leading lines. Often these two patterns were recorded simultaneously, although cohorts involved might move in different directions, but there is a clear tendency that peak intensity of one pattern did not coincide with peak intensity of the other. It is impossible to decide in which of these two migration patterns the largest number of birds participated. It is easy to suggest a number of possible advantages of each type of migration process in terms of orientation, energetics and so forth. Our material is much too small for elaborating on such problems. It is necessary to point out, however, that the low-flying cohorts by themselves represent a quantitatively prominent phenomenon and that much of the bird migration was found in this study to be completely unavailable to radar monitoring. Superficially, at least, it seems that the low-flying birds were much less at the mercy of environmental vicissitudes and much less likely to be subjected to large deviations than the high-flying cohorts. However, possibly this increased travelling safety has to be paid for in higher energy costs required by flight under head-wind conditions.

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