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Analysis and a theory of visible bird migration

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Daily records of autumn visible migratory intensity at Falsterbo, South Sweden, of fifteen different bird species have been analysed in relation to weather by univariate and multivariate statistics.
Average migratory intensity of most species decreases for a number of days after a large scale passage, but after a certain period the average intensity rises again. This is probably a combined effect of autocorrelation in the weather and changes in the internal state of the migrants.
Wind is the factor of primary importance to explain the variation in migratory intensity, but in addition there are in many species significant partial correlations with rain (negative correlation), barometric pressure trend (positive), minimum temperature trend (negative, in late-autumn migrants), cloud amount (negative) and visibility (positive).
A theory of the influence of wind on migratory activity, flight altitude, leading-line effect and travelling speed of the migrants is tested by comparison with field counts. There are important interspecific differences in the influence of wind on migratory activity – swifts prefer strong opposed winds for their summer flights, many species such as finches and starlings are only weakly selective of winds for their migratory flights, while wood pigeons and jackdaws are highly selective of following winds.

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Ежедневные визуальные регистрации интенсивности осенней миграции в Фалстербо (южн. Швеция) пятнадцати различных видов птиц анализировались в зависимости от погоды методами уни- и мультивариационной статистики. Средняя интенсивность миграции большинства видов снижается через несколько дней после массового пролета, но через определенный отрезок времени средняя интенсивность снова возрастает. Это- вероятно результат комбинированного влияния автокорреляции по погоде и изменения внутреннего состояния мигрантов. Ветер является фактором первостепенной важности для объяснения различий в интенсивности миграции. В дополнение к этому у многих видов имеются значительные парциальные корреляции с дождем (отрицательные), атмосферным давлением (положительные), колебаниями минимальных температур (отрицательные) и видимостью (положительные).
Теория влияния ветра на миграционную активность, высоту полета, влияние ведущей линии и скорости мигрантов проверялись сравнениями с данными полевых исследований. Имеются важные межвидовые различия в силе влияния ветра на активность миграции. Каменные стрижи предпочитают сильные встречные ветры при летних перелетах, многие виды - зяблики, скворцы слабо избирательны по отношению в ветру, в то время как лесные голуби и галки предпочитают попутный ветер.

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1. Introduction

The aim of this paper is to analyse the daily size of visible passage of migrating birds at a coastal site, Falsterbo in southwesternmost Sweden, in relation to weather. I will try to use the results from this analysis to illuminate the effects of weather on the migratory activity of different species, to shed light on the importance of variation in the migrants' internal state for the daily magnitude of migration, and to test a theory of the influence of wind on the migratory behaviour of the birds.

Many studies of visible bird migration have been carried out during the past hundred years, especially in Germany, Holland, England, Finland and Sweden. The numbers of passing migrants were counted from different observation sites, most often situated on coastlines or peninsulas, where great numbers of land-birds under certain conditions may concentrate on a very narrow front. These efforts have produced much knowledge of visible bird migration, and a wealth of data about the quantities of different species at different observation sites have accumulated. In Sweden Rudebeck (1950) carried out daily counts of visible migrants at Falsterbo during the autumns of 1942–1944, and such regular observations were later continued by Falsterbo Bird Station during eleven autumns 1949–1960 (Ulfstrand et al. 1974). Daily counts of migratory birds were regularly performed also at the southernmost point of the island of Öland in the Baltic by Ottenby Bird Station during ten autumns, 1947–1956 (Edelstam 1972). Summaries of the results of the field observations of migrating birds carried out in the countries mentioned above are given by Bergman (1950), Schüz and Kuhk (1951), van Dobben (1953), Snow (1953), Svärdson (1953), Drost (1958) and Gruys-Casimir (1965).

Migratory intensity as reflected by daily counts of passing migrants has been analysed in relation to weather in several studies (cf. the above references), and for many of the most numerous migrants, especially small passerines such as the chaffinch and starling, it has repeatedly been demonstrated that visible migration is most intensive under opposed winds. This finding led many authors, but not all, to conclude that headwinds stimulate the migratory activity of these species. However, Dutch ornithologists (cf. Deelder and Tinbergen 1947) in particular, were aware of the fact that considerable migration occurred also under following winds. These movements took place at high altitudes and were overlooked by the common methods of observation, but could be watched by observers lying supine with their binoculars directed vertically.

In the late 1950's radar became a tool of bird migration research, and this brought about a radically changed view of diurnal passerine migration. Particularly influential in this respect were the extensive radar studies in Great Britain by Lack (1959–1963). The use of radar makes it possible to record bird movements at high altitudes, while migrants travelling at the lowest altitudes may be lost below the radar horizon. Radar observations revealed large scale high altitude migration on a broad front under following winds, with little or no reaction by the migrants at coastlines or peninsulas. Consequently, the lack of covariation between radar and visible migration is striking (e.g. Axell et al 1963, Wilcock 1964, Rabøl and Hindsbo 1972, Alerstam and Ulfstrand 1972, 1975).

Radar observations of the impressive high broad-front movements led to the assumption that visible and coasting migrants may only represent an unimportant fringe of the total migratory movement (Axell et al. 1963). Furthermore, as flights under tailwinds will reduce the migrants' flying time, and hence energy expenditure, the positive correlation between migratory intensity and following winds, as demonstrated in radar studies, seems much more reasonable than the reverse relationship, which had been found for visible migration. As a consequence, the attention of bird migration researchers has focussed on radar observations during the past two decades. Analysing records of visible migration, as attempted in this study, may therefore appear hopelessly out of date. However, in my opinion it may now be time to use the experiences from the numerous radar studies in order to try to explain the behaviour of birds leading to intensive low-altitude migration along coastlines under some conditions and large scale high-altitude migration under others. It is reasonable to expect that both types of strategies have adaptive values, and I can certainly not accept the dismissal of migrants taking part in low-altitude movements along coastlines as an unimportant minority. In fact, for some species (and seasons) these movements encompass so many birds (cf. above references) that one cannot, according to my opinion, exclude the possibility that the majority of all migrants of these species may be involved. The only quantitative comparison between high-altitude migration as recorded by radar and low-altitude coasting movements as seen by a field observer was attempted by Evans (1966). Radar and visible densities were of the same order of magnitude, but the data were scarce and no firm conclusion about the general importance of the two types of movements could be drawn.

My presentation is organized as follows:

A) Variation in daily size of passage of migrating birds at Falsterbo has been analysed in relation to weather by univariate as well as multivariate statistics for fifteen different species in eleven autumns. The results are presented for each species in Appendix A.

B) The effect of a large-scale migratory passage on the migration intensity during succeeding days is, in Sect. 3, taken as the basis of an hypothesis about the interplay between internal and external factors governing the birds' migratory activity.

C) Sect. 4 is devoted to the influence of various weather variables, except wind, on migratory intensity. This section to a large extent relies upon the results from the multivariate statistical analyses. Several such analyses have been carried out on the basis of radar observations as recently summarized by myself (Alerstam 1976a). The most detailed and interesting one was made by Nisbet and Drury (1968). This study, together with one by Richardson (1974), should be consulted for information about limitations and difficulties in the interpretation of multivariate analysis. Furthermore, in this issue Richardson presents an extensive review of studies of the timing of bird migration in relation to weather, but this important and useful work was not available at the preparation of this paper. The main advantage of analysing records of visible migration, as in this study, in comparison with radar observations, is that different species may be treated separately.

D) The number of migrants counted by a field observer at a coastal site varies not only with overall migratory activity, but also with factors affecting their propensity to fly along coastlines, their flight altitudes and travelling speeds (Ulfstrand 1960, Evans 1966). I believe that wind is a factor of utmost importance to govern the process of migration in these various respects. This is the reason why I have reserved Sect. 4 for an evaluation of the influence of weather except wind, and deal with the (presumably)more complex influence of wind in Sect. 5. In this section I set out to develop a simple theory of the influence of wind on the process of bird migration. I evaluate predictions from this theory for the visible migration at Falsterbo and proceed to test it by comparison with field observations. I had this simple theory (which is not truly original but composed of suggestions often recurring in the literature) worked out well in advance of any results from the analyses of the Falsterbo data, and I therefore think it is appropriate to use these data for an independent test of the theory. The theoretical reasoning is consistently based on the assumption that the behaviour of the migrants is adapted to winds so as to minimize the energy expenditure for the migratory flight.

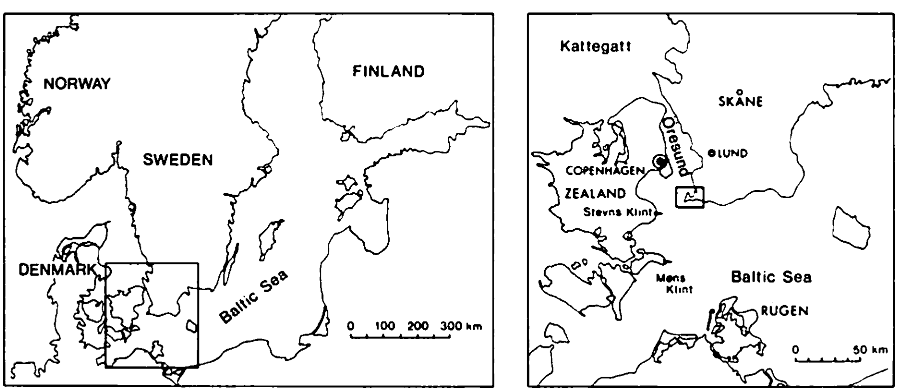
2. Observations and methods of analysis

2.1. Data on visible bird migration

2.1.1. Species and study area

This work is based on daily counts by a field observer of migrating birds passing the outermost tip of the Falsterbo peninsula in South Sweden (Fig. 1) during eleven autumns from 1949 to 1960, excluding 1951. A selection of fifteen species, representing different types of migrants which regularly pass Falsterbo in fairly large numbers, have been analysed (Tab. 1). Full details about the daily numbers of migrants of different species as well as about daily observation periods have been presented by Ulfstrand et al. (1974). Furthermore, the latter work provides information about observation routines and sources of error in the field observations, and include notes on the general migratory behaviour of the different species at Falsterbo. This latter aspect has been described and analysed in close detail by Rudebeck (1943, 1950).

In the present context it suffices to point out that



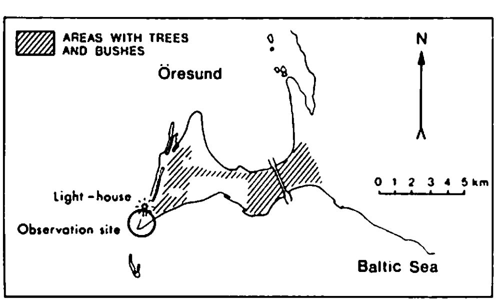


Fig. 1. This study is based on observations of visible bird migration during the autumn at Falsterbo in southwesternmost Skåne.

Tab. 1. Species and periods which are considered in the present analysis of visible bird migration at Falsterbo.

Species	Seasonal period	Daily number
Eider - August Somateria mollissima	31 Jul - 24 Aug	05 - 09 hr
Eider - October	29 Sep - 28 Oct	07 - 12 hr
Common buzzard Buteo buteo	18 Sep - 12 Oct	daily total
Honey buzzard Pernis apivorus	27 Aug - 17 Sep (excl. 1955)	daily total
Sparrow hawk - total Accipiter nisus	1 Sep - 20 Oct	daily total
Sparrow hawk - morning	1 Sep - 20 Oct	05 - 07 hr (1 Sep - 18 Sep) 06 - 08 hr (19 Sep - 20 Oct)
Sparrow hawk - noon	1 Sep - 20 Oct	10 - 14 hr
Black-headed gull Larus ridibundus	16 Jul - 24 Aug	05 - 08 hr
Wood pigeon (incl.unidentified Columba palumbus pigeons)	27 Sep - 20 Oct	daily total
Swift Apus apus	1 Jul - 10 Aug	05 - 09 hr
Swallow Hirundo rustica	22 Aug - 2 Oct	daily total
Hooded crow Corvus cornix	9 Oct - 1 Nov	daily total
Jackdaw Corvus monedula	8 Oct - 27 Oct	daily total
Yellow wagtail Motacilla flava	17 Aug - 8 Sep	daily total
Starling - July Sturnus vulgaris	1 Jul - 10 Jul	daily total
Starling - August	20 Aug - 3 Sep	daily total
Starling - October	4 Oct - 2 Nov	daily total
Chaffinch/Brambling Fringilla coelebs/montifring.	25 Sep - 17 Oct	daily total
Siskin Carduelis spinus	16 Sep - 16 Oct	daily total
Linnet Carduelis cannabina	29 Sep - 21 Oct	daily total

land-birds, which travel on courses in the sector between south and west during the autumn, become concentrated to Falsterbo because of the leading-line effects of the south and west coasts of Skåne. At Falsterbo the migrants depart over the sea towards Denmark. Except under poor visibility, Danish land is readily visible from Falsterbo, the coastal steeps at Stevns Klint, 24 km to the WSW, being the closest point (Fig. 1). The steeps at the island of Møn at a distance of about 50 km, are also fairly frequently within range of vision. Hence, migrants passing Falsterbo will have to fly between 25 and 50 km in a SW direction across the Baltic Sea before reaching the Danish Islands.

Two waterbird species, the eider and black-headed gull, are included in Tab. 1. Migrants of these species do not arrive at Falsterbo from over land but they travel westwards over the Baltic Sea to the south of the observer.

2.1.2. Definition of dependent variables

Daily counts of migrants have been analysed only within a limited interval of time during the autumn season (Tab. 1) in order to exclude, as far as possible, seasonal variation in migratory intensity. For most species the study period was defined to embrace 80% of the total number of migrants registered during the eleven autumns at Falsterbo, and the initial and final 10% of the migrants were excluded from the analysis. However, this was not feasible for all species. The eider and starling show a bimodal seasonal pattern, and the two migration peaks have been analysed separately. For the starling, an intervening period with a rather low level of average migratory intensity has also been analysed separately. Data from 1955, a year with a highly aberrant seasonal pattern of honey buzzard migration (Ulfstrand et al. 1974), were excluded from the analysis of this species.

Daily totals of migrants counted have been used as a measure of the daily intensity of visible migration at Falsterbo for most species. (Note that, throughout this study, I reserve the expression 'migratory activity' to signify the relative number of birds departing on a migratory flight on a certain day, and high migratory activity may or may not be associated with high migratory 'intensity', as recorded by radar of field observations at a particular site). However, for the eider, black-headed gull and swift, which commonly migrate in appreciable numbers during hours when observations have often been incomplete (Ulfstrand et al. 1974), daily numbers during a limited period with satisfactory observation cover and a high average level of migratory intensity have been used. For the sparrow hawk, migration in the early morning consisting of birds travelling by flapping flight has been analysed separately from migration around noon when a large proportion of the hawks travel with the aid of thermal currents like buzzards (Rudebeck 1950).

Generally there are rather few days with a very high number of migrants and a great many days with small or moderate sizes of migratory passage. Such a skewed frequency distribution is normal for phenomena which are governed in a multiplicative fashion by several independent variables. In order to reduce the degree of skewness I have transformed daily counts (N) to ln(N + 1) to be used as dependent variable in the following analyses. Of course I cannot count upon having eliminated skewness completely in this way, and I have therefore used, besides statistical methods which are rather sensitive to the frequency distribution of data, also methods with relaxed demands in this respect (but which are accordingly relatively less powerful).

2.1.3. Variation in visible migration

The variation in daily migratory intensity for different species at Falsterbo is presented in Fig. 2. The variation is larger for short-distance migrants travelling late in autumn, such as eider, common buzzard, wood pigeon, jackdaw and chaffinch/brambling, than for tropical migrants travelling relatively early in the autumn, such as honey buzzard, swallow and yellow wagtail. The sparrow hawk and starling (July) also show a comparatively small variability. The primary purpose of this study is to shed light on the variation in daily intensity of migration at Falsterbo.

As mentioned above, periods of analysis, as presented for the different species in Tab. 1, have been defined to minimize seasonal variation in migratory intensity. The seasonal variation may be determined from a fifth-degree polynomial regression of daily migratory intensity in relation to date during the study period as presented for each species in Appendix A. The square of the correlation coefficient (R^2) denotes the proportion of variance in daily migratory intensity which is accounted for by date. This proportion varies between 0.2 and 10.5% for the different species, with a mean at 3.4%. Except for the siskin and linnet with a fairly important component of seasonal variation in daily migratory intensity (10.5% and 8.1%, respectively), the time of season can only account for a few percent of the variation in daily migratory intensity to be analysed in this paper, and for the major portion of species this effect is not statistically significant.

2.2. Weather data

Weather variables have been measured at different weather stations and times, and defined according to the survey in Appendix B.

Weather variables are strongly intercorrelated, and I

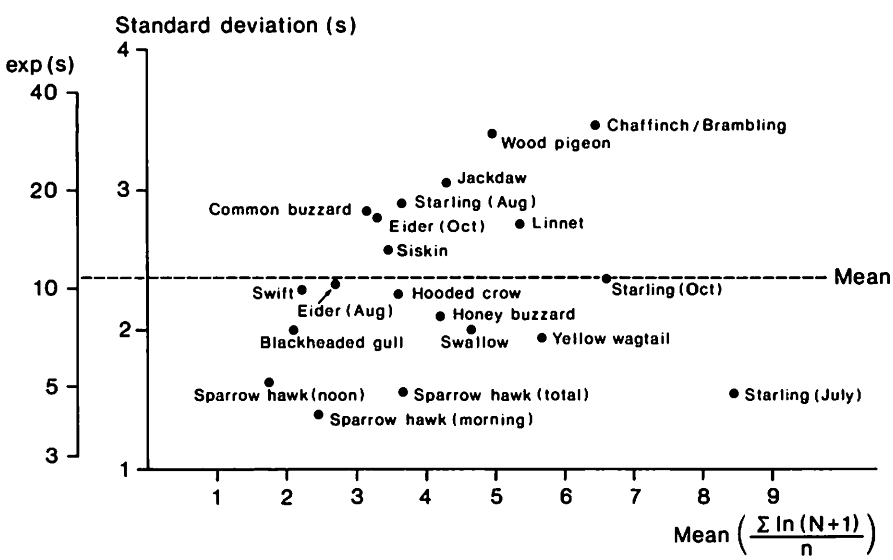


Fig. 2. Variation in daily migratory intensity for different species at Falsterbo. Standard deviation (s) is plotted in relation to the mean. The mean standard deviation for the twenty data points is indicated by a broken line. The exponent of s indicates the multiplicative range of variation.

have carried out factor analysis (Nie et al. 1975) to illuminate these interrelations. Usually the major part of the variance in a weather variable can be accounted for by a few underlying factors mirroring the changes in overall weather patterns, while a minor part reflects variation which is largely independent of other weather variables. Orthogonal (uncorrelated) weather factors were calculated separately for each of the four months July to October on the basis of data from the eleven study years. The number of factors, which should be minimal but still account for an adequate amount of the total variance, was determined by plotting roots as described by Gorsuch (1974). The resulting factor matrices are presented in Appendix B.

Five factors, accounting for 56 to 58% of the total variance in the thirty-six different weather variables, were distinguished for all months. The extraction of five factors in these analyses corresponds to the use of a minimum eigenvalue at 2 for acceptance of factors. This means that each factor accounts for at least twice the average variance in a single weather variable.

Overall weather patterns remain fairly similar throughout the autumn and the five main weather factors may be characterized as follows (cf. Appendix B).

A) One factor reflects the variation of winds along the NW–SE-axis. This factor is quite independent of variables other than wind direction, except barometric pressure trend in July and August – increasing pressure being associated with NW–Winds.

B) There is one additional 'wind direction-factor' reflecting wind variation along the SW–NE-axis. This factor also includes a decrease in temperature with winds from the NE quadrant (and with winds shifting towards this quadrant) in September and October, as well as sinking humidity and increasing air pressure under NE-winds in October.

C) A 'temperature-factor' shows the close covariation between morning, minimum and maximum temperatures. This factor also reflects the relationship between temperature and wind, high temperature being associated with E to SE-winds in July, E to S-winds in August, SE to SW-winds in September and S to W-winds in October. Furthermore, there is covariation between temperature and convective clouds as well as humidity in September.

D) One factor centres upon correlations between cloud amount, cloud ceiling, rain and barometric pressure. The structure of this factor remains very similar from July to September, a high pressure being associated with low amounts of clouds and rain. In addition, this factor includes high maximum temperatures, good visibility and low humidity in July and August, and weak NE to E-winds in September. However, this factor looks rather different in October. Low amounts of clouds and rain are then only weakly associated with high pressure, but more strongly with increasing pressure, and these conditions often coincide with decreasing temperature and minimum temperature.

E) The final factor reflects the variation in wind speed. High and increasing wind speeds tend to coincide with low and sinking humidity from August to October, and with sinking temperature and maximum temperature in July and August.

I will not use the factors in Appendix B in the following analyses. My primary intention by presenting them is to provide an objective survey of the most important relationships between different weather variables. This information, of course is, valuable for a correct interpretation of correlations between migratory intensity and weather variables.

2.3. Methods of analysis

Daily intensity of visible bird migration at Falsterbo has been analysed for different species by way of polynomial regression in relation to time of season, to the number of days since the latest large-scale migratory passage, and to wind speed under different wind directions. Correlation coefficients between daily magnitude of migration and weather variables have been calculated. In addition, daily migration totals have been grouped into four intensity categories and the association of these with weather has been determined by single-factor analysis of variance. The correlation coefficients and the means and scatter for the grouped data have been used as a basis for stepwise multiple regression and discriminant analysis, respectively. These analyses have been carried out by using standard computer programs (Nie et al. 1975). The results of all these analyses are presented in Appendix A, which also includes more detailed information about methods of analysis, grouping of data, etc.

The properties of univariate analyses are well-known, so there is no need to discuss their validity. However, multivariate statistics are less widely used, and I should like to offer a few comments about their usefulness: Multivariate analysis primarily provides a very simple formula for determining daily migratory intensity on the basis of weather. The simplicity of the formula rests partly with the fact that it is based on linear and additive effects of the weather variables and partly with the prescription to include as few as possible weather variables. Stepwise analyses start with the inclusion of the weather variable with the largest simple correlation coefficient and continue by successively including variables which account for a significant part of the residual variation in the dependent variable. This procedure may seem to lay almost unduly stress on variables with large simple correlation coefficients. However, as far as the simplicity criterion mentioned above is concerned, this has proven to be a sound method.

This reasoning clearly illustrates, and this is a point which needs emphasizing, that multivariate analysis provides no more than a statistical description of the data. However, statistical estimates of the relative importance of different weather variables for prediction of migratory intensity may of course give valuable indications (but no more than indications) as to which weather variables the birds respond. In this study I have used two different methods of multivariate statistics, i.e. linear regression and discriminant analysis. The former is slightly more powerful while the latter is relatively less sensitive to non-linearities in the data. The close agreement which has been found in this study between results from these two methods of analysis, indicates that the results are statistically consistent and not greatly biased because of skewed frequency distributions in the data.

3. Interplay between internal and external factors affecting migratory activity

3.1. Background

Whether a bird at any particular instance will depart on a migratory flight or not depends on its internal state as well as on prevailing environmental conditions. On the basis of facts and hypotheses presented by Hinde (1951), Nisbet and Drury (1968), Berthold (1975) and Gwinner (1975) the following brief account of the interplay between internal and external factors in bird migration may be outlined:

(a) Migratory birds are controlled by an endogenous time program, including a circannual rhythm in the development of *Zugdisposition* (physiological preparedness for a migratory flight) and *Zugunruhe* (execution of migratory activity). This endogenous circannual rhythm is adjusted to seasonal changes by external factors, notably the day-length in temperate zones, so that migration will take place at about the same date each year. The seasonal timing of migration may also be affected by weather, e.g. via its influence on the advancement of breeding activities prior to the autumn migration. However, the external influence on the seasonal timing of migration is not the concern of this study.

(b) For birds in *Zugdisposition* migration may be released by external stimulation in the form of appropriate weather (and perhaps geophysical) conditions. However, responsiveness to weather is not constant throughout the migratory period, but increases in the course of the season. Consequently, the threshold for external stimulation to release migration is high at the beginning of the migratory period so that the birds will fly only with favourable weather, while it is relatively lower during and after the migration peak, when the birds may be observed to fly also under moderately favourable weather.

(c) Individual weather variables may have additive stimulatory effects, and the 'stimulatory sum' attained for a given weather situation may or may not exceed the threshold value for release of the migratory flight. An inborn program in the birds determines which variables exert stimulatory effects, the relative importance of different variables in this respect, and the threshold value for the evoking of migratory flight. This program may differ between different points of time during the migratory period, between different geographical regions along the migratory route, and, needless to say, between different species of migrants.

The analyses in this study of visible bird migration at Falsterbo in relation to weather are restricted to relatively brief periods of time, usually the migration peak, in order to exclude important seasonal changes in the migrants' responsiveness to weather. For the eider and starling different periods of the autumn migration have been analysed separately, and one can suspect that the migrants' responsiveness may differ considerably between these periods.

(d) Even within a restricted period with a constant average responsiveness there is presumably a refined interplay between internal and external factors. During migratory flight the birds will use up their that reserves, which must be replenished during the following days. Hence, the act of migration increases the threshold for external stimulation. Conversely, the threshold will decrease as the delay since previous instance of migration grows progressively longer. Consequently, when unfavourable weather suddenly turns into favourable, intensive migration will be evoked, but migratory activity will soon vane, even if weather remains favourable, due to the reduced responsiveness of the migrants. Hence, the flow of migrants will occur in 'waves' or 'rushes'. However, it is easy to see that any tendency of a wave-like migration pattern may be utterly obscured or disappear if day-to-day changes in weather are extensive.

I will now turn to the Falsterbo data to try to discern the short-term interplay between internal and external factors.

3.2. Visible bird migration and duration of delay

3.2.1. Description

I have identified days with a large-scale passage of different species at Falsterbo and determined the average intensity of migration on succeeding days. In this analysis the first day after a day with large-scale passage, as defined for each species in Appendix A, is numbered 1, the second day 2 and so on up to and including the next day with large scale migration, whereupon the following day will be the first in a new 'run' numbered 1, and so on. Hence, the number of days in a run may vary from 1 (large scale migration takes place on consecutive days) and upwards. The relationship between migratory intensity and days of delay was analysed by polynomial regression as described in Appendix A. First- or second-degree equations were attained for all species (see Appendix A).

Results of these analyses are given in Tab. 2. Usually the daily totals of migrating birds decrease for a number of days after a large scale passage, but after a certain period average numbers will rise again. The following aspects are illuminated in Tab. 2:

Tab. 2. Daily number of visible migrants at Falsterbo (N) in relation to days of delay (x). Days of delay are the number of days since a day with large-scale migration, as defined for each species in Appendix A. The relationships between migratory intensity and delay are presented and plotted for each species in Appendix A. r^2 and R^2 denote the coefficient of determination for the linear and quadratic functions, respectively.

	First-degree function $\ln N = a+bx$		Second-degree function $\ln N = a+bx+cx^2$				
	b	exp b	b	exp (b+3c)	$-\frac{b}{2c}$	exp $(-\frac{b^2}{4c}-b-c)$	r^2 or R^2
Eider - August	-0.16	0.85					0.08
Eider - October			-1.09	0.42	7.1	0.06	0.14
Common buzzard			-0.50	0.68	7.0	0.28	0.03
Honey buzzard	-0.19	0.83					0.05
Sparrow hawk - total			-0.16	0.86	18.4	0.26	0.08
Sparrow hawk - morning	-0.05	0.95					0.03
Sparrow hawk - noon			-0.15	0.87	20.3	0.24	0.08
Black-headed gull			-0.27	0.79	11.2	0.29	0.05
Wood pigeon			-1.19	0.48	3.9	0.27	0.04
Swift			-0.33	0.74	16.1	0.10	0.12
Swallow			-0.23	0.82	12.6	0.29	0.05
Hooded crow	-0.13	0.88					0.04
Jackdaw			-1.21	0.45	4.4	0.20	0.05
Yellow wagtail			-0.45	0.71	6.7	0.34	0.04
Starling - August	-0.26	0.77					0.08
Starling - October			-0.46	0.67	10.9	0.13	0.08
Chaffinch/Brambling			-0.43	0.70	8.0	0.27	0.02
Siskin	-0.18	0.83					0.05
Linnet	-0.25	0.78					0.08
Mean				0.74		0.23	0.06

(1) Size of migratory passage is a function of days of delay, f(x), according to the equations:

$$\begin{cases} \ln N = a + bx \\ \ln N = a + bx + cx^2 \end{cases}$$

where N is the number of migrants (N + 1 is used in the calculations to avoid the logarithm of zero, but this approximation can be disregarded in this context) and x is the number of days of delay. Furthermore

$$\begin{cases} \dfrac{d(\ln N)}{dx} = \dfrac{dN}{dx} \cdot \dfrac{1}{N} = b \\ \\ \dfrac{d(\ln N)}{dx} = \dfrac{dN}{dx} \cdot \dfrac{1}{N} = b + 2cx \end{cases}$$

The coefficient b designates the instantaneous change in relative number of migrants with increasing number of days of delay at any time for the first-degree function and at x = 0 (an imaginary point of time immediately after a day of large-scale migration) for the second-degree function. There is an instantaneous reduction by more than 100% for the eider (October), wood pigeon and jackdaw, but by only 15 to 50% for the other species.

(2) In order to render the magnitude of reduction in migratory intensity after an instance of large-scale migration more clear, I have calculated the ratio of average number of migrants on day 2 to that on 1. This ratio is given by exp (b) for the first-degree function (in which case this ratio of course is the same for all consecutive days) and by exp (b + 3c) for the second-degree function. As seen from Tab. 2 the average ratio for all species is 74%, but for the eider in October, wood pigeon and jackdaw it is considerably lower, falling between 40 and 50%.

(3) The number of days of delay after which average migration rate will be at a minimum is given by $(-\frac{b}{2c})$. With reference to this interval of time three main categories of migrants may be discerned: (1) intensities of wood pigeon and jackdaw migration fall to a minimum already after four days of delay, while (2) the bulk of migrants show a minimum after 6 to 13 days of delay. (3) For the sparrow hawk and swift minimum migration does not take place until after 16 to 20 days of delay. However, for these two species the existence of a signi-

Tab. 3. Significant (P < 0.05) correlation coefficients between weather variables and f(x), which denotes a function of days of delay as presented for each species in Appendix A. ** = p < 0.01, *** = p < 0.001. See text for further explanation.

	Eider - August	Eider - October	Common buzzard	Honey buzzard	Sparrow hawk - total	Sparrow hawk - morning	Sparrow hawk - noon	Blackheaded gull	Wood pigeon	Swift	Swallow	Hooded crow	Jackdaw	Yellow wagtail	Starling - August	Starling - October	Chaffinch/Brambling	Siskin	Linnet
Cloud amount																			
Cloud ceiling																	-0.14		
Convective clouds						0.10	0.11		0.14			0.17			-0.25	0.16			
Visibility											0.12					0.18			
Rain 07hr	0.19													-0.21**					
Rain 07-13hr	0.18													-0.21**					
Relative humidity			0.21**				0.18***											0.19**	
Rel. humidity trend																			
Barometric pressure							-0.14**											-0.18**	
Barom. pressure trend			-0.18																
Temperature		-0.16		-0.23**	0.13**		0.14**			-0.44***	0.11		-0.22**		-0.38***		0.26***	0.22**	0.26**
Temperature trend																			
Min. temperature	0.23**	-0.19		-0.24**	0.10					-0.41***			-0.20	-0.17	-0.34***		0.18**	0.21**	0.25***
Min. temp. trend																			
Max. temperature					0.11					-0.32***					-0.25				0.15**
Max. temp. trend																			
Surface winds:																			
Wind speed													-0.17	-0.18				0.23***	
Wind speed trend			0.15								0.11								
N-wind										-0.16	-0.12			-0.17					-0.19**
N-wind trend			-0.17						0.18										
NE-wind							-0.11			-0.24**		0.20	0.18	-0.17			-0.24***	-0.28***	-0.22**
NE-wind trend									-0.20**					0.16					
NW-wind	-0.22	-0.15							0.17								0.29***	0.24***	
NW-wind trend			-0.15																
W-wind	-0.19									0.16		-0.20	-0.22**				0.35***	0.33***	
W-wind trend														-0.16					
High-altitude winds:																			
Wind speed									-0.16	0.20**			-0.19				0.14	0.23***	
Wind speed trend																			
N-wind				0.19	-0.11		-0.14**		-0.16		-0.12								-0.18
N-wind trend																			
NE-wind					-0.13**		-0.21***			-0.29***				-0.24**	-0.25		-0.21**	-0.20**	-0.24***
NE-wind trend																			
NW-wind	-0.20			0.21					-0.24***				-0.18				0.25***		
NW-wind trend														-0.17					
W-wind							0.15**		-0.17	0.28***				0.18			0.35***	0.22**	0.16
W-wind trend														-0.20**					
	127	185	200	144	436	420	399	232	203	182	336	130	140	179	91	207	217	208	192

ficant minimum seems doubtful, and I think the second-degree functions rather indicate that reduction in migratory intensity after an instance of large-scale migration is gradually arrested until it eventually disappears after a long period of delay.

(4) The ratio of average number of daily migrants on the 'minimum occasion' to that on day 1 is given by exp $(-\frac{b^2}{4c} - b - c)$. This ratio falls between 20 and 30% for most species, the overall mean being 23%.

(5) The proportion of variation in daily migratory intensity (measured as the variance of ln N) which can be explained by the effect of delay varies between 2 and 14% for the different species with an overall mean at 6%. Although this is not a large proportion, the effect is statistically significant for all species (which some doubtfulness for the chaffinch/brambling).

3.2.2. *Interpretation*

The observed relationship between migratory intensity and days of delay may be due to the influence of weather, the internal state of the migrants or to the combined effects of both these factors. Another factor which may possibly affect this relationship is the abundance of potential migrants in the recruitment area. However, I think this is of little importance, as emigration of birds from this area probably is closely correlated with immigration except during the final part of the migratory period, which is excluded from the present analysis. I will look closer at the three first-mentioned possible explanations:

(1) *Weather.* Meteorologists use the concept of persistence forecasts, which implies that weather is predicted to remain the same after the day of forecasting. This 'method of weather forecasting' is in fact considerably better than predictions on the basis of the average frequency of occurrence of different weather situations, as calculated over many years. This means that, for a given weather situation, there is a relatively high probability

that weather will remain similar on succeeding days, but this probability will gradually decrease through time to approach the overall average frequency of occurrence of this weather situation. Consequently, when weather promoting intensive migration is prevailing, there is relatively high probability that similarly favourable weather will prevail on succeeding days. According to this argument average migratory intensity will be expected to be relatively high soon after an occasion of large scale migration (day 1) and to decrease to reach a constant level after some time.

There are two ways of investigating whether weather persistence provides at least part of the explanation for the observed relationships between migratory intensity and delay. One is to find out if the first- and second-degree functions (f(x)) are significantly correlated with weather, and particularly with weather variables which in turn are significantly correlated with migratory intensity.

Correlation coefficients between weather variables and f(x) are presented in Tab. 3. It is seen from this table that f(x) is far from independent of weather. For many species there are highly significant correlations with several weather variables, many of which in turn are significantly associated with migratory intensity as seen in Appendix A. However, this correspondence is not complete. By way of example, clouds, rain, barometric pressure and wind speed show highly significant correlations with migratory intensity of the major part of the species (cf. Tab. 4), but these variables are generally not significantly correlated with f(x). Temperature and wind direction constitute the most important weather correlates to f(x), and I would suggest that they are the weather variables with most pronounced auto-correlations (correlations between values on consecutive days).

A second way of testing the association between weather and f(x) is to perform multivariate analysis of migratory intensity with weather variables as well as f(x) as independent variables. f(x) should be included as a significant variable into the multivariate models if it affords some explanation of migratory intensity independently of weather. (Stepwise multivariate analysis, as used in this study, provides only a rather crude test of this problem. The most efficient method would have been to calculate the partial correlation between migratory intensity and f(x) after the combined effects on migratory intensity of all weather variables had been taken into account.) As seen from Appendix A (and Tab. 5), f(x) is included into the multivariate models for most species, and the multiple correlation coefficient becomes significantly raised at the inclusion of this variable.

However, for the honey buzzard, wood pigeon, yellow wagtail and chaffinch/brambling, f(x) is not included into one or both of the two types of multivariate models used. In a few other species multivariate models including f(x) are not appreciably better in explaining migratory intensity than the corresponding models exclusively based on weather.

I conclude that the significant relationship between migratory intensity at Falsterbo and duration of delay is in part due to weather, but in addition, there seems to be an effect which is independent of weather.

(2) *Internal drive.* Other things being equal, one would expect migration to become reduced for some days after an occasion of large scale migration, whereafter mean migratory intensity should gradually increase as more and more birds will have built up complete fat reserves, and the average threshold for external release of migratory flight will have decreased. Hence, this hypothesis predicts a positive correlation between average migratory intensity and days of delay. However, for all species at Falsterbo this correlation is clearly negative soon after an instance of large-scale migration, and this hypothesis therefore can be ruled out as the only explanation of the observed relationship. For a fair part of the bird species, however, average size of passage attains a minimum and increases with additional days of delay. This increase may possibly be due to the decrease in threshold for external stimulation as described above.

(3) *Weather and internal drive in combination.* The above reasoning has paved the ground for considering the combined effects of weather and the migrants' internal drive, respectively: Weather may account for a decrease in average magnitude of migration with increasing delay while the internal drive may account for the reverse relationship. It seems logical to combine these two effects in order to explain the observations for many species, that after an initial decrease in migratory intensity with increasing delay the reverse trend appears after some time. My suggestion of an explanation is illustrated in Fig. 3.

The average favourability of weather (= probability of occurrence of favourable weather) decreases with prolongation of delay to reach a stable level corresponding to the mean frequency of occurrence of favourable weather. The average population threshold for external stimulation will change with time according to the following pattern: The threshold will rise abruptly on the day of large scale migration. On the days immediately thereafter, weather will remain favourable, and a large fraction of the birds will continue to migrate in spite of their relatively high threshold, which, accordingly , will increase further. After some time the average threshold will lie above weather favourability, and only a small number of birds will migrate. As the resting birds replenish their fat reserves their threshold will gradually sink, but since average favourability of weather also decreases, migratory intensity will be low. Finally, weather will stabilize while the threshold will continue to decrease, and many birds will depart on migration. Consequently, minimum migration will be expected to take place when the threshold exceeds weather favourability to the greatest extent.

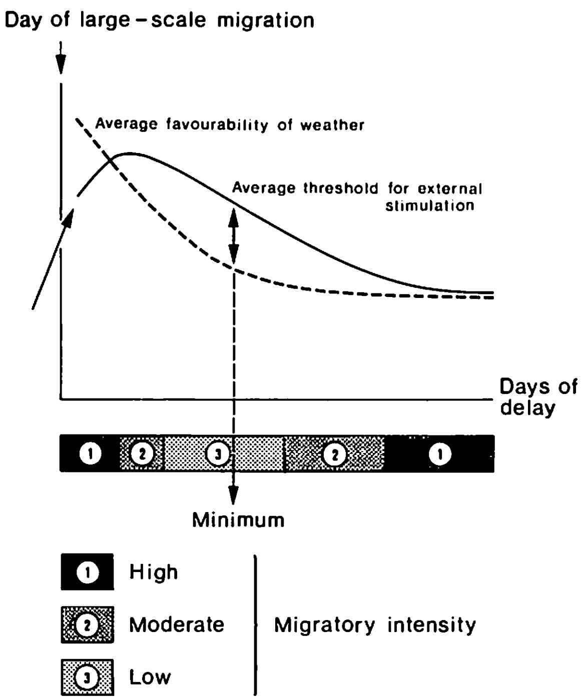


Fig. 3. Hypothetical variation in average migratory intensity after a day of large-scale migration. Migratory intensity is expected to be high when the average threshold for external stimulation is close to, or below, average favourability of weather and to be low when the threshold is considerably above favourability of weather.

With reference to Fig. 3 a few additional aspects are noteworthy:

(a) For birds, the migration of which is associated with relatively rare weather conditions, average favourability of weather will decrease steeply and, as a consequence, minimum migration will occur after a relatively short period of delay. Such a short time has been found for the wood pigeon and jackdaw at Falsterbo, and migration of these species is indeed primarily associated with northeasterly winds, which are of relatively rare occurrence (Appendix A).

(b) The average threshold may stabilize at a level clearly above average weather favourability. In this case the migratory intensity will be expected to decrease monotonically with prolonged delay, perhaps reaching a constant low level after a long time. This may be the explanation for species failing to show any significant increase in size of migratory passage at Falsterbo after a long period of delay.

(c) However, for this latter category of migrants I think the most likely explanation is that the average threshold is almost constant in relation to delay after sizeable visible migration at Falsterbo. This could happen because visible migratory intensity at Falsterbo may sometimes be a poor indicator of overall migratory activity (cf. Sect. 5).

Due to this reservation, the Falsterbo data can only give tentative support to the hypothesis in Fig. 3.

3.3. Comparison with other studies

Nisbet and Drury (1968) investigated the effect of delay for nocturnal passerine and waterbird migration, as registered by radar during the spring in Massachusetts. For the first-mentioned category there was a significant inverse partial correlation between migratory intensity and days of delay (as was the case also for visible migration of some species at Falsterbo). This was due to autocorrelation in the weather, and no effect of the migrants' responsiveness to weather could be discerned. However, for the waterbirds the situation was more complex, as both the autocorrelation in weather and the migrants' responsiveness seemed to be of importance. Calculating the deviation between the observed migratory intensity and that predicted on the basis of weather revealed that the migrants' average threshold for external stimulation was intermediate on the first night after a sizeable migration (relative difference, predicted minus observed migration = -0.03), high on the second ($+0.22$) and third ($+0.15$) night, and low on the fourth and fifth (-0.21) as well as on subsequent nights (-0.32).

Nisbet and Drury (1968) argued that many of the waterbirds were probably departing directly from their wintering grounds, and the above result may therefore be attributed to the progressive entry of birds into *Zugdisposition* without invoking short-term changes in responsiveness. However, the above result is in very good agreement with the hypothesis in Fig. 3, and in my opinion this hypothesis furnishes the most probable explanation.

Hence, the radar investigation by Nisbet and Drury (1968) gives some tentative support for short-term influence of the birds' internal drive on migratory intensity. However, this effect seemed to be relatively weak, and for one important category of birds, passerine night migrants, no effect at all could be discerned. This scattered picture resembles that arrived for migration at Falsterbo.

In contrast, there are also authors who maintain that their data show a picture as transparent as glass. Dolnik and Blyumental (1967) and Blyumental (1973) studied, by trapping and field observations, bird migration at the Rybachi Biological Station on the Kurishe Nehrung by the Baltic Sea (approx. 500 km east of Falsterbo). They were mainly concerned with chaffinch migration, although they also gave complementary data for many other species, and they maintained that the results arrived at for the chaffinch concerning the profound influence of the birds' internal state on migratory intensity are characteristic of most other species as well. The variation in chaffinch migratory intensity at Rybachi is described by Dolnik and Blyumental (1967) as follows (I have deleted a few references to Russian literature from the citations): "It is well known that migration in small birds commonly proceeds by waves. Days with intensive migrations are followed abruptly by days without migratory activity, then another wave comes along ... At the Kurishe Nehrung the migratory waves of chaffinches occur on almost the same dates yearly. It is possible to predict the time of flight each autumn. This regularity of migratory waves also occurs at other places in the Baltic region ... The comparison of migratory waves of chaffinches with movement of cyclonic conditions in Europe does not show a regular connection between weather and migration. The only factor which is well correlated with the flight of chaffinches at the Kurishe Nehrung is the fat level of the migrating birds. ... The migratory wave continues from one to seven days but usually lasts three days. After it is over, the following pause lasts from one to eight days but averages three days. During the pause there are only a few birds at the Kurishe Nehrung; they feed intensively throughout the day and increase their storage of fat."

I add some supplementary quotations from Blyumental (1973):

"Comparison of chaffinches' flights over the Courland Spit in different years has shown that the times of their beginning and end are always the same. The dates of different migration waves in various years deviate by no more than ± 1.5 days, and the number of waves remain constant. An attempt was made to find a correlation between variations in the weather (as provided by synoptic maps of Europe) and variations in the intensity of migration in 1958, 1960 and 1961. No stable connection has been found to exist between changes in weather conditions and migration, not only on the day of observation at the place of investigation, but also in other combinations of data (weather on preceding day; weather at the birds' starting point and at their goal; weather on the following day; etc.) ... Pulsating behaviour during migration is also exhibited by birds which remain in unchanging conditions, and differs from natural pulsating behaviour only (or principally) in that the rhythms of individual birds in captivity are not synchronized. In nature, these rhythms may be synchronized by insignificant changes of weather and mutual imitativeness".

The predictable pattern of waves of migrating chaffinches at Rybachi, without any clear correlation to weather is indeed very different from the situation at Falsterbo. The 'wave-like' pattern in the chaffinch/brambling migration at Falsterbo, as reflected in the covariation between average migratory intensity and time of delay, accounted for only 2% of the variation in daily counts of migrants and was of doubtful significance, whereas weather did account for 40% of this variation (Appendix A, Tab. 2). However, perhaps the effect of delay is misleadingly weak for chaffinch/brambling migration at Falsterbo – the mean effect for all species was 6%. Furthermore, visible migratory intensity at Falsterbo may be a poorer indicator of overall daily migratory activity than visible migration at Rybachi, and weather changes may be on the average more dramatic at Falsterbo than at Rybachi, where the effects of cyclonic passages probably have faded to some extent. However, even if all these reservations are taken into account, the difference in the migrants' pattern of occurrence between Falsterbo and Rybachi seems to me incredibly great.

Unfortunately, Dolnik and Blyumental (1967) and Blyumental (1973) do not present original data on daily migratory intensity at Rybachi nor on the relation between weather and migration, but only a few selected examples of a 'typical' migratory wave in combination with idealized illustrations. Their conclusions clearly contradict my hypothesis above, but I am sceptical about many of their general statements, presented in an authoritative manner without original data, and it seems necessary to have a further critical look into the possible covariation between weather and migration at Rybachi before one can judge the relative importance of external and internal factors in this case. Variation in daily migration at Rybachi seems to constitute an interesting problem and future studies will be awaited with great interest, all the more so if the purpose will be to criticize hypotheses rather than to seek out supporting evidence for them.

4. Covariation between weather and visible bird migration

4.1. Simple and partial correlations

Simple correlation coefficients between weather variables and daily counts of visible migrants at Falsterbo are given for each species in Appendix A, where these relationships are also illuminated by single-factor analysis of variance. In general, there is good agreement between the results from these two statistical analyses. In Tab. 4 I have broadly summarized the principal results by presenting the significant simple correlation coefficients for the different species. On the basis of this table one may distinguish between three main categories of weather variables:

(1) Weather variables which are significantly associated with visible migration in a majority of the species, and where the same sign of correlation pervades for practically all of these species. These weather variables are (sign of correlation coefficient is given in brackets): cloud amount (negative), cloud ceiling (positive, except for the swift which constitutes a special case discussed in Sect. 5), visibility (positive), rain (negative), barometric pressure and pressure trend (positive), min. temperature trend (negative), wind speed and wind speed trend (negative except for the swift), NE-wind trend (positive

Tab. 4. Signs of simple correlation coefficients between daily migratory intensity at Falsterbo and weather variables. Only statistically significant ($p < 0.05$) correlations are included (signs are shown in brackets for $0.01 < p < 0.05$). The table is based on data given in Appendix A.

	Eider - August	Eider - October	Common buzzard	Honey buzzard	Sparrow hawk - total	Sparrow hawk - morning	Sparrow hawk - noon	Black-headed gull	Wood pigeon	Swift	Swallow	Hooded crow	Jackdaw	Yellow wagtail	Starling - July	Starling - August	Starling - October	Chaffinch/Brambling	Siskin	Linnet	No. +	No. -	No. tot
Cloud amount			-	-	-	(-)	-	-	-		-	-	-	-	-	-	(-)				-	14	14
Cloud ceiling					+			+	+	-	+	+	+	+	+	+	(+)	(+)		(+)	12	1	13
Convective clouds			+				+	(+)													3	-	3
Visibility			(+)		+	+		+	+		(+)	+	+				(+)				9	-	9
Rain 07hr			-	-	-	-	-		-		-	-	-	-	-	-	-	-	(-)	-	-	16	16
Rain 07-13hr			-	-	-	-	-		-		-	-	-	-		-	-	-	-	-	-	15	15
Relative humidity									-		+								+		2	1	3
Rel. humidity trend																					-	-	-
Barometric pressure					+	+		+	+		+		+	+	+	+		+	(+)	(+)	12	-	12
Barom. pressure trend			+	+	+	+	+	+	+			+	+	+			+	(+)		(+)	13	-	13
Temperature		(+)	-	(-)					-	-	(+)	-	-					+	+	+	5	6	11
Temperature trend		(+)	-		-		-		-			-	-	(+)	(+)	(+)					4	6	10
Min. temperature			-	-					-			-	-	(-)		(-)		(+)	(+)		2	7	9
Min. temp. trend			-		-		-		-			-	-					-	(-)	(-)	-	9	9
Max. temperature					+		(+)			-	+							+	+	+	6	1	7
Max. temp. trend				+	(+)		+	(+)						+	(+)	+					7	-	7
Surface winds:																							
Wind speed		(-)	-	-	-	-	-		-	+	-	-	-	-	-	-	-	-	-	-	1	17	18
Wind speed trend		(-)	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	18	18
N-wind	-	-	+		(+)			(+)	+	(-)		+	+			(-)			(-)	-	6	6	12
N-wind trend	-	-	+				(+)					(+)	(+)								4	2	6
NE-wind		-	+						+	-		+	+	(-)	(+)			-	-	-	5	6	11
NE-wind trend		-	+		+		+	+	+			+	+			(+)					8	1	9
NW-wind	-	(-)	+				+	+	(-)	+						(-)					4	4	8
NW-wind trend	-	(-)									-					-					-	4	4
W-wind							+	(+)	-	+		-	-					+	+	+	6	3	9
W-wind trend			-		-		-	(-)	-		(-)	-	-			-					-	9	9
High-altitude winds:																							
Wind speed			-	(-)	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	1	17	18
Wind speed trend			-	-	-	(-)	-	-	-		-	-	-	-	-	-	(-)	-	-	-	-	17	17
N-wind	(-)		+					(+)								-	(-)				2	3	5
N-wind trend		-	+								(-)			(-)							1	3	4
NE-wind	(-)	(-)	+						+	-		+	+	(-)		(-)		-	(-)	-	4	8	12
NE-wind trend		(-)	+		+	(+)	(+)	+	(+)			+	(+)	(-)							8	2	10
NW-wind				(+)			(+)	(+)	-	+											4	1	5
NW-wind trend		-								(+)	(-)					(-)					1	3	4
W-wind		(+)					+		-	+		-	-	(-)				+		+	5	4	9
W-wind trend			-		-	(-)	-	-	-	+		-				(-)					1	8	9

except for the eider and perhaps yellow wagtail), W-wind trend (negative except for the swift).

(2) Weather variables which are significantly associated with visible migration in a large proportion of the species, but for which the sign of correlation frequently differs between the species. These variables are temperature, change in temperature and all wind direction variables (but not change in wind direction).

(3) Weather variables which are significantly correlated with migration in only a few species: convective clouds, relative humidity, humidity trend, max. temperature and max. temp. trend (these two variables are on the borderline to category 1), N- and NW-wind trend.

This survey provides indications about which weather variables are of general importance in governing the size of visible migratory passage at Falsterbo. However, as discussed in Sect. 2, weather variables are closely intercorrelated which may lead to spurious correlations and also to real correlations becoming obscured. In order to sort out such cases, I have identified the weather variables which are most important for prediction of visible migration by stepwise multiple regression and discriminant analyses. These analyses have been carried out both excluding and including the effect of delay (cf. previous section), and both sets of results are presented in Appendix A. Variables included into the multivariate models are summarized in Tabs 5 A and B.

As expected, significant correlations are much fewer in Tab. 5 than in Tab. 4. Repeating the division of weather variables into the three above-mentioned categories on the basis of Tab. 5 gives the following result:

Category 1 (note that some variables are included on rather generous grounds into this category): cloud amount (negative partial correlation), visibility (posi-

Tab. 5A. Signs of partial correlations between daily visible migratory intensity and weather variables as derived from stepwise multiple regression analysis presented for each species in Appendix A. x indicates that the effect of delay is included into the regression model.

	Eider - August	Eider - October	Common buzzard	Honey buzzard	Sparrow hawk-total	Sparrow hawk-morning	Sparrow hawk-noon	Black-headed gull	Wood pigeon	Swift	Swallow	Hooded crow	Jackdaw	Yellow wagtail	Starling - July	Starling - August	Starling - October	Chaffinch/Brambling	Siskin	Linnet	No. +	No. -	tot.
Cloud amount			-				(-)	(-)	-		-	-	-	-		-					-	9	9
Cloud ceiling																					-	-	-
Convective clouds			+																		1	-	1
Visibility					+	+		(+)				+					+	(+)	+		7	-	7
Rain			-	(-)	-	-	-		-		(-)		-		-	-	-	-	-	-	-	14	14
Relative humidity						+													+		2	-	2
Rel.humidity trend						(-)			(-)											-	-	3	3
Barometric pressure																					-	-	-
Barom.pressure trend				+	+		+					+	+					+			6	-	6
Temperature						(+)											(+)		+		3	-	3
Temperature trend	(+)													+							2	-	2
Min. temperature															-			+			1	1	2
Min. temp. trend									-				(-)					-		-	-	4	4
Max. temperature		(-)					(+)					+									2	1	3
Max. temp. trend			(+)	+																	2	-	2
Wind speed			(-)	-	-	-	-	-	-		-			-	-	-	-	-		-	-	14	14
Wind speed trend		-	-				-		-			-	-	-			-	(-)	-	-	-	11	11
N-wind			±				-													(-)	1	2	3
N-wind trend																					-	-	-
NE-wind		-								-	-		+				(-)	-		-	1	6	7
NE-wind trend			+					+													2	-	2
NW-wind					-								-								-	2	2
NW-wind trend		-																		(+)	1	1	2
W-wind				+	+	+	+	+	-	+		(-)		+							7	2	9
W-wind trend				-	-	-	-				-					-					-	6	6
Days of delay	x	x	x		x	x	x	x		x	x	x	x		?	x	x		(x)	x			15

tive), rain (negative), barometric pressure trend (positive), min. temperature trend (negative), wind speed and wind speed trend (negative), W-wind trend (negative).

Category 2: NE- and W-wind.

Remaining variables fall into the third category. The variable 'days of delay' is included into the multivariate models in a dominating proportion of the species.

4.2. Relative importance of different weather variables

Tab. 5 gives a qualitative survey of the weather variables most important for prediction of visible bird migration. The quantitative contribution of different variables in this respect, as determined from the multiple regression equations, is shown in Tab. 6. It must be emphasized that this table provides only very rough indications of the relative importance of the different weather variables. As discussed by Harris (1975) there are several different measures, each with certain drawbacks, of the relative importance of the independent variables in multiple regression models. The most straightforward measure is b^2, where b is the standardized multiple regression coefficient as given for each species in Appendix A. However, in Tab. 6 I have used $\frac{br}{R^2}$ (b defined as above, r = simple correlation coefficient, R^2 = proportion of variance in visible migration which is accounted for by the independent variables) as a measure of importance because the product br provides a directly additive partition of R^2. One should note that this measure does not correspond exactly to the relative drop in R^2 which occurs when the variable in question is eliminated from the regression equation (to fulfil this condition a third measure of importance, rather tedious to work out, must be used, cf. Harris 1975).

With the above reservations in mind the importance of weather for explaining visible bird migration at Falsterbo may be summarized on the basis of Tab. 6 as follows: On the average 39% of the variation in daily counts of visible migration can be explained by weather and duration of delay according to multiple regression analysis. Wind variables contribute almost half, 47%, of this proportion. Furthermore, the effect of days of delay (probably a combination of variation in weather and the migrants' internal drive, as discussed in Sect 3) accounts for 16% of this proportion, rain 13%, temperature 8%, cloud amount 6%, change in barometric pressure 5% and visibility 4%, whereas other variables provide only

Tab 5B. Signs of partial correlations between daily visible migratory intensity and weather variables as derived from stepwise multiple discriminant analysis presented for each species in Appendix A. x indicates that the effect of delay is included into the discriminant model.

	Eider - August	Eider - October	Common buzzard	Honey buzzard	Sparrow hawk-total	Sparrow-hawk-morning	Sparrow hawk-noon	Blackheaded gull	Wood pigeon	Swift	Swallow	Hooded crow	Jackdaw	Yellow wagtail	Starling - August	Starling - October	Chaffinch/Brambling	Siskin	Linnet	No. +	No. -	tot
Cloud amount			-				-		-		-		-	(-)						-	6	6
Cloud ceiling			(-)					+							(+)					2	1	3
Convective clouds									(+)						(+)					2	-	2
Visibility					+	+						+				+				4	-	4
Rain			-		-	-	-		-				-		-			-	-	-	9	9
Relative humidity									(-)											-	1	1
Rel. humidity trend																				-	-	-
Barometric pressure															+		+			2	-	2
Barom. pressure trend				+			(+)						+			(+)				4	-	4
Temperature						+				-						(+)		+		3	1	4
Temperature trend																				-	-	-
Min. temperature										+							(+)			2	-	2
Min. temp. trend									-			-	(-)			(-)	-			-	5	5
Max. temperature											(+)	+								2	-	2
Max. temp. trend																				-	-	-
Wind speed			(-)	-	-	-		(-)	-		-	-		-	(-)	-			-	-	12	12
Wind speed trend		(-)	-		-		-					-	(-)	-			-	-	-	-	10	10
N-wind																				-	-	-
N-wind trend		(-)																	(+)	1	1	2
NE-wind				(∓)		+	-		+	-	-			-		-	-		-	2	8	10
NE-wind trend			+					+	(+)											3	-	3
NW-wind							+	+	-											2	1	3
NW-wind trend		(-)									(-)				-					-	3	3
W-wind		(+)			+								-						(+)	3	1	4
W-wind trend	(-)			-	-		-			(+)	-									1	5	6
Days of delay	(x)	x	x	x	x	x	x	x		x	x	x	(x)	x	x	x		(x)	x			17

small contributions. This is the average situation for all species, and as seen from Tab. 6 there are considerable interspecific differences.

The profound importance of wind for the prediction of visible migration at Falsterbo is clearly brought forward in Tab. 6. There is covariation not only between wind and migratory activity, but also between wind and flight altitude, leading-line effect and travelling speed, all of which effects are important for the visible migration at Falsterbo. I will try to elucidate this complex relationship by presenting a theory of wind's influence on the birds' migratory behaviour in Sect. 5. In the present context I will only warn against any premature conclusions about the association between wind and migratory activity. Not even for wind speed, wind speed trend and W-wind trend, all variables of which show inverse partial correlations with visible migratory intensity in a large part of the species (Tab. 5), is it possible safely to draw the conclusion that these variables are significantly associated with overall migratory activity. (As discussed in Sect. 5, counts of migrants may be importantly affected by the birds' travelling speed, fewer birds passing the observation site when they fly slowly. This may lead to decreasing numbers of counted migrants with increasing cross and opposed wind speed and with winds shifting towards an opposed direction without necessarily invoking any effect of these weather variables on migratory activity.)

4.3. Influence of weather independently of wind

Mainly on the basis of Tab. 5 (see also Tab. 6 and Appendix A) I will discuss the covariation between visible migration and different weather variables independently of wind.

Rain is generally associated with a low visible migration intensity. It is reasonable to expect that energy costs for migration in rain, due to chilling and loading of the birds, are high. An additional factor rendering migration under these circumstances unfavourable is that orientation may become complicated. There are several records in the literature that migrants become disoriented when travelling in rain or fog (Lack 1963).

Migratory activity seems to be favoured by good visibility and the absence of clouds. These effects with all probability are not to be explained by the fact that low visibility and overcast in turn are associated with rain, since the effects of cloud amount and visibility are in-

Tab. 6. Relative importance of weather variables for prediction of visible migration at Falsterbo. The table is based on multiple regression models including the effect of days of delay (if significant), as presented in Appendix A. The measure of importance shown in the table is defined in the text. This measure of importance corresponds to the proportion of explained variance in daily visible migration contributed by the different weather variables.

	R^2	Cloud amount	Cloud ceiling	Convective clouds	Visibility	Rain (2 var.)	Humidity (2 var.)	Barometric pressure (2 var.)	Temperature (6 var.)	Wind (20 var.)	Days of delay
Eider - August	0.14								0.22		0.78
Eider - October	0.29								0.04	0.53	0.43
Common buzzard	0.49	0.13		0.09		0.15			0.01	0.55	0.07
Honey buzzard	0.38					0.09		0.25	0.18	0.48	
Sparrow hawk - total	0.44				0.06	0.35		0.07		0.36	0.16
Sparrow hawk - morning	0.30				0.15	0.52	0.04		0.01	0.20	0.08
Sparrow hawk - noon	0.41	0.06				0.09		0.18	0.02	0.51	0.14
Black-headed gull	0.21	0.13			0.13					0.44	0.30
Wood pigeon	0.46	0.14				0.10	0.02		0.15	0.59	
Swift	0.32									0.77	0.23
Swallow	0.30	0.10				0.07				0.64	0.19
Hooded crow	0.50	0.20			0.23			0.23	0.04	0.21	0.09
Jackdaw	0.56	0.24				0.15		0.14	0.09	0.32	0.06
Yellow wagtail	0.34	0.10							0.07	0.83	
Starling - July	0.67					0.33			0.04	0.63	-
Starling - August	0.48	0.17				0.18				0.46	0.19
Starling - October	0.36				0.12	0.14			0.03	0.53	0.19
Chaffinch/Brambling	0.40				0.01	0.14		0.07	0.31	0.47	
Siskin	0.29				0.02	0.14	0.13		0.41	0.18	0.12
Linnet	0.51					0.18	0.01		0.04	0.63	0.10
Mean	0.39	0.06	-	-	0.04	0.13	0.01	0.05	0.08	0.47	0.16

cluded together with rain into the multivariate models of most species. I am rather astonished that these two variables are included, since I did not expect any important disadvantage for migration either in fairly poor visibility (if not fog) or under overcast, because there are indications that migrating birds can rely on a magnetic compass for their orientation if celestial cues become obscured (Keeton 1969, Emlen 1975, Wiltschko and Wiltschko 1976). At any rate, these variables obviously exert only a restricted influence on migratory activity as intensive migration of several species may be observed at Falsterbo also with poor visibility and complete overcast provided wind conditions are favourable for a large-scale passage (Roos 1977).

Increasing barometric pressure is significantly associated with intensive migration independently of wind in various species such as the honey buzzard, sparrow hawk, hooded crow, jackdaw, starling and chaffinch/brambling. One may speculate that the migrants respond directly to pressure change, and that any such response to increasing pressure will bring about intensified migration soon after the passage of a depression (usually in the southwestern sector of the cyclone) corresponding to a synoptic situation relatively favourable for migration (see below). Indications that birds can respond to changes in air pressure were presented by Stolt (1969) on the basis of experiments in air pressure chambers. However, for a redpoll *Carduelis flammea* and a linnet in autumn, Stolt found a significant increase in total activity with falling air pressure, i.e. a correlation quite opposite to that described above. As pointed out by Stolt (1969) a positive correlation with falling air pressure does not seem to make sense as far as migratory activity is concerned, so it is more likely that locomotor activity other than migratory restlessness was responsible for the correlation found in the cage experiments.

Decreasing minimum temperature is associated with intensive visible migration independently of wind in the wood pigeon, hooded crow, jackdaw, starling (October), chaffinch/brambling and linnet. These are species which migrate during late autumn, and it seems clearly advantageous for these migrants to intensify their emigration at a cold spell because of the risk that living conditions at northerly resting grounds may become highly unfavourable.

The positive partial correlations between visible migration of the common buzzard, honey buzzard and sparrow hawk (noon) and convective clouds, maximum temperature and max. temperature trend probably reflect the fact that these species, other things being equal, depart on migration relatively more freely with relatively better thermal conditions.

4.4. Migration in relation to synoptical weather patterns

The synoptical weather pattern in NW Europe during autumn is highly variable, and it is impossible to distinguish a few basal situations. In order to investigate the association between weather and migration I therefore think by far the best method is to use measurements of individual weather variables, as has been done in this study, rather than trying to correlate migration with synoptical situations. However, I should like to throw some light on the consequences of the connections between migration and different weather variables, as revealed and discussed above, for the adaptation of migratory behaviour in relation to broad weather patterns.

The most characteristic feature of NW European weather is the eastward flow of successive cyclones. The centres of depression usually pass north of the study area. In the southeast sector of a cyclone weather is often characterized by overcast and rain, poor visibility, decreasing pressure and high and rising temperatures. In the southwest sector there are usually less clouds and rain, the air may be turbulent after the passage of a cold front, barometric pressure is rising. One can immediately see that the weather correlations discussed above all have the effect to guide migration into the latter type of situation, in the wake of a cyclone just having passed towards the east. The coincidence of migration with the eastward receding of a depression has been described for migration in Scandinavia by e.g. Svärdson (1953) and Nisbet (1957).

Hence, migration will tend to slip between successive cyclones as exemplified in Fig. 4. On the occasion illustrated in this figure a new cyclone is rapidly approaching from over the Atlantic, and although many weather variables are favourable for migration, such as absence of clouds and rain, good visibility etc., there is one factor which seems not so favourable, i.e. wind being directly opposed to the migrants. However, fairly long periods during the autumn may be characterized by cyclone passages in rapid succession, and there are really no better occasions offered for migration during such periods than those similar to the situation in Fig. 4. Of course, any such succession of cyclones will break down in due course and more favourable winds may prevail, but it is easy to see that it can be advantageous for some types of migrants not to be too strictly selective of favourable winds for their migratory flight.

After the passage of a depression there are sometimes no further cyclones coming along in the next few days, and an anticyclone may build up. One such instance is illustrated in Fig. 5. In this type of situation cold air sweeps down behind the depression and wind direction gradually shifts from NW to NE/E in connection with the approaching high-pressure centre. Generally there is large-scale diurnal as well as nocturnal migration on such instances, as revealed by radar observations

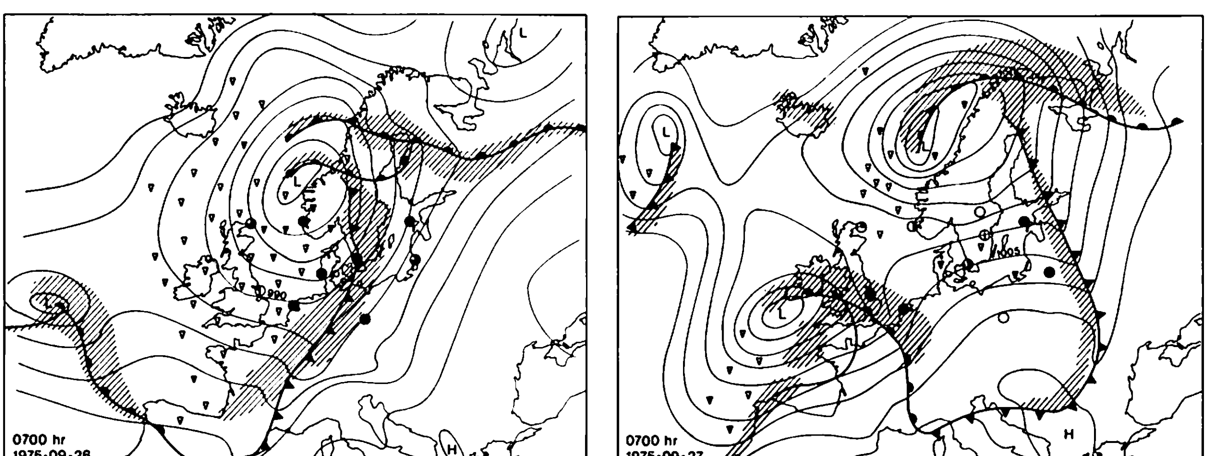
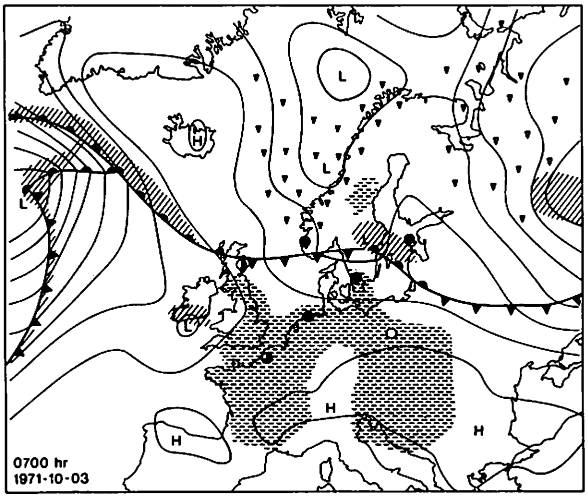


Fig. 4. (left) Northeastward passages of cyclones in rapid succession. The first day is maximally unfavourable for migration in southern Scandinavia with extensive rain and strong opposed winds. On the next day, (right) in connexion with a rise in air pressure, there is only little cloud cover, very scattered rain showers and good visibility, and tremendous numbers of passerine migrants, especially finches (about 380000), were recorded at Falsterbo on this morning (Roos 1977).



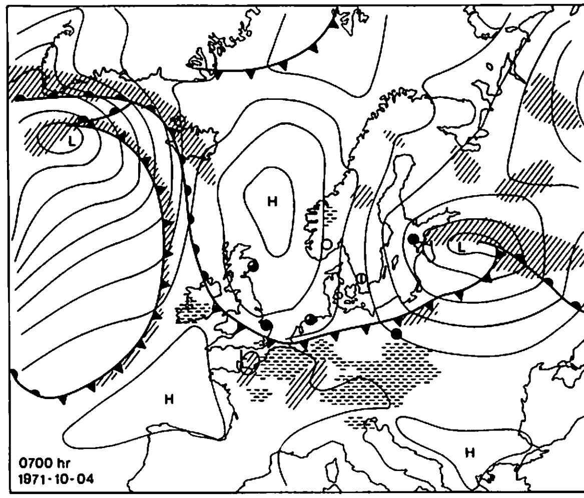


Fig. 5. Anticyclonic interlude between eastward passages of depressions. The first day (left) is unfavourable for migration in South Scandinavia, in the warm sector of a low pressure with overcast, some drizzle, poor visibility or fog. On the next day (right) the depression has receded eastwards and the high pressure has become reinforced and moved southeastwards over the Norwegian Sea. In Scandinavia there is highly favourable weather for migration with following northerly winds, clear skies, good visibility and falling temperature. This was a date with highly intensive migration both by day and night as revealed by radar observations (Alerstam and Ulfstrand 1972). The observer at Falsterbo recorded a large-scale passage of wood pigeons and common buzzards in the morning, but the great numbers of passerines which were seen on radar, escaped the field observer because of their high travelling altitudes and their lack of response to the coastlines as leading-lines.

(Alerstam and Ulfstrand 1975, Alerstam 1976a). It seems reasonable that the migrants should be keen to seize the opportunity of benefitting from the following winds. (The migrants' selectivity of following winds will be discussed in Sec. 5).

I think these selected examples indicate that the correlations between weather variables and visible migration, as found in this study, may well reflect a well-adapted response to weather by the birds, canalizing migration into 'windows' of relatively favourable weather in a highly complex and rapidly varying weather environment.

4.5. Other studies

There are a wealth of studies on the association between weather and bird migration. Lack (1960) presented a review of analyses based on field observations and univariate statistics, and Richardson (this issue) has made a comprehensive review including also the works from later years mainly based on radar records of migratory intensity and multivariate statistics. The latter method of analysis affords the possibility to decide the relative importance of different weather variables for prediction of migratory intensity, and almost all of these analyses indicate that wind conditions are of foremost importance in this respect (e.g. Lack 1963, Richardson and Gunn 1971, Richardson 1974). This is in agreement with the present analysis, where wind did contribute about half of the explainable variation in visible migratory intensity. The radar studies cited above demonstrated that intensive migration is associated with following winds. The precise nature of wind's influence on visible migration remains to be investigated in the next section.

The present study has produced indications that migratory activity may be affected by cloud amount, visibility, rain, change in pressure, min. temperature trend (for migrants in late autumn) and thermal conditions (for raptors) independently of wind. This is in some disagreement with results from the majority of studies using multivariate statistics which have indicated that there is only little variation in migratory intensity left to be explained by weather after the effect of wind has been taken into account (Alerstam 1976a). This discrepancy may be due to the fact that the radar studies have mostly dealt with nocturnal migration, and nocturnal migrants are probably, on the average, more selective of favourable winds than diurnal migrants. A contributing cause may be that the present study is based on an unusually large body of data making it possible to detect correlations of secondary, but still highly significant importance.

There is good principal agreement between this study and the analysis by Nisbet and Drury (1968) of nocturnal radar migration of songbirds and waterbirds. Not that the weather variables included into the multivariate models in these two studies are the same (by way of example, Nisbet and Drury found humidity to be of highly significant importance, whereas this variable seems to be of no importance according to this study), but in both investigations a fairly large share of the variation in migratory intensity is accounted for by a variety of weather variables besides wind.

Multivariate analysis can only help to suggest which weather variables are recorded by the birds and included into their mechanism of response; laboratory experiments (cf. Mascher and Stolt 1961, Stolt 1969) should be carried out to test these suggestions.

5. The influence of wind on visible bird migration

5.1. Theory

5.1.1. Aim

I assume that the behaviour of migrating birds is adapted to winds so as to minimize the energy expenditure for their migratory journey. On the basis of this assumption I will evaluate the influence of wind on migratory activity, the migrants' flight altitude, propensity for coasting, and travelling speeds over land and along the coasts. All these relationships are expected to affect the size of visible migratory passage at a coastal site. I will proceed to compare observations from Falsterbo with predictions that emerge from this theoretical reasoning, and these predictions will be evaluated in relation to the schematic geographical model in Fig. 6.

5.1.2. Migratory activity

I assume that it is of prime interest for the migrants to maximize their ratio of travelling speed along their preferred track direction to the power required. The

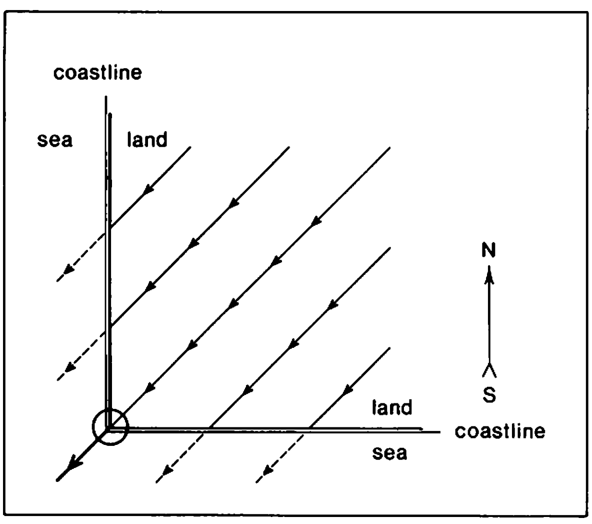


Fig. 6. Schematic geographical model for predicting the magnitude of visible bird migration at Falsterbo in relation to winds. Falsterbo is assumed to correspond to the site, encircled in the figure, at the intersection between the south and west coast. The mean preferred track direction of the migrants is approximatively towards SW, and there is of course a considerable scatter around this mean. The migrants may, depending on wind conditions, turn to fly along the coastlines passing Falsterbo or they may depart directly over the sea.

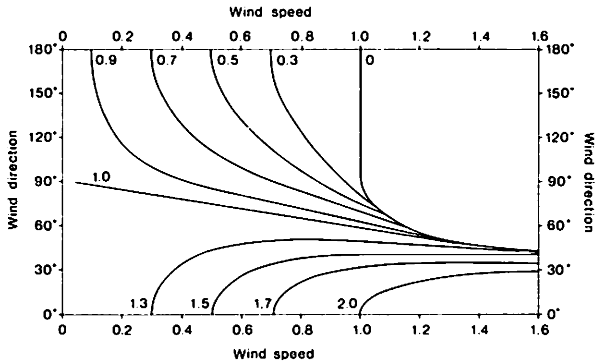


Fig. 7. Ground speed in relation to wind direction and speed. Wind speed is expressed as the ratio to the birds' air speed. Wind direction = 0° corresponds to due tailwinds and 180° to due headwinds. Continuous lines, 'isospeeds', show the birds' ground speed expressed as the ratio to their air speed. The birds are not able to fly along their preferred track direction under opposed winds if wind speed exceeds or equals their air speed, and under following side winds if wind speed exceeds or equals $(\sin\beta)^{-1}$, where β = wind direction.

selection pressure for migration under winds producing a high ground speed may, under different circumstances, be modified or suppressed by other selection factors. However, data available from the literature support the view that selection for high travelling speed generally is of superior importance (Alerstam 1976b). The ground speed may be calculated on the basis of wind data according to the equation

$$G = a \cos\beta + \sqrt{1 - (a \sin B)^2} \qquad (1)$$

where G = the ratio of ground speed to the birds' air speed, a = the ratio of wind speed to the birds' air speed, and β = wind direction in relation to the birds' track direction (0° = tailwind, 180° = headwind). Note that the birds will not be able to travel along their preferred track direction for $a \geq 1$ if $\beta \geq \arcsin a^{-1}$. The ground speed is related to wind direction and speed as indicated in Fig. 7.

What is the precise nature of the relationship between migratory activity and the ground speed along the migrants' preferred track direction? Due to interactions between the ecological requirements of different bird species, the time-table of migration and weather and wind patterns along the migratory route, some species have probably evolved high selectivity for high ground speed during their migratory flight, while the optimal strategy of others may require less selectivity in this respect. In this context I refrain from speculating about possible combinations of factors promoting higher or lower selectivity of winds leading to high ground speeds, but wish to emphasize the assumption that the relationship between migratory activity and ground speed, although different between species, will always be positive. In Fig. 8 I have suggested two different relationships between migratory activity and ground speed to

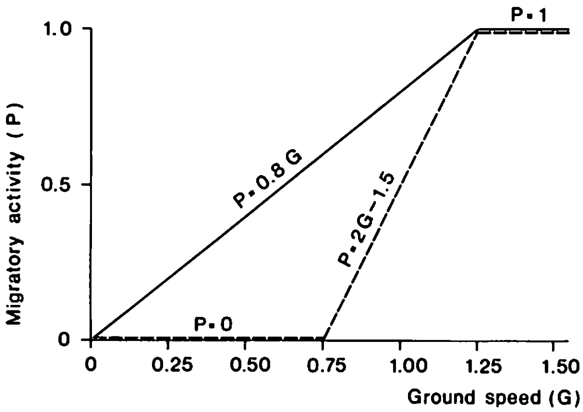


Fig. 8. Hypothetical relationships between migratory activity and ground speed along the migrants' preferred track direction. The solid line refers to migrants which are weakly selective of high ground speed for their migratory activity, and the broken line represents migrants which are highly selective of high ground speed in this respect. G is the ratio of ground speed to the migrants' air speed (the latter is assumed to be constant). P is the average probability of birds in 'Zugdisposition' to depart on a migratory flight.

provisionally represent the behaviour of migrants which are more or less selective, respectively, of high ground speed for their migratory flights. These relationships will be used in the following calculations.

It would be of great interest to obtain field data to illuminate the general relationship between migratory activity and ground speed for different species and regions. Especially investigations involving the use of tracking radar, making it possible to identify different categories of migrants and to cover migration at all different height intervals, seem to have good prospects of producing reliable information.

5.1.3. Flight altitude

The migrants are assumed to fly at altitudes with winds enabling them to travel as fast as possible along their preferred track direction. Radar studies have indicated that migrating birds carefully select their flight altitudes to profit from the most favourable wind conditions (Bellrose 1967, Bruderer 1971, 1975, Steidinger 1972). The flight altitude will affect the detectability of the migrants to a field observer as well as to radar.

Mainly due to friction, wind speeds at low and high altitudes differ considerably. Godske et al. (1957) estimated that surface wind speed (at 60° N) amounts to about 46% of the geostrophic wind speed (prevailing at about 500–1500 m altitude). This is of course only a provisional estimate; high- and low-altitude winds are expected to differ to a larger degree than indicated above over rough and hilly country, and, conversely, to be more similar over very flat and open land, and over the sea.

Migrants can be expected to travel at low altitudes in order to encounter minimum wind speed under opposed and cross winds, while they should fly at high altitudes to make use of a high wind speed under tailwinds. Assuming the ratio of surface to geostrophic wind speed to be 0.5, the migrants' travelling speed will be the same at low and high altitudes for the wind direction:

$$\beta = \arctan\left(\frac{\sqrt{4 - a^2}}{3a}\right) \qquad (2)$$

Surface wind direction, β, and speed, a, have been defined above. Under wind directions $>\beta$ the birds will travel faster at low than at high altitudes and therefore can be expected to fly at low altitudes, while the reverse holds for wind directions $<\beta$. The derivation of the above relationship is illustrated in Fig. 9.

In the above calculations I have assumed that the directions of geostrophic and surface winds coincide. However, this is generally not the case; Godske et al. (1957) estimated that surface wind at 60° N is directed on the average 37° anticlockwise in relation to geostrophic wind direction over land and 13° anticlockwise over the sea. Taking this difference into account produces an asymmetry between winds from the mi-

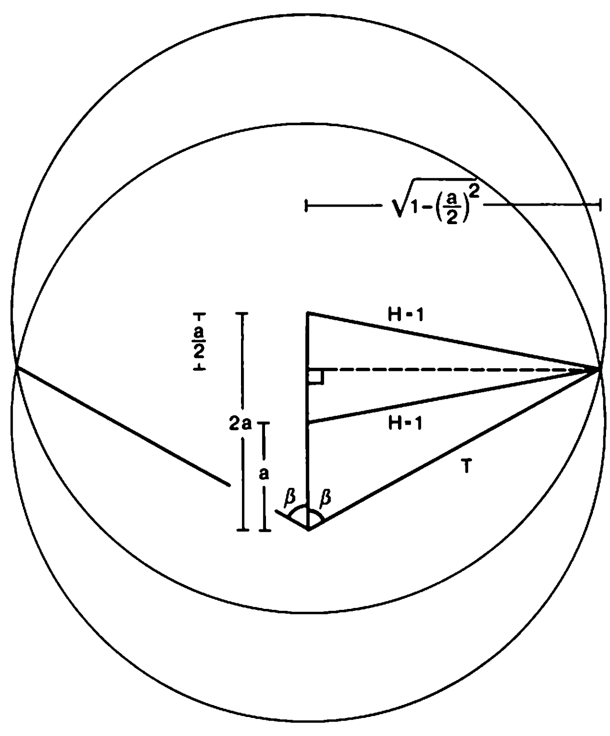


Fig. 9. Derivation of winds leading to equal ground speeds for birds flying at low and high altitudes. Wind speed at low altitude = a (expressed as the ratio to the birds' air speed), and at high altitude = 2a. Surface and high-altitude wind directions are assumed to coincide. Heading velocity (H, the birds' air speed = 1) is added to surface and high-altitude wind velocity, respectively, by drawing circles with the radius = 1. Intersections between these circles mark points where track velocities (T), and hence ground speeds, coincide at low and high altitudes. Wind direction (β) may be solved according to Eq. (2) as given in the text.

grants' right and left, respectively, as to their expected flight altitudes. In view of the fairly small average difference between high, and low-altitude wind directions and of the very simplified nature of the present evaluation, I have decided to leave this difference out of account. The principal conclusions and predictions on the basis of this theory will not be significantly affected by this approximation.

5.1.4. *Leading-line effect*

Radar studies suggest that migrants become partially wind drifted over the sea, while complete compensation for wind drift is achieved over land (cf. review by Alerstam 1976b). A possible explanation of the drift over the sea is that the migrants use the waves, which move in relation to land, for their orientation (Alerstam and Pettersson 1976).

Alerstam and Pettersson (1977) evaluated the significance of the inferior ability of wind drift compensation over the sea as compared to over land, for the land-birds' choice, when facing the sea, between departing directly over it or following the coastline for some distance. Coastal migration will be expected if onshore drift exceeds the angle between the birds' preferred track direction and the coastline, and also under specific conditions of offshore drift when flying-time via the coastline to the goal will be shorter than that along a direct over-sea route. Predictions about the propensity for coasting under different wind conditions in migrants with different angles between their goal direction and the coastline are presented by Alerstam and Pettersson (1977).

Due to reduced friction, surface winds over the sea generally are more similar to geostrophic winds than over land. Godske et al. (1937) estimated the surface wind forces over sea and land at 70 and 46%, respectively, of the geostrophic wind force (at 60° N). Due to this difference, flying time to the goal will become reduced under opposed and cross winds along a route via the coastline, where wind speed is lower than over the open sea, in relation to a direct over-sea route, and to an increasing degree with increasing wind speed.

On the basis of the above-mentioned two factors, i.e. absence of drift and relatively slow wind speeds at the coast, I have roughly estimated the migrants' propensity for coasting under different wind conditions in Fig. 10. As can be seen from this figure, the leading-line effect of a coastline will be important under cross and opposed winds, and relatively more so with high wind speeds. It should be noted that it is particularly difficult to estimate the leading-line effect under offshore winds as it depends on the distance across the sea in relation to the total goal distance (Alerstam and Pettersson 1977). With respect to very short sea-crossings, the leading-line effect indicated in Fig. 10 for these winds is probably overestimated.

The above arguments may also apply to water-bird migration along coastlines. These migrants will probably become displaced by the wind (or rather waves, cf. above) over the sea, and they will therefore be drifted to fly along coastlines under strong onshore winds just like the land-birds. Furthermore, it will be advantageous for them to adhere to coastlines under offshore winds to save valuable flying time to the goal. The reduced wind speed at the coast in comparison with that over the open sea contributes to make it profitable to fly at low altitudes along coastlines under opposed and cross winds for land-birds and water-birds alike. One difference between these two types of migrants may be that the former gains relatively greater advantage by following the coast under opposed onshore winds. Under these conditions land-birds can fly parallel to the coast some distance inland protected by vegetation and topography from the wind (cf. Gruys-Casimir 1965), while water-birds do not seem prepared to do this, and thus will be relatively more exposed to the wind travelling immediately off the shoreline.

Observations of southbound wader migration along the coast of Jutland in relation to wind, as recently presented by Meltofte and Rabøl (1977), agree nicely with the above arguments. Waders departing over the North Sea from southern Norway are obviously drifted by

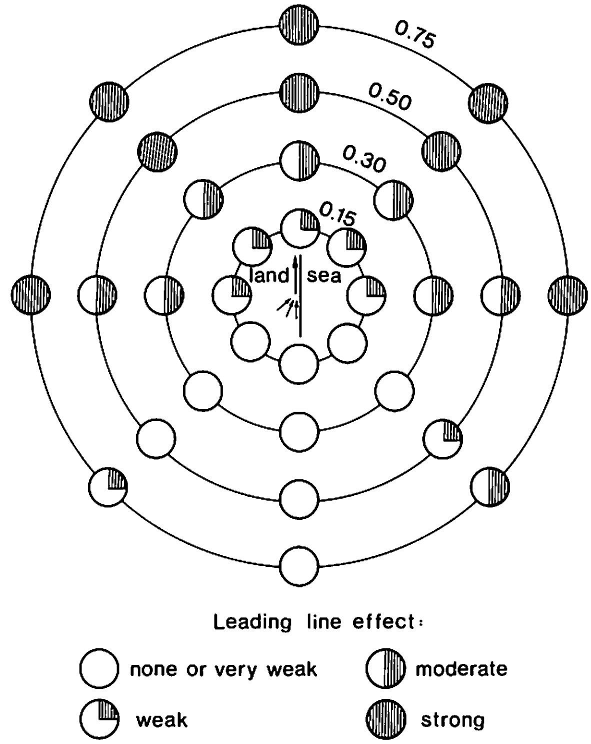


Fig. 10. Propensity of migrating land-birds to follow the coastline rather than departing directly over the sea, in relation to wind direction and speed. Wind speed is expressed as the ratio to the migrants' air speed. Coasting movements will be expected mainly with opposed or cross winds along the coastline, and to an increasing extent with increasing wind force.

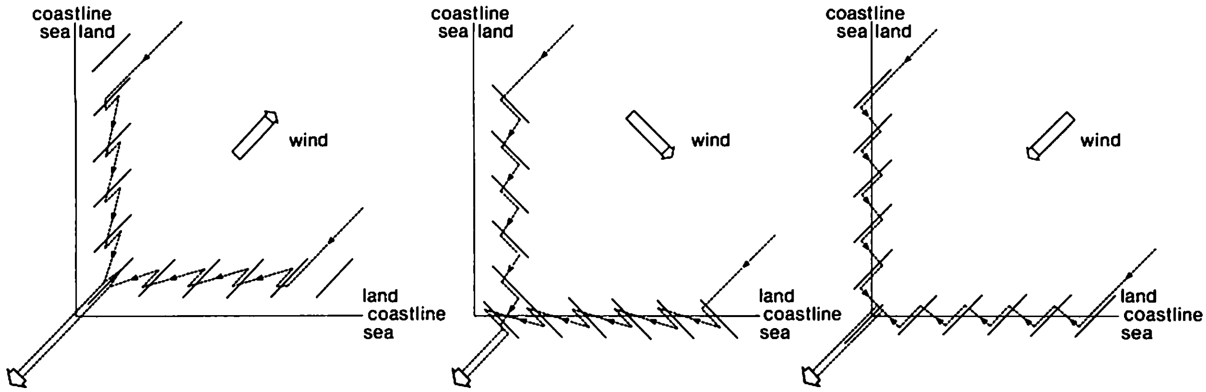


Fig. 11. Schematic pattern of coastal movements of migrating birds using thermal air currents under opposed, cross and following winds, respectively. The migrants' tracks are shown by dotted lines. Due to drift of thermals by horizontal winds, as indicated by thin lines in the figure, the migrants are expected to travel parallell with the coast some distance inland under onshore winds, but over or even off the coastline under offshore winds. Hence, from an observation site at the shoreline, migrants will be seen mainly under offshore winds. However, also migrants coasting some distance inland can be seen to a fairly large extent from an observation site at the corner of the land mass (corresponding to Falsterbo), when they depart over the sea. The pattern illustrated in this figure is to a large extent based on descriptions of the behaviour of thermal migrants by Rudebeck (1950, 1972).

westerly winds towards Jutland and sizeable coasting movements are seen primarily with opposed onshore winds. Other species of waders arrive from the north-east over Danish land and do not depart over the North Sea but change flight direction and follow the coastline mainly under opposed offshore winds. Meltofte and Rabøl favour the view that a strong leading-line effect is explained by the migrants travelling at low altitudes and under these conditions being highly responsive to the topography. Low flight altitudes are in turn explained by the prevalence of opposed winds (the implicit argument is that it is less energy-consuming to travel under relatively slow opposed winds at low altitudes than under strong winds at high altitudes). While I completely agree about the latter argument, I think the former, which is long-established, is a poor one (Alerstam and Pettersson 1977).

The above evaluation of the leading-line effect does not apply to species which use thermal soaring during migration. One may safely assume that the cross-country soaring technique is highly energy saving for these species, and they will refrain from departing over the sea (where no thermals develop) not only under opposed and cross winds but also under following winds. The predicted pattern of coastal movements of these migrants is illustrated in Fig. 11. When the angle between the birds' preferred track direction and the coastline becomes large, there will be little gain for the birds to turn sharply and follow the coastline but they will be expected to depart across the sea. To judge the angle critical in this respect under different wind conditions one needs to know the ratio of energy consumption during active flapping flight (over the sea) to that during thermal soaring along the coast, but unfortunately there are no such estimates available.

5.1.5. Travelling speed

Even if there were no variation in flight altitude and leading-line effect, field observers' counts of migrating birds do not only reflect the variation in migratory activity (i.e. the relative density of birds departing on a migratory flight), but are also affected by the migrants' travelling speeds, which in turn are determined by wind conditions (Sect. 5.1.2.). The effect of ground speed on counts of migrating birds at different types of observation sites has been evaluated by Evans (1966). On the basis of Evans' work and the assumption that the daily periodicity of migratory activity is uncorrelated to its magnitude the following facts emerge:

At an inland site, where migration is unaffected by leading-lines, the daily counts (N) by a field observer should be directly proportional to the migratory activity (P) as well as to the birds' ground speed (G_l):

$$N = k\,P\,G_l \tag{3}$$

where k is a constant which is the product of the observer's range of detection (d) and the relative daily temporal pattern of migratory activity as illustrated in Fig. 12A. Consequently, other things being equal (which generally is not the case), the number of birds observed should be greater under following winds than opposed winds by an amount which is determined by the relation between ground speeds under these different wind conditions. Ground speed has been illustrated in relation to wind direction and speed in Fig. 7.

Daily counts (N) from a site at a leading-line, for example a coastline, to which the migrants adhere after reaching it on their preferred overland track, depend on the migratory activity (P) as well as on the migrants' ground speed over land (G_l) and along the coastline (G_c):

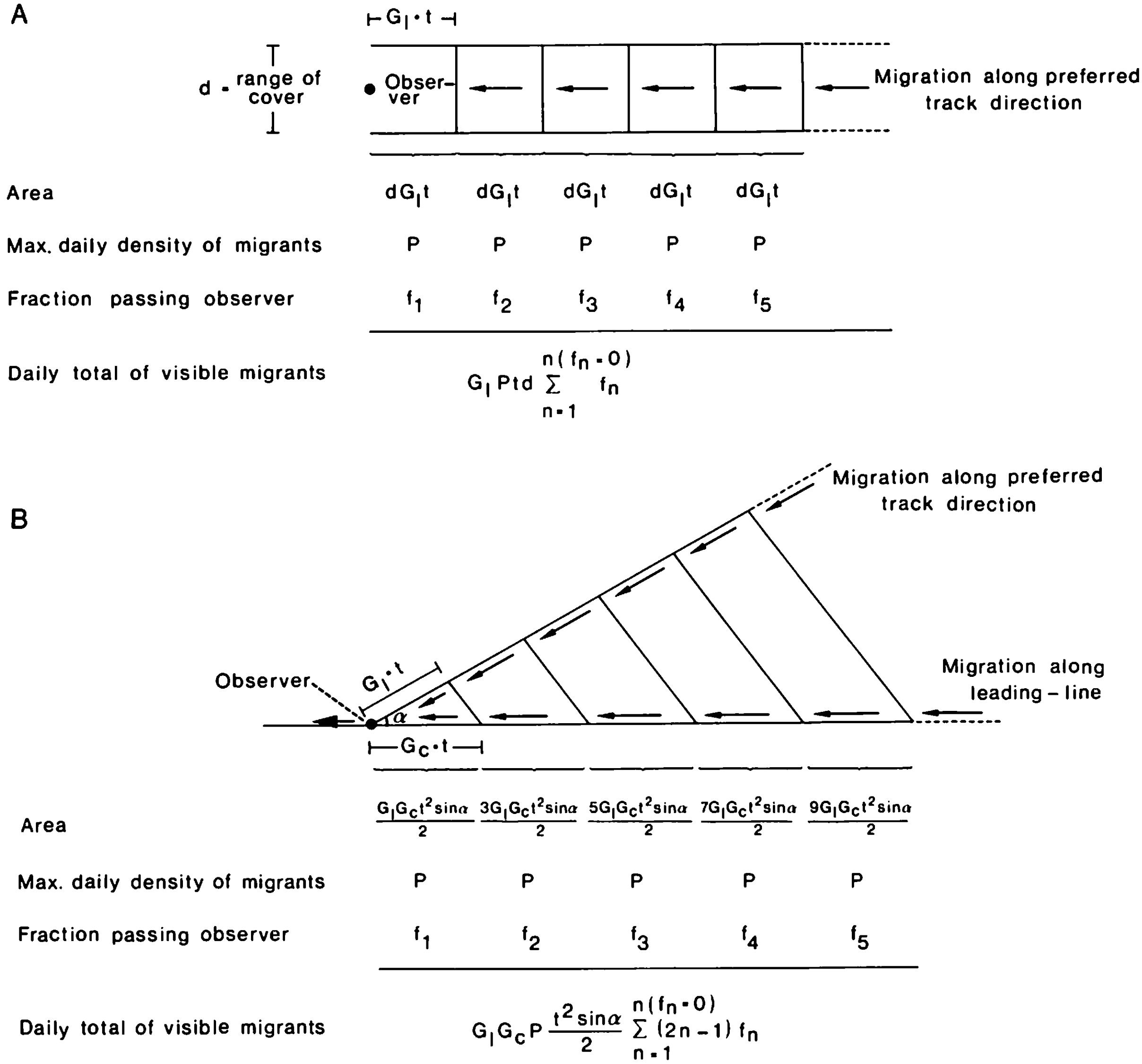


Fig. 12. A). Daily number of migrants recorded by a field observer at a site with no leading-line migration. The number of migrants is dependent on migratory activity (P), the birds' ground speed (G_l), the observer's range of cover and the daily temporal pattern of migration. f_1 = fraction of migrants, in relation to maximum daily migratory activity (P), which are migrating during the time interval t after the initial departures, f_2 = the corresponding fraction during the time t next ensuing, and so on. By way of example, many diurnal migrants such as pigeons, skylarks and finches use to depart almost simultaneously in the early morning and $f \sim 1$ during the next one to three hours, whereupon the migrants gradually settle to rest, and after noon there is only very sparse migration and $f \sim 0$ (cf. Evans 1966 and Ulfstrand et al. 1974).
B). Daily number of migrants recorded by a field observer at a site with leading-line migration. The angle between the leading line and the migrants' preferred track direction = α. The number of migrants is dependent on migratory activity (P), the birds' ground speed along their preferred track direction (G_l) and along the leading line (G_c), the angle α and the daily temporal pattern of migration (f has been defined above).

$$N = m\,P\,G_l\,G_c \qquad (4)$$

where m is a constant which is related to the angle (α) between the migrants' preferred track direction and the coastline, and to the relative daily temporal pattern of migratory activity as shown in Fig. 12B.

The product of ground speeds over land and along the coast is related to wind direction and speed in Fig. 13, using as an example a situation where the angle between the birds' preferred track direction and the coastline is 45°. From this figure it is seen that, other things being equal, the greatest number of birds will pass the observation site with following winds from between the birds' preferred track direction and the coastline, and the

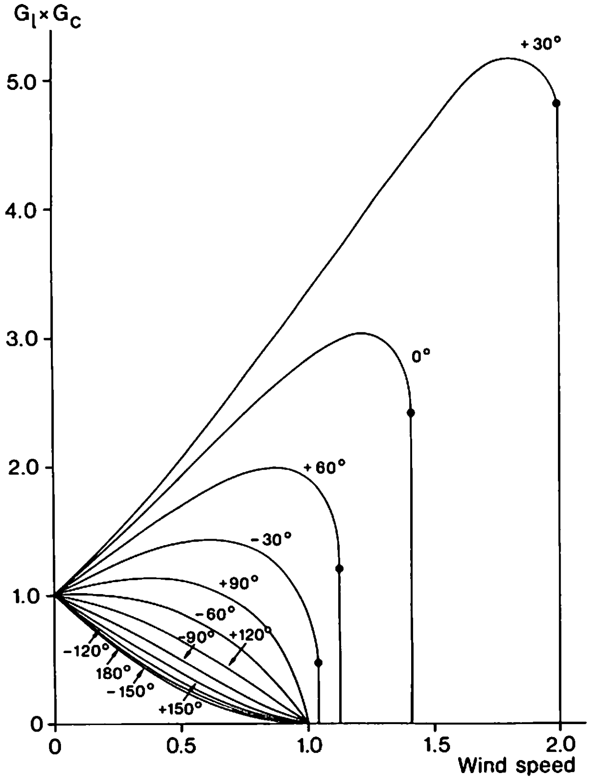


Fig. 13. Product of migrating birds' ground speed along their preferred track direction over land (G_l) and along a coastline (G_c), in relation to wind direction and wind speed. The coastline is directed +45° from the over-land track direction. Tailwind direction (relative to the over-land track) = 0°, headwind direction = 180°. Ground speeds as well as wind speed are expressed as ratios ot the birds' air speed. The birds will not be able to fly along a fixed track direction under following winds ($0° \leq \beta \leq 90°$) if wind speed $\geq (\sin\beta)^{-1}$, as indicated by black dots in the figure, and under opposed winds ($90° \leq \beta \leq 180°$) if wind speed ≥ 1. It is assumed that the birds encounter the same winds over land as along the coast.

smallest number of birds will pass under the corresponding opposed winds. It should be noted that the data in Fig. 13 are calculated on the assumption that the migrants encounter the same winds over land as along the coast. If the birds' flight altitudes differ over land and along the coast, this assumption is not valid, and the ground speed values to be entered into the above equation must be separately calculated for the different wind conditions encountered by the migrants.

Daily counts of migrating birds from the point of intersection between two coastlines (Fig. 6) will be influenced, in addition to migratory activity (P), also by the migrants' ground speeds over land and along the two coastlines according to the equation:

$$N = m\,P\,G_l\,(G_s + G_w) \qquad (5)$$

where G_s and G_w denote ground speeds along the south and west coasts, respectively.

5.1.6. Synopsis

Taking all factors discussed above into consideration, i.e. migratory activity, flight altitude, leading-line effect and travelling speed, the daily size of visible migratory passage at the observation site in Fig. 6 under a given wind situation may be determined from the equation:

$$N = m\,P\,A\,G_l\,(C_sG_s + C_wG_w) \qquad (6)$$

where m is a constant, P migratory activity, and G_l, G_s and G_w ground speeds over land and along the south and west coasts, respectively, as defined above.

A is the detectability to a field observer of migrants flying at different altitudes. For small-sized birds travelling at high altitudes A will be close to zero, whereas A will be unity for low-altitude migration. Large-sized migrants and migrants travelling in large flocks will, to some extent, be recorded by a field observer also at high altitudes and A will be expected to fall between 0 and 1.

C_s and C_w denote the fraction of migrants coasting along the south and west coasts, respectively. As seen from Fig. 10, C can be expected to be almost unity for strong opposed winds and zero under following winds along the coastline, while intermediate values will be expected under other winds. However, for migrants using thermal soaring, C will be close to unity under all winds.

The change in size of visible passage with changing wind speed under a given wind direction may be determined by differentiating Eq. (6) with respect to wind speed:

$$\frac{\delta(\ln N)}{\delta a} = \frac{\delta N}{\delta a} \cdot \frac{1}{N} = \frac{N'}{N} = \frac{P'}{P} + \frac{A'}{A} + \frac{G_l'}{G_l} + \frac{C_s'G_s + C_s\,G_s' + C_w'G_w + C_wG_w'}{C_sG_s + C_wG_w} \qquad (7)$$

where a is the wind speed expressed as the ratio to the birds' air speed and notations with a prime affix signify partial derivatives with respect to a.

The relation between size of visible passage and wind speed depends on many factors which may be acting together or counteracting each other to produce a positive or negative slope under different wind conditions. By way of example, with opposed winds, i.e. winds from the SW quadrant (cf. Fig. 6), one will, according to the reasoning in preceding sections, expect the following signs for the seven terms in Eq. (7): −, +, −, +, −, +, −. Hence, flight altitude will become lowered and the leading line effect at the two coastlines enhanced with increasing wind speed, contributing to an increase in visible migratory intensity, whereas this will be counteracted by reduction in migratory activity and ground speeds over land as well as along the two coastlines with increasing wind speed. Adding up may give a positive or negative result, i.e. visible migration may increase or decrease with increasing wind speed, depending on the

Tab. 7. Predicted flight altitudes, leading-line effects and ground speeds (expressed as the ratio to the birds' air speed) under different wind conditions for bird migration according to the schematic geographical pattern in Fig. 6. Calculations are described in the text.

Wind		Flight altitude high = H low = L			Leading line effect none or very week=0, weak = (C), moderate = C, strong = 1		Ground speed		
dir.	speed	over land	along S-coast	along W-coast	along S-coast	along W-coast	over land	along S-coast	along W-coast
N	0.15	H	L	H	(C)	0	1.19	0.99	1.30
	0.30	H	L	H	C	0	1.33	0.95	1.60
	0.50	H	L	H	C	0	1.41	0.87	2.00
	0.75	L	L	H	1	0	1.38	0.66	2.50
NE	0.15	H	H	H	0	0	1.30	1.19	1.19
	0.30	H	H	H	0	0	1.60	1.33	1.33
	0.50	H	H	H	0	0	2.00	1.41	1.41
	0.75	H	L	L	(C)	(C)	2.50	1.38	1.38
E	0.15	H	H	L	0	(C)	1.19	1.30	0.99
	0.30	H	H	L	0	C	1.33	1.60	0.95
	0.50	H	H	L	0	C	1.41	2.00	0.87
	0.75	L	H	L	0	1	1.38	2.50	0.66
SE	0.15	L	H	L	0	(C)	0.99	1.19	0.89
	0.30	L	H	L	0	C	0.95	1.33	0.77
	0.50	L	H	L	(C)	1	0.87	1.41	0.58
	0.75	L	L	L	C	1	0.66	1.38	0.32
S	0.15	L	L	L	(C)	(C)	0.89	0.99	0.85
	0.30	L	L	L	C	C	0.77	0.95	0.70
	0.50	L	L	L	C	1	0.58	0.87	0.50
	0.75	L	L	L	1	1	0.32	0.66	0.25
SW	0.15	L	L	L	(C)	(C)	0.85	0.89	0.89
	0.30	L	L	L	C	C	0.70	0.77	0.77
	0.50	L	L	L	1	1	0.50	0.58	0.58
	0.75	L	L	L	1	1	0.25	0.32	0.32
W	0.15	L	L	L	(C)	(C)	0.89	0.85	0.99
	0.30	L	L	L	C	C	0.77	0.70	0.95
	0.50	L	L	L	1	C	0.58	0.50	0.87
	0.75	L	L	L	1	1	0.32	0.25	0.66
NW	0.15	L	L	H	(C)	0	0.99	0.89	1.19
	0.30	L	L	H	C	0	0.95	0.77	1.33
	0.50	L	L	H	1	(C)	0.87	0.58	1.41
	0.75	L	L	L	1	C	0.66	0.32	1.38

numerical importance of the different terms in equation (7).

Under strong opposed winds one may expect that an increase in wind speed will not appreciably affect either the migrants' flight altitude (they are already flying at the lowest altitudes) or the leading-line effect (which is already almost at the maximum). Consequently, the above positive terms will be close to zero, and the size of visible passage will be expected to decrease with increasing wind speed. In contrast, under weak and moderate opposed winds it may well happen that the positive terms will exceed the negative ones, and there will be more visible migration with increasing wind speed.

5.1.7. *Predictions*

Eq. (6) can be used for prediction of the daily size of visible migratory passage at Falsterbo (corresponding to the site in the schematic (Fig. 6) under different wind conditions. I have determined the expected flight altitude, leading-line effect and ground speeds for every 45° of wind direction and for four different surface wind speeds (ratios of wind speed to the birds' air speed = 0.15, 0.30, 0.50 and 0.75, respectively) in Tab. 7.

I proceed to calculate the predicted number of migrants in relation to wind speed for each quadrant of wind direction by the following procedure:

(a) P is calculated on the basis of Fig. 8 for migrants which are more or less selective of high ground speed for their migratory flight. P is determined by the ground speed over land, and I use the ground speed at high or low altitudes depending on whether the birds are expected to travel at high or low altitudes, respectively.

(b) A depends on the predicted flight altitude. I distinguish between two types of migrants, one with A (high altitude) = 0 and A (low altitude) = 1 and the other with A = 1 at both high and low altitudes. The former category refers to small sized migrants, while the latter comprises large birds or birds migrating in large and easily detectable flocks. I admit that the detectability to a field observer of high-altitude migration even of large birds probably is significantly inferior to that of low-altitude movements. The effect of my setting A = 1 for high- as well as low-altitude migration of these birds will be to overestimate the size of visible passage under winds from the NE quadrant (following winds). The extent of this overestimate is hard to judge.

(c) Referring to Fig. 10 I estimate C = 0 for none or very weak, C = 0.25 for weak, C = 0.50 for moderate and C = 1 for a strong leading-line effect. For migrants using thermal air C = 1 for all winds.

(d) On the basis of Tab. 7 and the above assumptions I can now calculate N according to Eq. (6) for all combinations of wind directions and speeds, and for different categories of birds. The mean of predicted N for three wind directions, under a given wind speed, gives the predicted N for the relevant quadrant of wind direction. Hence, predicted number of visible migrants for the NE quadrant = mean of predicted number of migrants for N-, NE- and E-winds, predicted number of migrants for the SE quadrant = mean of predicted number of migrants for E-, SE- and S-winds, and so on.

Predictions calculated in this manner are presented in Fig. 14.

Fig. 14A refers to small sized migrants which are relatively weakly selective of high ground speed for their migratory flight. Maximum size of passage will occur under slow to moderate opposed (SW) and cross (NW/SE) winds. The magnitude of visible migration will fall off with high wind speeds, more rapidly so with opposed than cross winds. The size of passage under following (NE) winds will be very small.

For large birds and birds in large flocks which are recorded by the field observer also when travelling at high altitudes (Fig. 14B), there will be little difference in predicted size of passage between wind directions under slow to moderate winds, whereas migration will fall off under high wind speed, more markedly for SW- than NW-winds (strong NE- and SE-winds do not occur at Falsterbo). By choosing values of A (detectability of migrants, cf. above) between 0 and 1 for high-altitude movements one may arrive at predictions in between those presented in Figs. 14A and B, respectively.

Fig. 14C refers to small sized migrants which are highly selective of a favourable ground speed for their migratory flight. Maximum number of migrants will be counted under slow opposed and cross winds, and migratory intensity will decrease with increasing wind speed, most markedly for SW-winds. High-altitude migration under NE-winds will escape the observer's notice.

For migrants, which are visible also at high altitudes (Fig. 14D), maximum number will be registered under moderate following or cross winds, while migratory intensity under SW-winds will be low. Again, it should be noted that predictions between Figs 14C and D will be obtained for values of A (see above) between 0 and 1.

Fig. 14E shows the predicted number of migrants (weakly selective of high ground speed) using thermal air. It is assumed that they are normally recorded also when travelling at high altitudes, but if this is not so, the NE-wind curve should be displaced to a lower level.

Before turning to the comparison of these predictions with the Falsterbo observations, a few additional points need to be borne in mind:

Average leading-line effects at the west and south coast do not differ according to the above calculations based on the schematic Fig. 6, but they almost certainly do so in reality. As seen from Fig. 1 the west coast is much more irregular than the south coast. Along the west coast there are many small bays and promontories, which tend to increase the probability that the migrants will set out across the sea at local places where the direction of the coastline deviates markedly from their preferred track direction. Perhaps even more important, the distance to be crossed by the birds over the sea is distinctly less from the west coast than from the south coast. The distance across Öresund along a south-westerly track is maximally 40 km but normally about 20 km with a narrowest passage at 5 km. Hence, land on the opposite side of Öresund is usually clearly visible to the migrants even if they fly at low altitudes. The shortest and longest distance SW across the Baltic Sea from the south coast are about 50 and 200 km, respectively.

Migrants are expected to be less prone to coasting, especially under offshore winds, if the distance to be crossed over the sea is short (Alerstam and Pettersson 1977). Furthermore, if the migrants are able to use landmarks to attain full compensation for wind drift during the sea passage (merely horizontal landmarks are not sufficient, cf. Alerstam and Pettersson (1976), which may well be the case for migrants approaching the west coast of Skåne at relatively high altitudes, their propensity for coasting will be poor.

According to my predictions on the basis of Eq. 6 migrants passing Falsterbo under SE-winds mainly comprise coasting movements along the west coast, while movements along the south coast are relatively more important under NW-winds. Consequently, if the west coast is less efficient as a leading-line than the south coast, as argued above, predicted magnitude of visible migration during SE-winds generally will fall below that during NW-winds (cf. Fig. 14). This will be the case also for birds using thermals on their migration – due to the small width of Öresund they will be able to travel across it without having to use flapping flight to any large extent, especially under offshore, i.e. easterly, winds.

The predictions illustrated in Fig. 14 are based on the assumption that the migrants' mean preferred track direction is approximatively towards SW. If this direction is more towards SSW/S migrants will be expected to be recruited to Falsterbo mainly via the west coast, and if it is towards WSW/W the south coast will be most important in this respect (the less the angle between the birds' preferred flight direction and the coastline the larger the probability for coasting movements). This will mainly

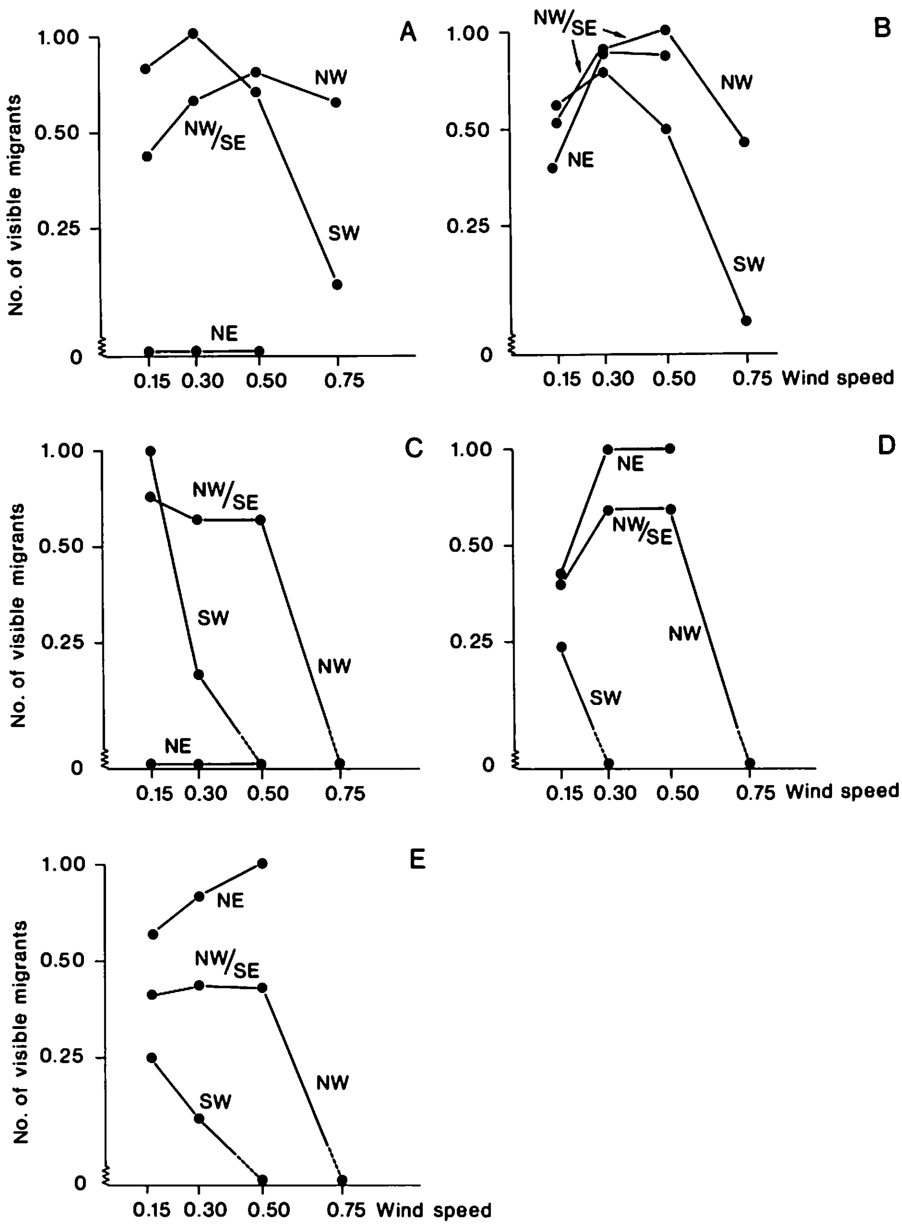


Fig. 14. Predicted relative magnitudes of visible passage at Falsterbo in relation to wind according to equation (6). Calculations of predictions have been performed for all combinations of wind directions and speeds in Tab. 7. Predictions for NE-winds refer to the mean of predicted magnitudes of migration under N-, NE- and E-winds, for SE-winds to the mean of predicted magnitudes under E-, SE- and S-winds, and so on. Predictions for strong NE- and SE-winds (wind speed = 0.75) are omitted because such winds do not occur at Falsterbo. Furthermore, predictions for strong NW-winds (wind speed = 0.75) refer to the mean of predicted magnitudes of migration under W- and NW-winds only, as N-winds of this strength occur very rarely at Falsterbo. The maximum predicted score in each case is set at 1, and the relative scores are plotted on a logarithmic scale.
A) Small-sized and B) large migrants (or migrants in large flocks) which are weakly selective of high ground speed for their migratory flight.
C) Small-sized and D) large migrants (or migrants in large flocks) which are highly selective of high ground speed for their migratory flight.
E) Large birds migrating with the aid of thermal air currents which are weakly selective of high ground speed.
See text for further explanations.

affect the predictions in Fig. 14 as to the relative sizes of migratory passage under SE- and NW-winds, respectively.

Hence, the weak leading-line influence of the west coast, bringing the effect of reducing the predicted number of migrants at Falsterbo under SE- in comparison with NW-winds, may be compensated (or even overcompensated) for if the migrants have a preferred flight direction towards S/SSW. Conversely, for migrants with a mean track direction towards WSW/W, SE-winds will be associated with distinctly less migration at Falsterbo than NW-winds.

Eq. (6) stresses the importance of coasting movements for visible migration at Falsterbo; if the leading-line effect at both the south and west coasts would be absent, the predicted size of visible passage at Falsterbo becomes zero. However, in reality some migrants would certainly have been observed without any leading-line effects. In fact, Falsterbo would be equivalent to an inland observation site under such circumstances (cf. Fig. 12). For small sized birds and for birds which are weakly selective of high ground speed for their migratory flight one can feel safe to neglect the predicted number of migrants without any leading-line effect in comparison with numbers of coasting birds (as done in Eq. 6). However, for migrants which may be recorded by the field observer at far distances (corresponding to a wide range of cover in Fig. 12A) and which are highly selective of favourable ground speed (concentrating migration to NE-wind occasions), the numbers may be significant in spite of the lack of leading-line effects. Consequently, this reservation is relevant mainly for Fig. 14D, and the effect of taking it into account is to increase the number of migrants predicted under NE-winds.

5.2. Field observations

5.2.1. Treatment of data

I will discuss visible migratory intensity at Falsterbo in relation to the theory presented above. For this purpose I will primarily refer to the polynomial regressions of migratory intensity on wind speed under different wind directions, as presented in Appendix A, because the results from these analyses are directly comparable to the theoretical predictions summarized in Fig. 14. Unless otherwise stated I will refer to surface wind conditions. Taking the average difference in speed and direction between surface and high-altitude winds into account (cf. Sect. 5.1.3.), the analysis of visible migration in relation to the latter winds generally confirms the picture arrived at for surface winds (Appendix A).

5.2.2. Migration associated with W-winds

Most species analysed in this study are recorded at Falsterbo in greatest number under westerly winds. From Tab. 8 it is seen that the regression curve for daily migratory intensity in relation to wind speed shows a peak at fairly low wind speed with SW-winds for almost all of these species (see below about the swift), and for some of them also with SE- and NW-winds. Surface wind speed at maximum migratory intensity is about 4 m s^{-1}, which corresponds to approximatively 30% of the birds' air speed. Few migrants of these species are observed at Falsterbo under NE-winds. Hence, the relationship between visible migratory intensity and wind for the

Tab. 8. Wind speed (in m s^{-1}) associated with maximum magnitude of visible migration at Falsterbo under different wind directions (cf. Appendix A). The table includes only migrants which are seen at Falsterbo in greatest numbers under W-winds. For cases with monotonically decreasing migratory intensity with increasing wind speed, I have indicated in the table that most migrants are recorded at low wind speed. Absence of any notation in the table means that there is no significant covariation between magnitude of visible migration and wind speed.

	Surface wind direction				High-altitude wind direction			
	NE	SE	SW	NW	NE	SE	SW	NW
Sparrow hawk - morning		3.7	3.8	low		(10.9)	6.2	9.8
Swift			9.8	14.0			12.7	15.5
Swallow	low	3.5	low	4.7	low	low	low	4.9
Yellow wagtail	low	low	3.5	4.3		low	7.2	6.7
Starling - August	low	3.7	low	low	?	low	low	low
Starling - October			4.1	low	low		8.2	low
Chaffinch/Brambling	low		3.7	low		8.4	7.8	9.3
Siskin			3.5	low		8.7	7.1	low
Linnet	low	4.7	4.0	low			7.6	9.4

species listed in Tab. 8 agrees with the prediction in Fig. 14A, which is relevant for small-sized migrants which are only weakly selective of high ground speed for their migratory flight. However, there are distinct differences among these species, and at least three categories may be distinguished on the basis of the relationship between visible migration and wind.

Swift. This species markedly differs from all others because it shows an overall positive correlation between size of visible passage and wind speed. Swift migration culminates under strong westerly winds, while there are very few birds to be seen at Falsterbo under easterly winds. Peak numbers occur with wind speeds at 10 to 14 m s^{-1} for SW- and NW-winds, respectively. These wind speeds are close to the swifts' air speed (Bruderer and Weitnauer 1972), and the swifts obviously travel at very modest ground speeds. The large number of birds recorded in spite of their low travelling speed strongly indicate that migratory activity is positively correlated to westerly (opposed) winds. Consequently, the speculative relationships between migratory activity and ground speed as exemplified in Fig. 8 obviously do not hold for the swift.

It is important to note that the swift movements analysed in this study do not primarily reflect normal autumn migration in this species, but mainly refer to so-called weather or summer movements, which are peculiar to the swift. Summer movements in Fenno-Scandia were first described and analysed by Koskimies (1950), and later studies at Ottenby in southeastern Sweden (Svärdson 1951) and in England (Lack 1955, 1956, 1958) have corroborated the early findings. Koskimies demonstrated that intensive summer movements of swifts take place in the southeastern sector of a depression approaching from the west. He postulated that, by flying against the wind, most often in a southwesterly direction, the swifts would fly around the southern sector of the cyclone, avoiding or rapidly passing through the rain belt. After cyclone passages northward movements of returning swifts have been recorded, but these are much less conspicuous than the southward flights, the birds usually travelling singly or in scattered small flocks at high altitudes in fine weather. The summer movements are thought to comprise immature swifts but also part of the breeding population. The ultimate cause of these movements probably is that the swifts must avoid extensive rain with low availability of food in the form of air-borne insects.

The Falsterbo observations are in agreement with the above description and interpretation, and they also lend tentative support to the proposal by Lack (1955) that the swifts respond directly to strong winds for initiation of their movements. Besides wind, there is a firm correlation of swift movements at Falsterbo with low morning temperatures, and this correlation is also entered into the multiple discriminant (but not regression) models independently of the effect of wind (and together with a positive correlation with minimum temperature, cf. Appendix A). However, this study cannot provide conclusive evidence whether the swift movements are initiated by strong westerly winds alone or by wind in combination with other weather cues (perhaps temperature), or by the birds' direct experience of a decrease in air-borne insects. The latter alternative seems to be the least probable as the swifts use to depart in advance of the rain (Koskimies 1950), and furthermore as movements have been recorded into strong winds even when no major depression has been in the neighbourhood (Lack 1955).

Chaffinch, brambling, siskin and linnet. The relationship between daily number of these species at Falsterbo and wind agrees almost completely with the prediction in Fig. 14A. Characteristics of this relationship are given in Tab. 8, and, in addition, a few points should be noted:

(a) There are slightly more migrants with SW- than NW-winds at weak and moderate wind forces (<8 m s^{-1}, corresponding to a ~0.6, cf. above), whereas the reverse holds under strong winds.

(b) Migratory intensity is lower under SE- than NW-winds. This is to be expected due to the inferior leading-line effect of the west coast of Skåne in comparison with the south coast.

(c) Very few birds are observed under NE-winds.

Sparrow hawk (morning), swallow, yellow wagtail and starling. This is a heterogenous group with regard to the relation between migratory intensity at Falsterbo and wind. The smallest number of migrants are noted under NE-winds, but besides this common feature, the observations of migrants in relation to wind span from a pattern rather similar to that of the four species discussed in the previous paragraph, as in the yellow wagtail and starling (October), to a situation with little difference between migration under different wind conditions, as in the sparrow hawk (morning).

(a) Except for the starling in August, migratory intensity is higher with SW- than NW-winds at wind speeds <6 to 10 m s^{-1}, while the reverse holds at strong winds (the difference at strong winds is very small for the swallow). This is according to theoretical expectation as seen in Fig. 14A.

(b) For the swallow and starling (October), migratory intensity under SE-winds is on par with that under NW-winds, and for the starling in August, it is higher under SE- than NW-winds. This indicates that the relative inferiority of the west coast as a leading-line in comparison with the south coast is compensated for by these migrants' preferred track direction being between south and southwest. This factor in combination with a relatively high selectivity of high ground speed for the migratory flight (cf. Fig. 14C) may provide the explanation for the decidedly large numbers of August starlings under SE-winds. In August, starling migration is rather sparse, and it seems not at all unreasonable that migration is initiated only under particularly favourable wind conditions. For the sparrow hawk and yellow wagtail there are fewer migrants with SE-than NW-winds as was the case for the finches, siskin and linnet.

(c) Even if winds from the NE quadrant is associated with a low number of migrants of the present species, there are relatively more NE-wind migration at Falsterbo of these species, most markedly of the sparrow hawk, than of finches, siskins and linnets. This may be because high-altitude migration of the present species is relatively more easily detected by the field observer. This seems entirely reasonable for the sparrow hawk, being a comparatively large-sized bird, and the starling, often travelling in large and dense flocks, but is harder to accept for the swallow and yellow wagtail.

(d) The relatively shallow negative regression slope of number of sparrow hawks in relation to strong wind forces indicates that sparrow hawks are very weakly, if at all, selective of high travelling speed for their migration.

5.2.3. Migration associated with NE-winds

The *wood pigeon, crow* and *jackdaw* are recorded at Falsterbo in greatest number under NE-winds. The general pattern of visible passage in relation to wind direction and speed for these species agrees well with the prediction in Fig. 14D, referring to migrants which are highly selective of high ground speed for their migratory flight and which become registered by the field observer to an important degree also when they travel at relatively high altitudes. Combined radar and field studies in South Sweden have demonstrated that wood pigeons are indeed highly selective of following winds for their migratory flight (Alerstam and Ulfstrand 1974). Furthermore, it seems reasonable that high-altitude migration of these three species is rather effectively registered by a field observer as the size of the birds is relatively large and as they use to travel in large flocks, most markedly so the wood pigeon with an average flock size at about 100 individuals (Alerstam 1977). Two further points should be noted:

(a) Migrants are generally less numerous under SE- than NW-winds. This may well be due to the inferior leading-line effect of the west coast of Skåne in comparison with the south coast.

(b) There is relatively less difference between wind directions as to their associated magnitude of visible passage in the crow than in the wood pigeon and jackdaw. Furthermore, in the crow but not in the wood pigeon and jackdaw, there is slightly more migration with NW- than NE-winds. Both these facts indicate that the crow is relatively less selective than the other two species of high ground speed, leading to a closer resemblance of the pattern of crow observations to the prediction in Fig. 14B rather than to that in 14D.

5.2.4. Migration by thermal soaring

The *common buzzard, honey buzzard* and *sparrow hawk* (noon) usually travel with the aid of thermal currents. Migration of these species at Falsterbo is relatively intensive under NW-winds but sparse with SE-winds. This marked difference is probably due to the fact that, for thermal migrants, the west coast is highly ineffective as a leading-line under easterly winds. Under these winds thermals drift westwards over Öresund, where soaring birds can leave them at high altitudes and glide off towards Zealand to reach and regain height in new thermals over Denmark. Under westerly winds the leading-line effect of the west coast probably is much stronger as thermal conditions are unfavourable for a westward crossing of Öresund (but favourable for an eastward crossing), thermals being drifted inland from the west coast of Skåne (cf. Fig. 11). According to this reasoning thermal migrants arrive in Falsterbo along both the west and south coasts under westerly winds but almost exclusively along the south coast with easterly winds. Hence, predictions in Fig. 14E should be markedly reduced for SE-and NE-winds in order to take this effect into account.

Rudebeck (1950, 1972) described and analysed migration in the Falsterbo region of birds using thermals. Rudebeck's findings about the covariation between formation of thermals in coastal areas and the behaviour of migrants form the basis of my reasoning in this paper on this issue (cf. Fig. 11). In order to explain the small number of migrants seen at Falsterbo under easterly winds in comparison with the relatively high migratory intensity with NW-winds, Rudebeck (1950) postulated that thermal migrants drift by crosswinds when travelling over the inland. However, I think there is no need to postulate drift over land, but the marked difference between leading-line effect at the west coast under westerly and easterly winds (see above) will suffice as an explanation. According to my view, considerable coasting movements normally build up along the northern part of the west coast (bordering the wide expanse of Kattegatt). Further south there are only the narrow straits of Öresund to separate Skåne from Zealand and, with easterly winds, many migrants will cross Öresund resuming a southwestward track. Due to the northwestward offshore drift of thermals under SE-winds, raptors will be expected to cross Öresund farthest to the north under these winds, and they will continue southwestwards over northern Zealand as observed by Holstein (1946). Under NE-winds the raptors will be expected to travel across regions of Zealand slightly more to the south (and at higher altitudes). Under westerly winds many birds will adhere to the west coast of Skåne and reach Falsterbo.

Unfortunately, there are no inland observations available to decide whether Rudebeck (1950) is correct in postulating extensive wind drift or I am correct in being sceptical to it. The principal grounds for my scepticism are that (1) diurnal migrants generally seem to be able to compensate completely for wind drift over land (Tinbergen 1956, Alerstam 1976b), (2) the only detailed study about compensatory capability in a species using thermals during migration, i.e. the crane, has demonstrated that complete compensation over land is achieved by this species (Alerstam 1975) and (3) there is good reason to expect complete compensation to be generally desirable for migrating birds, and the most probable mode of accomplishing it is for the birds to use the landscape as a reference frame for their flight course (Alerstam 1976b). If this is so, I can see no reason why the raptors should be less apt than the crane to compensate completely for drift during migration over land.

I have found some support for this view in the literature: Holstein (1946) observed that buzzards and sparrow hawks in northern Zealand glide off towards south under southeasterly winds, but on some rare occasions with southwesterly winds (cf. above) they did fly more towards southwest. My interpretation of these observations is that the resulting track of the raptors was towards southwest in both wind situations and the southward glides under SE-winds have served to compensate for a northwesterly drift during the soaring in thermals. Another important aspect about raptor migration over land to be noted from Holstein's paper is the existence of local patterns of flight routes suitable for thermal migrants. Hence, under certain wind conditions the birds travel along specific routes, presumably those with the most favourable thermal currents, while another set of 'microroutes' will be preferred under other winds. This variation in flight routes may, of course, be compatible with complete compensation for wind drift by the birds.

Evans and Lathbury (1973) reported both field and radar observations in the Gibraltar region indicating compensation for wind drift by the migrating raptors. However, Bernis (1975) in describing his extensive field observations in this region seems to implicitly assume that the migrants are drifted by wind over land in southern Spain.

Richardson (1975) presented highly interesting radar observations of autumn raptor migration at Lakes Erie and Ontario. With offshore winds the birds often fly over the shoreline and become recorded at observatories such as Hawk Cliff, while the main flight line is a few miles inland with onshore winds and the migrants pass largely unnoticed from the shoreline (Haugh 1972 as cited in Richardson 1975, see also Fig. 11). As revealed by radar there may be intensive broad-front migration over the inland under both onshore and offshore winds, and there seem to be no marked differences in track directions under different winds. However, the analysis of the migrants' flight pattern is complicated by the fact that the birds travel across the study region along certain lines (visible as lines of echoes on the radar), and the location of these widely spaced lines may shift considerably from day to day and also during the days, at least to some extent depending on wind conditions. These observations indicate that the local pattern of raptor migration is related to topography, general weather and wind in a complex fashion, and this is probably due to the migrants continually searching for routes with optimal thermal conditions.

However, there are also outspoken advocates for the existence of wind drift (Mueller and Berger 1961, 1967a, b). These authors analysed autumn migration of mainly *Buteo* and *Accipiter* along the east shore of Lake Michigan and also along the Atlantic coast in NE United States. Unfortunately, they had no inland observations to rule out the possibility that the coastal observations were due to local shifts in the raptors' flight routes as discussed above. Hence, in principle I agree with Murray (1964) that the wind drift hypothesis may well be challenged and that it seems quite reasonable to explain the coastal observations without invoking extensive inland drift. Anyhow, I will not prolong this discussion about drift and compensation in raptor migration, but rather hope that someone will soon settle the issue by critical field and radar observations.

I will now return to the common buzzard, honey buzzard and sparrow hawk and the visible passage of these species at Falsterbo in relation to winds. NW-winds are associated with markedly more migration than SW-winds in the common buzzard, and less pronounced, also in the sparrow hawk. This is according to the prediction in Fig. 14E. The difference between these two species may be due to the fact that common buzzards are relatively more selective of favourable ground speed for their migratory flight and/or that the leading-line effect is almost 100% (C = 1, cf. Sect. 5.1.7.) for the common buzzard under westerly winds, while it is somewhat weaker under NW- than SW-winds (especially at the west coast) for the sparrow hawk in some comformity with the situation for migrants not using thermals (Fig. 10).

For the honey buzzard, NW- and SW-winds are associated with practically the same amount of migration at Falsterbo. The explanation is probably that this species represents a further step, past the sparrow hawk (noon), towards a reduction in leading-line dependence, showing a response in this respect which is very similar to migrants not using thermals. Hence, the relation between magnitude of visible passage and wind in the honey buzzard (see also Ulfstrand 1958) is very similar to the prediction in Fig. 14A which is relevant for migrants which are weakly selective of favourable travelling speed for their migratory flight and which respond to leading-lines without much regard to thermal conditions. The culmination of honey buzzard migration at Falsterbo under moderate westerly winds resembles that of 'W-wind migrants' described above (Tab. 8).

This is in good agreement with the observations by Rudebeck (1950) that the honey buzzard is much less dependent on thermals for its migratory flight than the common buzzard, which in fact is very little short of an obligate thermal migrant. According to Rudebeck the sparrow hawk is even less dependent on thermals than the honey buzzard, being recorded on ordinary flapping-flight migration almost every morning in the autumn. However, in this study I have treated sparrow hawk migration in the morning separately from that taking place around noon (1000–1400 hours), and it does not seem unreasonable that the latter category of sparrow hawk migration involves thermal flights to an extent intermediate between that of the common and honey buzzard migration.

5.2.5. Waterbird migration

Eiders and *black-headed gulls* pass Falsterbo travelling westwards over the Baltic Sea. Eider flocks are often barely visible far offshore south of the observation site. Large numbers of eiders at Falsterbo are associated with southerly (SE and SW) winds, and the most probable explanation is that the migrating ducks are drifted northwards over the sea to fly within visual range along the south coast of Skåne. Bergman and Donner (1964) demonstrated by radar studies that the day-time flow of flocks of migrating common scoters *Melanitta nigra* and long-tailed ducks *Clangula hyemalis* takes place close to the shore-line with onshore winds, but far out over the sea with offshore winds.

Under westerly winds eider migration becomes reduced with increasing wind speed, while there is no correlation between size of passage and wind speed under easterly winds. This is to be expected as the ground speed of eiders travelling westwards will be low with strong W-winds and, as a result, relatively few flocks will reach Falsterbo during the observation period. A contributing factor may of course be that migratory activity is lower with opposed than following winds (cf. Alerstam et al. 1974).

The black-headed gull differs from the eider in that the birds at Falsterbo usually fly in close contact with the south coast; Rudebeck (1943) says that the gulls adhere to the coastline as a leading-line. As seen from Appendix A most gulls are observed under NW-winds, and there is a tendency of an inverse correlation between size of passage and wind speed for all wind directions. I have no very good explanation at hand for this pattern, so I can only speculate:

The closer adherence to the south coast of migrating black-headed gulls than eiders indicates that the preferred flight direction in the former species is towards W/WNW, while in the latter species it is towards W/WSW. If this is so one may ask why the gulls do not depart inland from the south coast to fly on their preferred track direction slightly north of west. Actually I think that this is exactly what they do under easterly and southwesterly winds, but under NW-winds they can advance goalwards with minimum energy costs by flying at a low altitude on the leeward side of the coastline rather than departing into the wind over land. An additional aspect which perhaps should be considered in this context is the drift by north and south winds of gulls over the Baltic Sea east of Skåne, southerly winds possibly being associated with migration across Skåne, while northerly winds will displace the birds to the south coast of this province.

5.2.6. Migratory activity and wind

The relationship between migration and weather variables others than wind has been treated in Sect. 4, and I will now turn to the question of migratory activity in relation to wind. Migratory activity has been defined as P in Sect. 5.1.2., where I have also suggested different relationships between migratory activity and the migrants' travelling speed, assuming a positive correlation between these variables. This may seem to be a daring assumption to be used as a basis for explaining visible bird migration, considering the fact that the majority of researchers dealing with visible migration have affirmed and reaffirmed the reverse of this assumption, i.e. that headwinds are stimulating for the migratory activity. However, as mentioned in the Introduction, radar studies have convincingly contradicted this conclusion, and I think it is time to try to reconcile the observations of visible bird migration with a general positive correlation between migratory activity and following winds.

Can I conclude that my suggestions in Sect. 5.1.2. are correct? Apparently I can conclude that they *may well be* correct, since the predictions from my theory are in fairly good agreement with the field observations at Falsterbo, as evident from the preceding sections. I think this is a step forward, promising that radar and visible migration can be interpreted on a common and simple basis.

Is it possible for me to be even more specific and to rule out the possibility of an inverse correlation between migratory activity and following winds on the basis of the Falsterbo observations? I venture to make this attempt:

My aim is to solve P'/P from Eq. (7). As seen from this equation there are many factors besides migratory activity which govern the daily size of visible passage at Falsterbo, and I must see through the cloud of these factors to disentangle P'/P. This is only feasible under wind conditions permitting approximations to be made. Under strong opposed and cross winds, i.e. strong SW- and NW-winds at Falsterbo, it seems reasonable to assume that migration takes place at low altitudes and that detectability of migration to a field observer will not increase much further with increasing wind speed ($A' \sim 0$, cf. Sect. 5.1.6.). Furthermore, I assume that the leading-line effect under these winds at both the west and south coasts is virtually complete ($C \sim 1$) and, consequently, there will be little room for any increase in leading-line effect with increasing wind speed ($C' \sim 0$). These approximations will reduce Eq. (7) to:

$$\frac{P'}{P} = \frac{N'}{N} - \left[\frac{G_l'}{G_l} + \frac{(G_s' + G_w')}{(G_s + G_w)}\right] \tag{8}$$

Ground speeds over land and along the two coastlines may be calculated according to Eq. (1). The derivative of ground speed with respect to wind speed is given by:

Tab. 9. Predicted decrease in visible migratory intensity with increasing wind speed due to the effect of opposed and cross winds on the migrants' ground speed. The table shows values of the term bracketed in equation (8) calculated for SW- and NW-winds with a speed at 10 m s^{-1} as described in the text.

Airspeed of birds ms^{-1}	SW-winds ($\beta_1 = 180°$)	SW-winds ($\beta_1 = 135°$)	NW-winds ($\beta_1 = 90°$)
13	-0.64	-0.50	-0.19
15	-0.38	-0.29	-0.11
18	-0.23	-0.18	-0.06

$$\frac{\delta G}{\delta a} = G' =$$

$$\cos\beta - (a \sin^2\beta)\left[\sqrt{1-(a \sin\beta)^2}\right]^{-1} \quad (9)$$

Wind direction (β) for movements along the south and west coasts is +45° and −45°, respectively, in relation to that for migration over land. Dividing G' by the estimated air speed of the birds in m s^{-1}, will give the derivative with respect to wind speed in m s^{-1}. N'/N is the relative change in numbers of migrants with increasing wind speed and may be directly determined as the derivative of ln(N) with respect to wind speed (in m s^{-1}) from the equations presented and plotted for each species in Appendix A.

I have calculated the term within brackets in Eq. (8) for SW- and NW-winds with a speed at 10 m s^{-1} for birds with air speeds at 13, 15 and 18 m s^{-1}, respectively (Tab. 9). The air speed is expected to be lower for small birds (the average air speed of the chaffinch at low altitudes under headwinds is about 13 to 14 m s^{-1} according to Bruderer 1971) than for large ones (the mean air speed of the wood pigeon is 17 m s^{-1} according to Alerstam and Ulfstrand 1974). In Tab. 9 I have presented, for winds from the SW quadrant, a minimum value (at β_1 = 180°, corresponding to SW-winds, i.e. due headwinds) and a maximum value (at β_1 = 135°, corresponding to S- and W-winds), while I have calculated an average value for NW-winds (using β_1 = 90°).

N'/N for surface SW- and NW-winds at a speed of 10 m s^{-1} is presented for the different land-bird species in Tab. 10. There are some obvious reservations about the usefulness of these estimates: It may be questionable to derive such estimates from equations calculated according to the method of least squares and incorporating many observations of zero migration (although it is difficult to suggest any more reliable way of fitting equations to the observations). Hence, derivatives from these equations must be treated with due care. For many species a straight line provides a good fit to the observations for the whole range of wind speed, and it

Tab. 10. Change in size of visible passage of migrating land-birds at Falsterbo with increasing wind speed under SW- and NW-winds with a speed at 10 m s^{-1}. Values of N'/N are calculated from equations in Appendix A as described in the text.

Species	SW-wind first-degree equation	SW-wind polynomial equation	NW-wind first-degree equation	NW-wind polynomial equation
Common buzzard	-0.21		-0.16	
Honey buzzard		-0.18		-0.21
Sparrow hawk - morning		-0.13	-0.05	
Sparrow hawk - noon	-0.15		-0.09	
Wood pigeon	-0.35			-0.23
Swift		-0.01		+0.31
Swallow		-0.23		-0.23
Hooded crow		-0.22	-0.11	
Jackdaw	-0.31		-0.16	
Yellow wagtail		-0.56		-0.31
Starling - August	-0.30		-0.38	
Starling - October		-0.36	-0.16	
Chaffinch/Brambling		-0.44	-0.13	
Siskin		-0.45	-0.21	
Linnet		-0.42	-0.24	
Mean (excl. the Swift)	-0.31		-0.19	

goes without saying that the derivative of such a linear equation represents only a very rough approximation of the situation at any specific wind speed.

By subtracting the estimates in Tab. 9 from those in Tab. 10 one can solve P′/P (cf. Eq. 8). It turns out that these two sets of estimates are in the same order of magnitude, and therefore I cannot directly conclude with any confidence whether migratory activity is positively or negatively correlated with the migrants' ground speed. In fact, the figures in Tabs 9 and 10 seem to indicate that there is no distinct correlation at all between these variables. There is one obvious exception to this – for the swift P′/P is clearly positive, showing that migratory activity in this species is positively correlated with cross and opposed wind speed (Sect. 5.2.2.).

In order to come to a judgement about the relationship between migratory activity and winds for the majority of species, I should like to take the following points into account:

(a) What is the magnitude to be expected for the value of P′/P according to the hypothesis in Sect. 5.1.2.? For birds which are weakly selective of high ground speed for their migratory flight as exemplified in Fig. 8, the predicted value of P′/P under SW-winds at 10 m s^{-1} is between −0.30 and −0.33 (for β_1 = 135° and 180°, respectively) if the birds' air speed = 13 m s^{-1}, between −0.18 and −0.20 for birds with an air speed at 15 m s^{-1}, and −0.11 to −0.13 for birds with an air speed at 18 m s^{-1}. Corresponding figures for NW-winds (β_1 = 90°) at 10 m s^{-1} are −0.15, −0.08 and −0.05 for birds with air speeds at 13, 15 and 18 m s^{-1}, respectively.

(b) If the approximation made initially, that the leading-line effect is complete under strong SW- and NW-winds is unwarranted but there is a significant increase in leading-line effect with increasing wind speed, this will lead to a decrement in P′/P, as calculated from the Falsterbo observations.

(c) Similarly, if detectability of migrants is not constant but increases with increasing wind speed, this will also lead to a decrement in P′/P. Considering these three aspects in conjunction with Tabs 9 and 10 I conclude: The available data from Falsterbo point towards a positive correlation between migratory activity and ground speed. However, the data cannot be used to definitely refute the possibilities of a lack of such a correlation or even the existence of an inverse correlation, although the latter alternative seems to be highly improbable. Hence, as far as such a strict refutation was the purpose of the above analysis, I have failed.

For eider and black-headed gull migration under strong SW- and NW-winds I provisionally assume that the birds travel due westwards, that their detectability to the field observer at Falsterbo is uncorrelated to wind speed and that they are deflected by the south coast of Skåne to a small extent only. Consequently, I arrive at the relationship:

$$\frac{P'}{P} = \frac{N'}{N} - \frac{G'}{G} \qquad (10)$$

N′/N may be determined directly from the graphs in Appendix A as the derivative of ln(N) with respect to wind speed in m s^{-1}, and G′/G can be calculated from Eqs (1) and (9) using β = 135° (corresponding to SW- as well as NW-winds) and a wind speed at 10 m s^{-1}.

For the eider, with an air speed at 21 m s^{-1} (Alerstam et al. 1974b), G′/G = − 0.08, which is similar to N′/N in August (−0.04 and −0.09 for SW- and NW-winds, respectively), indicating a lack of correlation between migratory activity and opposed wind speed. However, N′/N is markedly smaller in October (−0.17 and −0.16 for SW- and NW-winds, respectively) suggesting that eider migratory activity decreases with increasing opposed wind speed (and decreasing ground speed).

Guessing the air speed of the black-headed gull to be 15 m s^{-1}, G′/G for this species will be −0.18. N′/N (−0.07 and −0.08 for SW- and NW-winds, respectively) exceeds this value, indicating that the gulls' migratory activity increases with increasing opposed wind speed (or that the above approximations are misleading).

5.2.7. *Testing the theory*

How successful has the theory, as summarized in Eq. (6), been in explaining the field observations of migrating birds at Falsterbo under different winds, as judged from the above comparisons between predictions and observations? I think the theory has led some way towards an understanding of visible migration, but it did not provide a full explanation. In order to account for general discrepancies between observations and predictions, as well as interspecific differences, I have introduced a few auxiliary hypotheses:

(1) I have repeatedly argued that the leading-line effect of the west coast of Skåne is inferior to that of the south coast. This is of course not an hypothesis advanced gratuitously, but there are perfectly sound reasons to believe that it is true.

(2) In order to explain interspecific differences I have speculated about differences in preferred track direction between species.

(3) For the same purpose I have speculated about differences in use of thermals during migration between different species. There are observations to corroborate some of the suggestions under (2) and (3), while others remain purely speculative.

After supplementing the theory with these auxiliary hypotheses, there seems to be little of the relation between visible migration at Falsterbo and wind that is left unexplained. Consequently, is it not proper to conclude that the theory developed in this paper has passed a critical test? No, unfortunately I do not think so. The theory may have passed a test but not one as severe as one would wish. The theory is based on assumptions about the relationships between wind and migratory activity, flight altitude, leading-line effect at two different coastlines, migration with the aid of thermals, travelling speed over the inland as well as along coastlines, and daily temporal pattern of migration. It is true that these different assumptions stem from a general underlying view that the birds' behaviour is adapted to bring them as far as possible along their preferred track at minimum energy costs, but the most critical way of testing the theory is to dissect it and investigate the different assumptions separately. This can in many cases not be properly done on the basis of data from Falsterbo, a site where all the above-mentioned factors often interact simultaneously.

This is a point worthy of notice for the student of bird migration. Rudebeck (1950) explained why he did choose Falsterbo as site for observing bird migration: "I found it imperative to work upon a comprehensive material, for far too many papers concerning the correlation between weather conditions and bird migration have been based upon too few observations". Of course, it is of greatest importance to have extensive and reliable observation data, but at Falsterbo one will have them at the price of a highly complex situation to interprete. However, I am far from arguing that the gathering of extensive observations from Falsterbo, or from sites at mountain ridges, bays , promontories and islands, is a mistake. On the contrary, the tremendous concentrations of migrating birds at these places form an indispensable challenge to bird migration research. Hence, my plead is merely that there will be future field observations and analyses of bird migration also from 'geographically simple' sites, such as inland sites and sites along unbroken straight coastlines. Such observations may be used for critically testing the present theory.

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APPENDIX A. Visible bird migration at Falsterbo in relation to weather

Results from the analysis of daily visible bird migration at Falsterbo during eleven autumns 1949–1960 in relation to weather are given here for fifteen different species. Data for each species are normally presented on two facing pages, one with figures and the other with tables. The following information is given for each species:

(1) Daily totals of migrants (daily observation periods are given in Ulfstrand et al. 1974) have been related to date during the autumn season by way of a fifth-degree polynomial regression calculated by the method of least squares. For the eider and starling with relatively prolonged and complex seasonal patterns, a seventh-degree polynomial regression has been calculated. Numbers of observation days are given, and the study period, to which all further analyses refer, is framed within vertical lines. This presentation serves only to give a general overview of the broad seasonal pattern of migration – more detailed information is presented in Ulfstrand et al. (1974).

(2) Daily numbers of migrants have been related to date during the study period by way of a fifth-degree polynomial regression. Number of observation days are given as well as the coefficient of determination, R^2, denoting the proportion of variance in daily number of migrants accounted for by the polynomial equation. Study periods are defined as described in the main text.

(3) Daily numbers of migrants have been related to number of days of delay by way of polynomial evaluations of first-degree to fifth-degree equations. The second-degree function was accepted if the quadratic term did account for a significant ($p < 0.05$) proportion of the residual variation in the dependent variable (migration). In one case (chaffinch/brambling) was the effect of the quadratic term only barely significant while the linear term was insignificant, and the second-degree equation as a whole was not significant. A third-degree function was accepted if the cubic term did account for a significant fraction of the residual variation in the dependent variable. However, if both the linear and quadratic terms were insignificant it was accepted only if the complete third-degree equation was statistically significant. A fourth-degree function was accepted if the fourth-degree term did account for a significant fraction of the residual variation in the dependent variable. However, if the quadratic and cubic terms were both insignificant it was accepted only if the complete fourth-degree equation was statistically significant. An analogous judgement for acceptance of the fifth-degree equation was adopted. Number of observations are considerably less than the total for the study period, due to the exclusion of data before the first instance of large-scale migration in each autumn and to the exclusion of data during and after days with missing or deficient observations till the succeeding instance of large-scale migration.

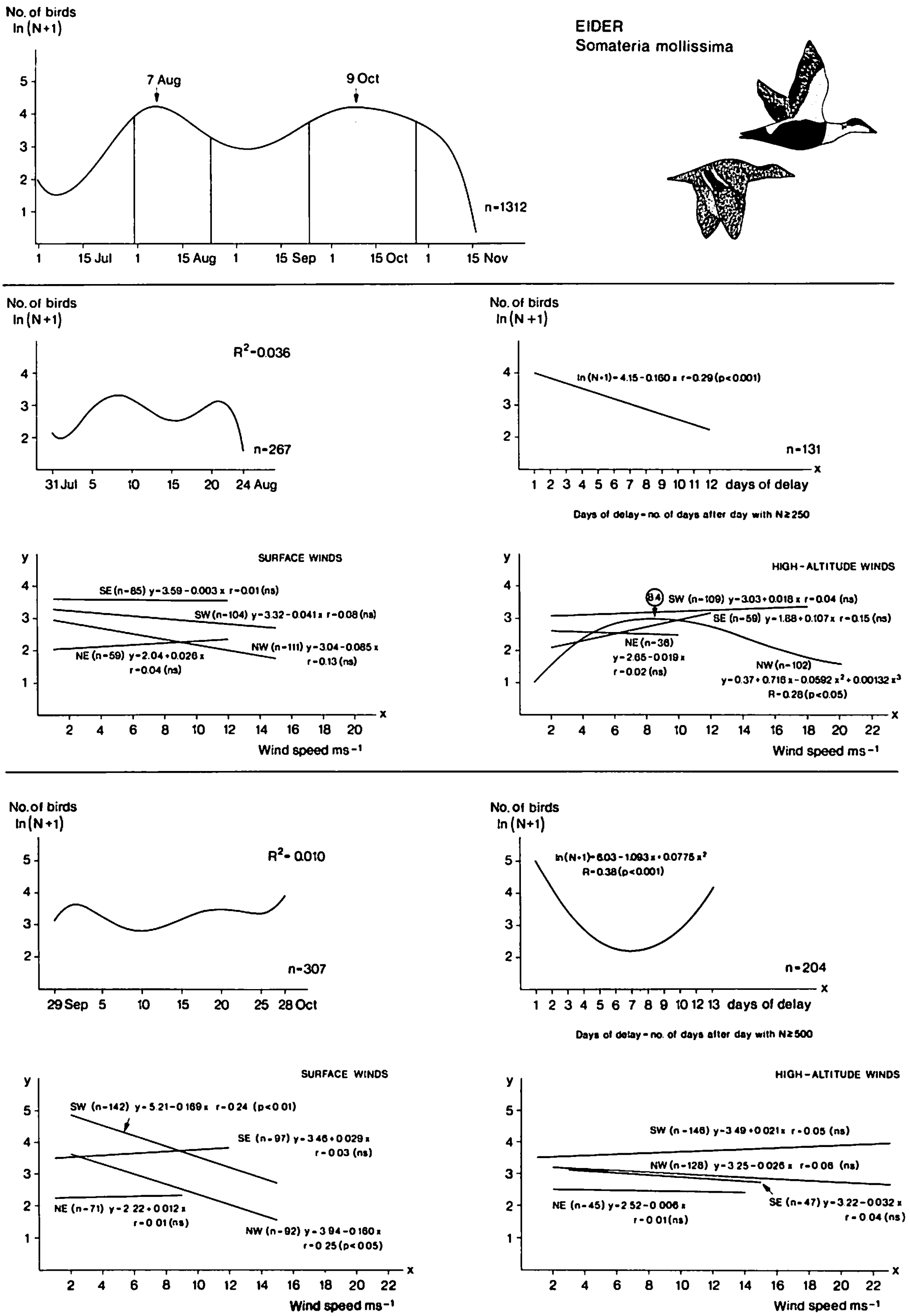
(4) Daily numbers of migrants are illustrated in relation to surface wind speed for each quadrant of wind direction. These relationships have been evaluated by considering first-degree to fifth-degree polynomial equations as described in (3). Wind directions at the limit values between quadrants (i.e. due N-, E-, S- and W-winds) have been included into the analyses of both adjacent quadrants. Because of this 'double-use' of some data, the sum of observations for all four quadrants exceeds the total number during the study period. Wind speeds at distinct minima and maxima are indicated in the figures.

(5) The analysis described in (4) has been repeated for high-altitude winds.

(6) Correlation coefficients (r) between daily number of migrants and different weather variables are tabulated, and significant correlations are indicated by one ($p < 0.05$), two ($p < 0.01$) or three ($p < 0.001$) asterisks.

(7) Observations have been divided into four groups with smallest number of daily migrants in group 1 and largest in group 4 (exact definitions of groups are given below for each species). Means of weather variables for each group are tabulated, and the difference between the four group means in each variable has been tested by single-factor analysis of variance. Significant differences between group means, as determined from the variance ratio (F), are indicated by asterisks as described in (6).

(Cont. p. 313)



No. of birds ln(N+1)
EIDER
Somateria mollissima
7 Aug
9 Oct
n=1312
1 15 Jul 1 15 Aug 1 15 Sep 1 15 Oct 1 15 Nov
R²=0.036
n=267
31 Jul 5 10 15 20 24 Aug
ln(N+1)=4.15-0.160x r=0.29 (p<0.001)
n=131
days of delay
Days of delay = no. of days after day with N≥250
SURFACE WINDS
SE (n=85) y=3.59-0.003x r=0.01 (ns)
SW (n=104) y=3.32-0.041x r=0.08 (ns)
NW (n=111) y=3.04-0.085x r=0.13 (ns)
NE (n=59) y=2.04+0.026x r=0.04 (ns)
Wind speed ms⁻¹
HIGH-ALTITUDE WINDS
SW (n=109) y=3.03+0.018x r=0.04 (ns)
SE (n=59) y=1.88+0.107x r=0.15 (ns)
NE (n=36) y=2.65-0.019x r=0.02 (ns)
NW (n=102) y=0.37+0.716x-0.0592x²+0.00132x³ R=0.28 (p<0.05)
Wind speed ms⁻¹
R²=0.010
n=307
29 Sep 5 10 15 20 25 28 Oct
ln(N+1)=6.03-1.093x+0.0775x² R=0.38 (p<0.001)
n=204
days of delay
Days of delay = no. of days after day with N≥500
SURFACE WINDS
SW (n=142) y=5.21-0.169x r=0.24 (p<0.01)
SE (n=97) y=3.46+0.029x r=0.03 (ns)
NE (n=71) y=2.22+0.012x r=0.01 (ns)
NW (n=92) y=3.94-0.160x r=0.25 (p<0.05)
Wind speed ms⁻¹
HIGH-ALTITUDE WINDS
SW (n=146) y=3.49+0.021x r=0.05 (ns)
NW (n=128) y=3.25-0.026x r=0.06 (ns)
NE (n=45) y=2.52-0.006x r=0.01 (ns)
SE (n=47) y=3.22-0.032x r=0.04 (ns)
Wind speed ms⁻¹

EIDER (AUGUST)

Variable	Correlation Coefficient n = 247	Mean Group 1 n = 151	Group 2 n = 32	Group 3 n = 39	Group 4 n = 25	F^{3}_{243}
Cloud amount (scale 0-8)	0.03	4.7	5.0	4.7	4.9	0.1
Cloud ceiling (scale 0-9)	0.07	5.8	5.6	6.5	6.1	1.4
Convective clouds (scale 0-1)	0.00	0.50	0.56	0.49	0.56	0.3
Visibility (scale 0-9)	0.01	7.5	7.7	7.5	7.4	0.5
Rain 0700 hr (scale 0-2)	0.03	0.13	0.06	0.15	0.24	0.6
Rain 0700-1300 hr (scale 0-2)	0.03	0.26	0.31	0.26	0.32	0.1
Relative humidity (%)	0.05	87.4	86.0	88.5	89.8	1.9
Rel. humidity trend (%)	0.04	-0.2	0.0	1.2	0.5	0.4
Barometric pressure (mb)	0.01	1012.3	1013.6	1013.7	1011.4	0.9
Barom. pressure trend (mb)	-0.03	0.16	-0.88	0.22	0.47	1.5
Temperature (°C)	0.09	-0.07	0.49	0.36	-0.04	1.3
Temperature trend (°C)	0.12	-0.16	0.34	0.31	-0.12	2.5
Min. temperature (°C)	0.02	-0.17	0.16	-0.26	-0.37	0.4
Min. temp. trend (°C)	0.04	-0.06	0.16	0.18	-0.40	0.5
Max. temperature (°C)	0.07	-0.21	0.22	0.51	0.09	0.7
Max. temp. trend (°C)	0.01	-0.05	-0.50	-0.05	0.36	0.8
Surface winds:						
Wind speed (m/s)	-0.06	6.2	6.9	5.4	5.3	1.5
Wind speed trend (m/s)	-0.09	0.1	0.6	-0.2	-0.8	0.5
N-wind	-0.25***	0.03	-0.10	-0.17	-0.16	1.7
N-wind trend	-0.19**	0.09	-0.06	-0.06	-0.24	2.0
NE-wind	-0.11	-0.13	-0.25	-0.10	-0.24	0.5
NE-wind trend	-0.08	0,03	-0.02	0.05	-0.08	0.3
NW-wind	-0.20**	0.18	0.10	-0.14	0.02	2.1
NW-wind trend	-0.17**	0.10	-0.06	-0.14	-0.27	2.3
W-wind	-0.07	0.22	0.25	-0.03	0.18	1.2
W-wind trend	-0.07	0.05	-0.03	-0.14	-0.13	0.9
High-altitude winds:						
Wind speed (m/s)	0.06	9.0	9.9	8.7	9.0	0.4
Wind speed trend (m/s)	0.11	-0.6	1.0	0.4	0.7	1.1
N-wind	-0.15*	-0.04	-0.29	-0.12	-0.002	1.5
N-wind trend	-0.09	0.05	-0.19	-0.03	-0.03	1.4
NE-wind	-0.13*	-0.27	-0.53	-0.25	-0.29	1.7
NE-wind trend	-0.09	0.05	-0.29	0.10	0.03	2.9*
NW-wind	-0.06	0.20	0.12	0.08	0.25	0.5
NW-wind trend	-0.04	0.02	0.02	-0.15	-0.07	0.8
W-wind	0.04	0.33	0.46	0.23	0.38	0.7
W-wind trend	0.04	-0.02	0.22	-0.17	-0.07	2.3

Multiple regression equation	n = 247, R = 0.25	Multiple regression equation incl. days of delay	n = 127, R = 0.37
-0.250 N-wind (s)	$p < 0.001$	-0.326 days of delay -1	$p < 0.001$
		+0.172 temp.trend	$p < 0.05$

Multiple discriminant function	n = 247, R_c = 0.21	Multiple discriminant function incl. days of delay	n = 127, R_c = 0.33
Mean of standardized discriminant score: Group 1=-0.01 Group 2=-0.45 Group 3=0.22 Group 4=0.29		Mean of standardized discriminant score: Group 1=-0.18 Group 2=-0.45 Group 3=0.44 Group 4=0.38	
+1.087 NE-wind trend (h)	$p < 0.05$	-0.783 days of delay -1	$p < 0.05$
-0.708 N-wind trend (s)	$p < 0.05$	-0.597 W-wind trend (h)	$p < 0.05$

EIDER (OCTOBER)

Variable	Correlation Coefficient n = 283	Mean Group 1 n = 139	Mean Group 2 n = 68	Mean Group 3 n = 60	Mean Group 4 n = 16	F^{3}_{279}
Cloud amount (scale 0-8)	0.11	5.8	5.8	6.4	6.1	1.1
Cloud ceiling (scale 0-9)	0.07	4.9	5.2	5.1	5.8	1.1
Convective clouds (scale 0-1)	-0.09	0.35	0.29	0.32	0.25	0.3
Visibility (scale 0-9)	-0.02	7.1	7.1	7.1	7.5	0.6
Rain 0700 hr (scale 0-2)	0.03	0.23	0.19	0.25	0.25	0.1
Rain 0700-1300 hr (scale 0-2)	0.03	0.35	0.29	0.33	0.56	0.6
Relative humidity (%)	0.06	90.5	91.2	90.4	89.6	0.3
Rel. humidity trend (%)	0.10	-0.7	0.9	0.1	2.2	0.8
Barometric pressure (mb)	0.01	1014.1	1013.9	1015.5	1013.0	0.5
Barom. pressure trend (mb)	-0.00	-0.76	-0.57	-0.46	-0.93	0.1
Temperature (°C)	0.12*	-0.17	-0.04	0.42	0.39	0.8
Temperature trend (°C)	0.15*	-0.26	-0.13	0.20	0.68	1.8
Min. temperature (°C)	0.02	-0.01	0.03	-0.07	0.08	0.0
Min. temp. trend (°C)	0.09	-0.27	0.15	0.13	0.06	0.7
Max. temperature (°C)	0.05	-0.03	0.15	0.05	0.55	0.2
Max. temp. trend (°C)	0.13*	-0.42	-0.07	0.05	0.38	1.6
Surface winds:						
Wind speed (m/s)	-0.12*	7.7	6.5	6.5	7.2	2.2
Wind speed trend (m/s)	-0.13*	0.8	-0.6	-1.2	-0.0	3.1*
N-wind	-0.33***	0.05	-0.18	-0.26	-0.63	9.1***
N-wind trend	-0.25***	0.12	0.06	-0.16	-0.53	5.4**
NE-wind	-0.28***	-0.07	-0.24	-0.42	-0.52	4.9**
NE-wind trend	-0.19**	0.08	0.08	-0.14	-0.25	2.2
NW-wind	-0.13*	0.14	-0.01	0.05	-0.37	3.1*
NW-wind trend	-0.15*	0.09	0.01	-0.10	-0.51	3.4*
W-wind	0.10	0.15	0.16	0.33	0.11	0.9
W-wind trend	0.02	0.00	-0.05	0.03	-0.18	0.4
High-altitude winds:						
Wind speed (m/s)	-0.02	11.3	11.0	10.5	11.8	0.3
Wind speed trend (m/s)	-0.09	0.6	-0.1	-1.1	0.1	1.1
N-wind	-0.09	0.02	-0.13	0.01	-0.21	1.2
N-wind trend	-0.23***	0.11	-0.04	-0.21	-0.37	5.4**
NE-wind	-0.15*	-0.24	-0.39	-0.35	-0.50	1.5
NE-wind trend	-0.15*	0.07	-0.01	-0.09	-0.21	1.7
NW-wind	0.01	0.27	0.21	0.36	0.20	0.6
NW-wind trend	-0.18**	0.09	-0.06	-0.21	-0.31	4.2**
W-wind	0.12*	0.36	0.43	0.50	0.50	0.8
W-wind trend	-0.02	0.01	-0.04	-0.08	-0.07	0.4

Multiple regression equation — n = 283, R = 0.48

-0.597	N-wind (s)	p < 0.001
+0.353	N-wind (h)	p < 0.001
-0.334	N-wind trend (h)	p < 0.001
+0.183	barom.pr.trend	p < 0.01
+0.180	NW-wind trend (s)	p < 0.05
-0.133	wind speed trend (s)	p < 0.05

Multiple regression equation incl. days of delay — n = 185, R = 0.54

+0.346	days of delay -2	p < 0.001
-0.317	NE-wind (s)	p < 0.001
-0.220	NW-wind trend (h)	p < 0.001
-0.191	wind speed trend (s)	p < 0.01
-0.128	max temp.	p < 0.05

Multiple discriminant function — n = 283, R_c = 0.45

Mean of standardized discriminant score
Group 1 = -0.41 Group 2 = 0.11 Group 3 = 0.60 Group 4 = 0.85

-1.219	N-wind (s)	p < 0.001
+0.802	N-wind (h)	p < 0.001
-0.649	NW-wind trend (h)	p < 0.001
-0.457	wind speed trend (s)	p < 0.01
+0.369	NW-wind trend	p < 0.05

Multiple discriminant function incl. days of delay — n = 185, R_c = 0.51

Mean of standardized discriminant score
Group 1 = -0.48 Group 2 = -0.04 Group 3 = 0.60 Group 4 = 0.97

+0.766	days of delay -2	p < 0.001
-0.391	NW-wind trend (h)	p < 0.05
+0.386	W-wind (s)	p < 0.05
-0.324	N-wind trend (s)	p < 0.05
-0.317	wind speed trend (s)	p < 0.05

(8) Daily migratory intensity has been investigated in relation to weather by multiple regression analysis. Stepwise analysis with $p = 0.05$ as the limit for inclusion and deletion of independent variables has been carried out according to Nie et al. (1975). The resulting standardized multiple regression equation is presented for each species. Standardization of a variable is attained by subtracting the mean and dividing by the standard deviation. The regression coefficients in a standardized equation (known as 'beta coefficients') measure the number of standard deviations by which the dependent variable (migration) is expected to change when the corresponding independent variable (a weather variable) is changed by one standard deviation. In this sense, the standardized regression coefficients show the relative importance of the different weather variables and are directly comparable from one equation to another (Nisbet and Drury 1968). Hence, I have ranked the weather variables in the multiple regression equations according to their beta coefficients. R is the multiple correlation coefficient.

(9) The above analysis has been repeated with 'days of delay' as an additional independent variable. This brings about a considerable reduction in number of observations as explained in (3). For species with a linear relationship between daily migratory intensity and delay, the variable 'days of delay – 1' was simply defined as the number of days of delay. For species with a second-degree function accounting for this relationship, the variable 'days of delay – 2' corresponds to the value of this function, f(x), for the appropriate number of days of delay (x). The result of the present analysis has not been presented if the variable 'days of delay' was not included into the regression equation.

(10) The grouped data, as described in (7), have been used as a basis for stepwise multiple discriminant analysis with $p = 0.05$ as the limit for exclusion and deletion of independent variables according to Wilks' method as presented by Nie et al. (1975). Except for the sparrow hawk (morning) and hooded crow (see special comments for these species below), only the first discriminant function is presented because the second and third functions usually do not allow any reasonable interpretation, and they are statistically insignificant in most species. Discriminant function coefficients based on standardized independent variables are presented. Such a coefficient illustrates the change in discriminant score when the corresponding weather variable is changed by one standard deviation. The effect of this change on group prediction can be inferred from the group means of the discriminant score. Hence, the interpretation of the discriminant function coefficients is similar to that of beta weights in multiple regression, and I have ordered the variables in the discriminant equations according to their relative importance. Rc is the canonical correlation coefficient for the first discriminant function. The square of this coefficient denotes the proportion of variance in the migration canonical variate (a linear combination of group dummy variables) accounted for by the discriminant function.

(11) Stepwise multiple discriminant analysis as described in (10) has been repeated with 'days of delay' as an additional independent variable. This variable is defined as explained in (9).

Survey of species

The following list contains information about seasonal and daily study periods, and grouping of data, as well as supplementary comments for each species:

Eider, Somateria mollissima

1) 31 July–24 Aug 05–09 hours.

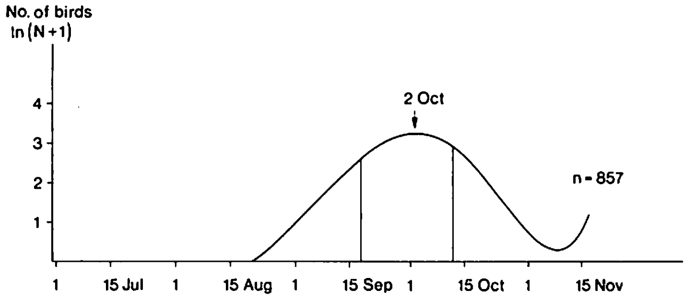
Group 1: daily number of migrants, $N < 50$. Group 2: $50 \leq N < 120$. Group 3: $120 \leq N < 300$. Group 4: $N \geq 300$. In the following I will abbreviate the information about grouping like: Group limits: 50, 120, 300.

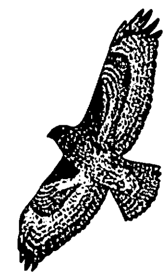
2) 29 Sept–28 Oct 07–12 hours. Group limits: 50, 250, 1250.

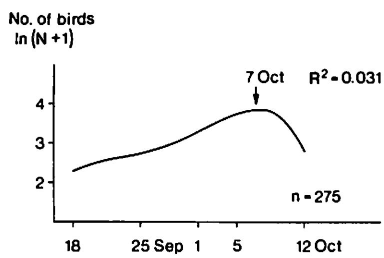
The principal part of eider migration in the autumn takes place in October, and I am uncertain about which eiders make up the secondary migration peak in August (cf. Ulfstrand et al. 1974). It is too late

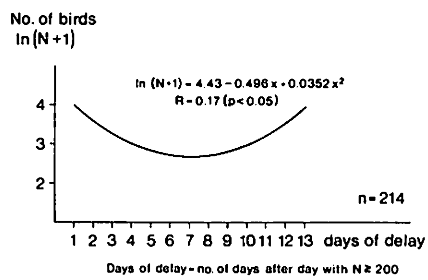
(Cont. p. 339)

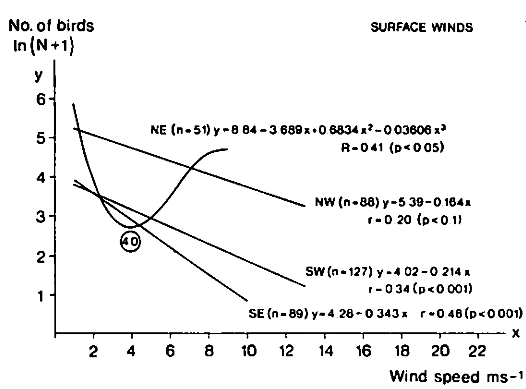
COMMON BUZZARD
Buteo buteo

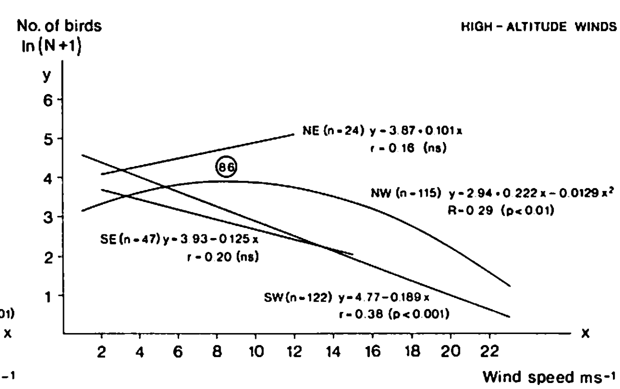












COMMON BUZZARD

Variable	Correlation Coefficient n = 256	Mean Group 1 n = 114	Group 2 n = 54	Group 3 n = 57	Group 4 n = 31	F^3_{252}
Cloud amount (scale 0-8)	-0.33***	6.4	4.9	4.7	3.9	10.6***
Cloud ceiling (scale 0-9)	-0.02	5.1	5.8	5.4	4.6	2.8*
Convective clouds (scale 0-1)	0.25***	0.32	0.44	0.54	0.61	4.6**
Visibility (scale 0-9)	0.13*	7.2	7.4	7.3	7.6	1.7
Rain 0700 hr (scale 0-2)	-0.21***	0.27	0.11	0.07	0.00	3.3*
Rain 0700-1300 hr (scale 0-2)	-0.34***	0.54	0.09	0.09	0.03	12.4***
Relative humidity (%)	-0.09	91.8	90.6	91.2	90.7	0.5
Rel. humidity trend (%)	-0.04	0.5	-0.7	-0.5	0.2	0.4
Barometric pressure (mb)	0.06	1013.7	1014.1	1015.4	1013.2	0.6
Barom. pressure trend (mb)	0.32***	-1.12	-0.30	0.37	2.28	8.5***
Temperature ($^{\circ}$C)	-0.17**	0.35	-0.40	0.01	-0.95	3.1*
Temperature trend ($^{\circ}$C)	-0.33***	0.41	-0.27	-0.53	-0.98	8.2***
Min. temperature ($^{\circ}$C)	-0.16**	0.21	-0.52	-0.01	-1.34	3.0*
Min. temp. trend ($^{\circ}$C)	-0.27***	0.40	-0.26	-0.35	-1.61	6.5***
Max. temperature ($^{\circ}$C)	0.04	-0.53	0.04	0.35	-1.09	2.7*
Max. temp. trend ($^{\circ}$C)	0.07	-0.39	-0.02	0.00	0.03	0.8
Surface winds:						
Wind speed (m/s)	-0.27***	8.2	6.2	5.8	6.5	6.5***
Wind speed trend (m/s)	-0.34***	1.2	-0.4	-0.6	-3.5	9.1***
N-wind	0.35***	-0.31	-0.22	0.01	0.27	10.2***
N-wind trend	0.23***	-0.13	-0.05	0.16	0.36	4.8**
NE-wind	0.24***	-0.40	-0.23	-0.05	-0.08	4.6**
NE-wind trend	0.31***	-0.19	-0.01	0.20	0.39	8.0***
NW-wind	0.19**	-0.03	-0.08	0.06	0.46	4.8**
NW-wind trend	0.04	0.00	-0.06	0.04	0.13	0.4
W-wind	-0.03	0.26	0.11	0.08	0.38	1.6
W-wind trend	-0.19**	0.14	-0.04	-0.11	-0.18	2.6
High-altitude winds:						
Wind speed (m/s)	-0.24***	11.7	9.2	9.1	9.0	5.2**
Wind speed trend (m/s)	-0.27***	1.4	-0.5	-0.6	-3.6	6.4***
N-wind	0.19**	-0.14	-0.08	-0.07	0.27	3.1*
N-wind trend	0.16**	-0.10	0.07	0.04	0.25	2.8*
NE-wind	0.22***	-0.47	-0.34	-0.27	-0.12	3.7*
NE-wind trend	0.28***	-0.19	0.02	0.11	0.34	8.0***
NW-wind	0.07	0.27	0.23	0.17	0.49	1.6
NW-wind trend	-0.04	0.05	0.08	-0.06	0.02	0.5
W-wind	-0.10	0.52	0.40	0.31	0.43	1.6
W-wind trend	-0.23***	0.17	0.05	-0.12	-0.23	5.3**

Multiple regression equation n = 256 R = 0.64

+0.301	N-wind (s)	p < 0.001
-0.241	W-wind trend (h)	p < 0.001
-0.207	rain 07-13hr	p < 0.001
-0.204	wind speed (s)	p < 0.01
+0.199	convective clouds	p < 0.001
-0.185	NE-wind (h)	p < 0.01
-0.172	wind speed trend (s)	p < 0.01
-0.166	cloud amount	p < 0.01

Multiple regression equation incl. days of delay n = 200 R = 0.70

-0.298	wind speed trend (s)	p < 0.001
+0.277	N-wind (s)	p < 0.001
+0.223	NE-wind trend (h)	p < 0.001
+0.221	days of delay -2	p < 0.001
-0.215	N-wind (h)	p < 0.01
-0.196	rain 07-13hr	p < 0.001
+0.178	convective clouds	p < 0.01
-0.170	cloud amount	p < 0.01
-0.128	wind speed (h)	p < 0.05
+0.110	max temp.trend	p < 0.05

Multiple discriminant function n = 256 R_c = 0.60

Mean of standardized discriminant score

Group 1 = -0.62 Group 2 = 0.18 Group 3 = 0.55 Group 4 = 0.96

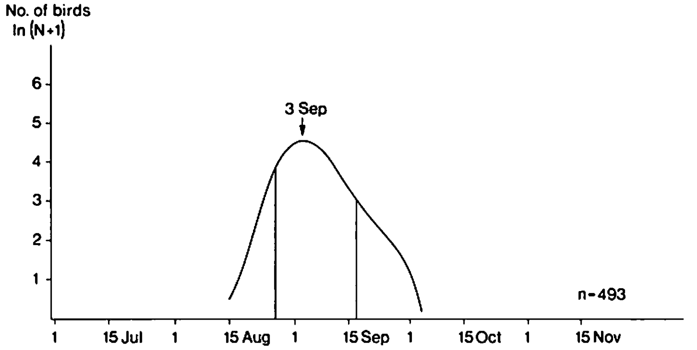
+0.432	N-wind (s)	p < 0.001
-0.421	W-wind trend (h)	p < 0.001
-0.369	rain 07-13hr	p < 0.001
-0.317	wind speed (s)	p < 0.001
-0.306	cloud amount	p < 0.01
+0.294	convective clouds	p < 0.05
-0.206	wind speed trend (s)	p < 0.01

Multiple discriminant function incl. days of delay n = 200 R_c = 0.61

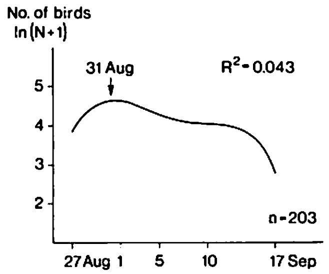
Mean of standardized discriminant score

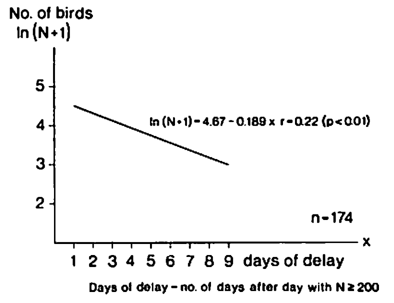
Group 1 = -0.70 Group 2 = 0.13 Group 3 = 0.42 Group 4 = 0.96

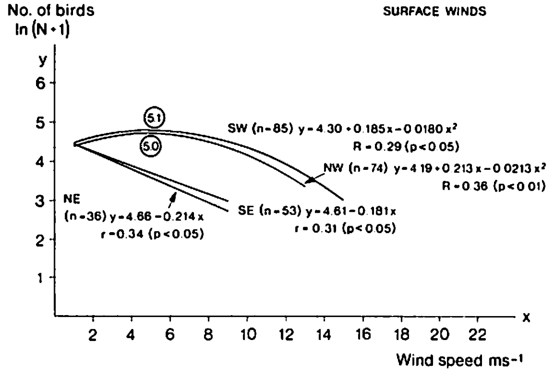
-0.437	cloud amount	p < 0.001
-0.422	rain 07-13hr	p < 0.001
+0.395	NE-wind trend (h)	p < 0.01
+0.332	days of delay -2	p < 0.01
-0.286	wind speed trend (s)	p < 0.01
-0.192	wind speed (s)	p < 0.05
-0.184	cloud ceiling	p < 0.05

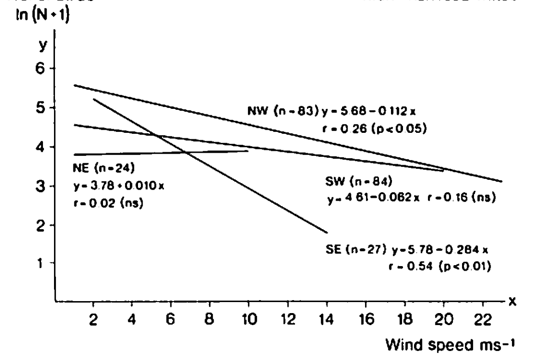


HONEY BUZZARD
Pernis apivorus









HONEY BUZZARD

Variable	Correlation Coefficient n = 170	Mean Group 1 n = 34	Group 2 n = 56	Group 3 n = 62	Group 4 n = 18	F^{3}_{166}
Cloud amount (scale 0-8)	-0.20**	5.4	4.9	4.2	3.8	1.8
Cloud ceiling (scale 0-9)	0.03	5.7	5.9	5.8	5.4	0.3
Convective clouds (scale 0-1)	0.09	0.50	0.46	0.48	0.72	1.3
Visibility (scale 0-9)	0.01	7.6	7.2	7.5	7.6	1.9
Rain 0700 hr (scale 0-2)	-0.22**	0.32	0.25	0.06	0.06	2.3
Rain 0700-1300 hr (scale 0-2)	-0.23**	0.62	0.30	0.23	0.22	2.8
Relative humidity (%)	0.12	87.6	91.5	91.0	90.3	2.6
Rel. humidity trend (%)	0.09	-2.5	1.7	-0.5	1.7	2.2
Barometric pressure (mb)	0.08	1012.6	1015.3	1014.5	1013.2	0.9
Barom. pressure trend (mb)	0.34***	-1.86	-0.41	0.89	0.74	7.5***
Temperature (°C)	-0.16*	0.50	0.77	0.04	-0.61	3.6*
Temperature trend (°C)	0.03	-0.19	0.03	-0.39	-0.01	0.8
Min. temperature (°C)	-0.22**	0.78	0.51	-0.35	-0.81	3.5*
Min. temp. trend (°C)	-0.09	0.21	0.09	-0.66	-0.22	1.8
Max. temperature (°C)	0.07	-0.56	0.79	0.08	-0.41	2.1
Max. temp. trend (°C)	0.33***	-1.18	-0.48	0.27	0.61	5.4**
Surface winds:						
Wind speed (m/s)	-0.27***	8.4	6.8	5.8	6.4	3.6*
Wind speed trend (m/s)	-0.24**	1.3	0.5	-0.6	-2.0	3.3*
N-wind	-0.00	-0.02	-0.02	-0.07	-0.08	0.1
N-wind trend	-0.00	-0.09	0.12	-0.08	-0.11	1.2
NE-wind	-0.12	-0.20	-0.08	-0.32	-0.52	2.7
NE-wind trend	0.10	-0.22	0.08	-0.03	0.06	1.2
NW-wind	0.10	0.17	0.04	0.22	0.40	1.4
NW-wind trend	-0.10	0.09	0.08	-0.09	-0.21	1.1
W-wind	0.14	0.26	0.08	0.38	0.65	3.2*
W-wind trend	-0.13	0.22	0.00	-0.04	-0.20	1.1
High-altitude winds:						
Wind speed (m/s)	-0.19*	11.9	9.8	8.8	10.6	3.1*
Wind speed trend (m/s)	-0.22**	1.9	0.3	-0.4	-1.7	2.6
N-wind	0.15	-0.06	-0.12	-0.03	0.31	2.3
N-wind trend	-0.02	0.06	0.03	-0.02	0.12	0.3
NE-wind	0.01	-0.33	-0.37	-0.41	-0.32	0.2
NE-wind trend	0.08	-0.08	0.01	0.04	0.13	0.5
NW-wind	0.19*	0.25	0.20	0.37	0.76	3.9**
NW-wind trend	-0.11	0.17	0.02	-0.08	0.04	1.1
W-wind	0.13	0.41	0.41	0.55	0.76	2.0
W-wind trend	-0.14	0.18	0.01	-0.09	-0.06	1.4

Multiple regression equation — n = 170, R = 0.61

+0.414	W-wind (h)	$p < 0.001$
-0.309	wind speed (s)	$p < 0.001$
-0.302	W-wind trend (h)	$p < 0.001$
+0.275	barom pr.trend	$p < 0.001$
+0.212	max temp.trend	$p < 0.01$
-0.144	rain 07hr	$p < 0.05$

Multiple regression equation incl. days of delay — n = , R =

Multiple discriminant function — n = 170, R_c = 0.55

Mean of standardized discriminant score

Group 1=-0.82 Group 2=-0.27 Group 3=0.49 Group 4=0.71

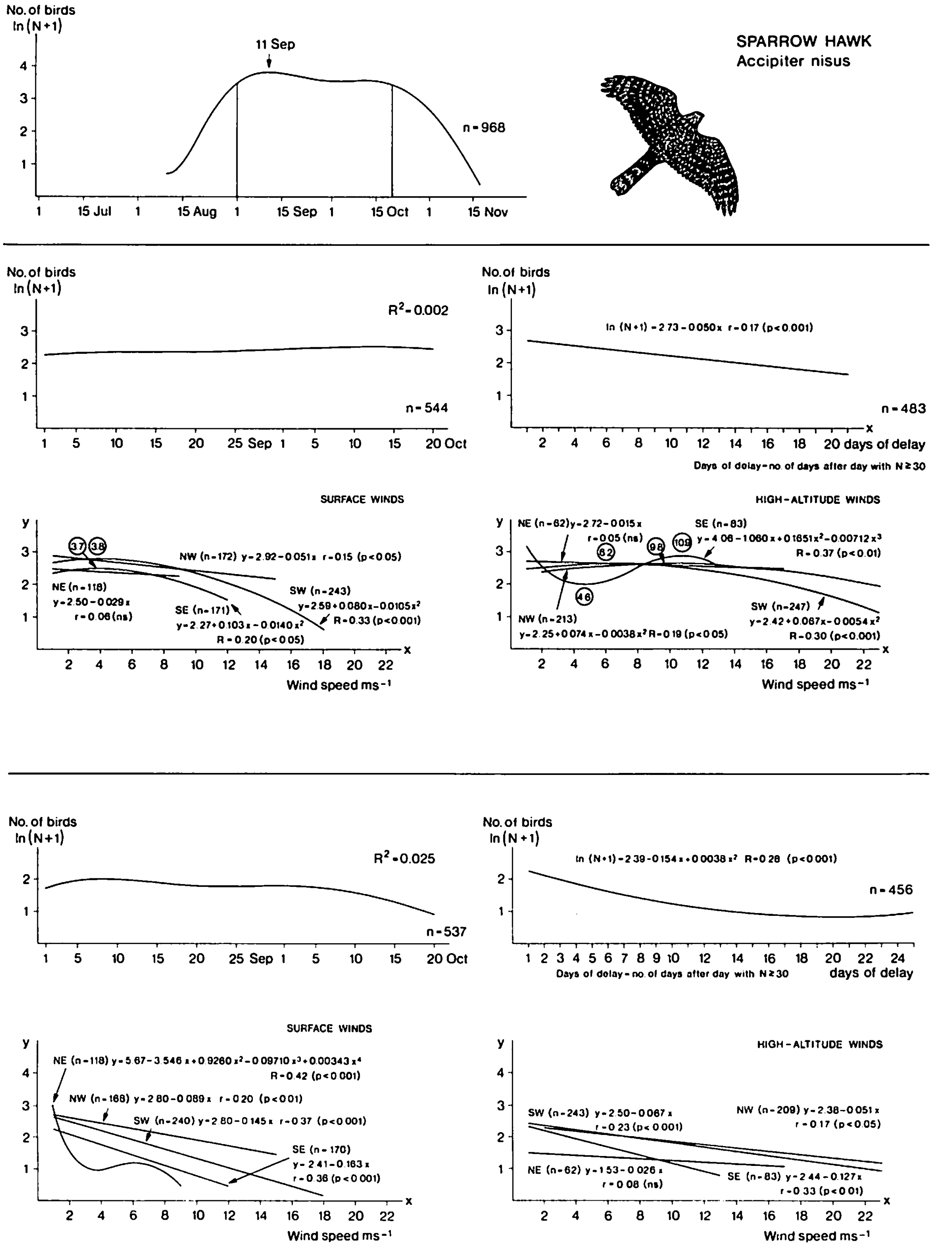
-0.840	NE-wind (s)	$p < 0.001$
+0.709	barom.pr.trend	$p < 0.001$
-0.628	W-wind trend (s)	$p < 0.001$
-0.487	wind speed (h)	$p < 0.01$
+0.113	N-wind (h)	$p < 0.05$

Multiple discriminant function incl. days of delay — n = 144, R_c = 0.59

Mean of standardized discriminant score

Group 1=-1.01 Group 2=-0.18 Group 3=0.47 Group 4=0.78

-0.817	NE-wind (s)	$p < 0.001$
-0.575	W-wind trend (s)	$p < 0.001$
+0.573	barom.pr.trend	$p < 0.001$
-0.467	wind speed (h)	$p < 0.01$
-0.200	days of delay -1	$p < 0.01$
+0.136	NE-wind (h)	$p < 0.05$


SPARROW HAWK
Accipiter nisus
No. of birds
ln(N+1)
11 Sep
n=968
1 15 Jul 1 15 Aug 1 15 Sep 1 15 Oct 1 15 Nov
R²=0.002
n=544
1 5 10 15 20 25 Sep 1 5 10 15 20 Oct
ln (N+1) = 2.73 − 0.050x r=0.17 (p<0.001)
n=483
2 4 6 8 10 12 14 16 18 20 days of delay
Days of delay = no. of days after day with N≥30
SURFACE WINDS
NW (n=172) y=2.92−0.051x r=0.15 (p<0.05)
NE (n=118) y=2.50−0.029x r=0.08 (ns)
SE (n=171) y=2.27+0.103x−0.0140x² R=0.20 (p<0.05)
SW (n=243) y=2.59+0.080x−0.0105x² R=0.33 (p<0.001)
Wind speed ms⁻¹
HIGH-ALTITUDE WINDS
NE (n=62) y=2.72−0.015x r=0.05 (ns)
SE (n=83) y=4.06−1.060x+0.1651x²−0.00712x³ R=0.37 (p<0.01)
NW (n=213) y=2.25+0.074x−0.0038x² R=0.19 (p<0.05)
SW (n=247) y=2.42+0.067x−0.0054x² R=0.30 (p<0.001)
Wind speed ms⁻¹
R²=0.025
n=537
1 5 10 15 20 25 Sep 1 5 10 15 20 Oct
ln (N+1) = 2.39 − 0.154x + 0.0038x² R=0.28 (p<0.001)
n=456
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
Days of delay = no. of days after day with N≥30
days of delay
SURFACE WINDS
NE (n=118) y=5.67−3.546x+0.9260x²−0.09710x³+0.00343x⁴ R=0.42 (p<0.001)
NW (n=168) y=2.80−0.089x r=0.20 (p<0.01)
SW (n=240) y=2.80−0.145x r=0.37 (p<0.001)
SE (n=170) y=2.41−0.163x r=0.36 (p<0.001)
Wind speed ms⁻¹
HIGH-ALTITUDE WINDS
SW (n=243) y=2.50−0.067x r=0.23 (p<0.001)
NW (n=209) y=2.38−0.051x r=0.17 (p<0.05)
NE (n=62) y=1.53−0.026x r=0.08 (ns)
SE (n=83) y=2.44−0.127x r=0.33 (p<0.01)
Wind speed ms⁻¹

SPARROW HAWK (MORNING)

Variable	Correlation Coefficient n = 478	Mean Group 1 n = 106	Group 2 n = 152	Group 3 n = 186	Group 4 n = 34	F^{3}_{474}
Cloud amount (scale 0-8)	-0.09*	5.7	5.2	4.9	5.5	2.2
Cloud ceiling (scale 0-9)	0.08	4.9	5.6	5.7	4.7	5.0**
Convective clouds (scale 0-1)	0.02	0.42	0.41	0.44	0.50	0.3
Visibility (scale 0-9)	0.17***	7.0	7.3	7.5	7.4	4.8**
Rain 0700 hr (scale 0-2)	-0.36***	0.58	0.10	0.05	0.00	26.1***
Rain 0700-1300 hr (scale 0-2)	-0.29***	0.66	0.28	0.19	0.06	14.5***
Relative humidity (%)	0.03	90.8	91.2	90.9	91.9	0.3
Rel. humidity trend (%)	-0.06	0.2	0.7	-0.4	-3.1	2.2
Barometric pressure (mb)	0.14**	1010.6	1015.0	1015.7	1011.7	9.4***
Barom. pressure trend (mb)	0.19***	-1.71	-0.41	0.48	-0.30	8.1***
Temperature (°C)	0.01	0.31	0.00	0.23	0.46	0.6
Temperature trend (°C)	-0.07	0.08	-0.17	-0.06	-0.55	1.4
Min. temperature (°C)	-0.04	0.38	-0.24	-0.09	0.45	1.5
Min. temp. trend (°C)	-0.09	0.21	-0.26	-0.20	-0.41	1.2
Max. temperature (°C)	0.05	-0.29	0.19	0.21	-0.20	1.0
Max. temp. trend (°C)	0.05	-0.39	-0.26	0.10	-0.62	2.4
Surface winds:						
Wind speed (m/s)	-0.19***	8.8	6.1	6.2	8.0	15.0***
Wind speed trend (m/s)	-0.16***	1.5	-0.4	-0.7	0.3	6.1***
N-wind	0.04	-0.25	-0.03	-0.05	-0.28	4.1**
N-wind trend	0.04	-0.09	0.08	-0.01	0.01	1.3
NE-wind	-0.00	-0.36	-0.08	-0.19	-0.52	6.1***
NE-wind trend	0.09	-0.13	0.02	0.03	0.07	1.4
NW-wind	0.06	0.01	0.04	0.10	0.13	0.6
NW-wind trend	-0.04	-0.00	0.09	-0.05	-0.06	1.0
W-wind	0.04	0.26	0.09	0.20	0.46	2.6
W-wind trend	-0.08	0.09	0.05	-0.06	-0.09	1.1
High-altitude winds:						
Wind speed (m/s)	-0.15***	12.5	9.1	9.5	11.7	10.9***
Wind speed trend (m/s)	-0.10*	1.4	-0.6	-0.1	-0.0	2.6
N-wind	0.03	-0.15	-0.07	0.00	-0.21	1.8
N-wind trend	0.04	-0.05	0.04	0.01	0.02	0.4
NE-wind	0.01	-0.48	-0.31	-0.29	-0.65	5.4**
NE-wind trend	0.10*	-0.12	0.02	0.04	0.06	1.8
NW-wind	0.03	0.27	0.22	0.29	0.35	0.5
NW-wind trend	-0.04	0.05	0.03	-0.02	-0.03	1.3
W-wind	0.01	0.53	0.38	0.41	0.71	3.7*
W-wind trend	-0.09*	0.12	0.01	-0.04	-0.06	1.7

Multiple regression equation — n = 478, R = 0.47

-0.265	rain 07hr	p < 0.001
-0.213	wind speed (s)	p < 0.001
-0.210	NE-wind (s)	p < 0.001
+0.170	NE-wind (s)	p < 0.001
-0.156	rain 07-13hr	p < 0.001
+0.147	visibility	p < 0.001

Multiple regression equation incl. days of delay — n = 420, R = 0.55

-0.242	rain 07hr	p < 0.001
+0.226	visibility	p < 0.001
-0.216	wind speed (s)	p < 0.001
-0.181	rain 07-13hr	p < 0.001
+0.167	rel. humidity	p < 0.01
-0.164	W-wind trend (s)	p < 0.001
+0.157	W-wind (s)	p < 0.01
-0.157	days of delay -1	p < 0.001
-0.119	rel.hum.trend	p < 0.05
+0.098	temperature	p < 0.05

Multiple discriminant function — n = 478, R_c = 0.48

Mean of standardized discriminant score
Group 1=-0.90 Group 2=0.20 Group 3=0.31 Group 4=0.21

-0.573	rain 07hr	p < 0.001
-0.535	wind speed (s)	p < 0.001
+0.291	visibility	p < 0.01
+0.230	NE-wind trend (h)	p < 0.05
-0.228	rain 07-13hr	p < 0.05
-0.101	NE-wind (h)	p < 0.01

-0.894	NE-wind (h)	
+0.476	wind speed (s)	Group 1 = -0.01
+0.435	NE-wind trend (h)	Group 2 = -0.12
-0.433	rain 07-13hr	Group 3 = -0.05
+0.141	visibility	Group 4 = 0.81
-0.097	rain 07hr	

Multiple discriminant function incl. days of delay — n = 420, R_c = 0.54

Mean of standardized discriminant score
Group 1=-1.06 Group 2=0.16 Group 3=0.37 Group 4=0.12

-0.507	wind speed (s)	p < 0.001
-0.487	rain 07hr	p < 0.001
+0.337	visibility	p < 0.001
+0.283	temp.	p < 0.01
-0.246	rain 07-13hr	p < 0.01
+0.209	NE-wind (h)	p < 0.001
-0.155	days of delay -1	p < 0.001

-0.602	NE-wind (h)	
-0.567	days of delay -1	
+0.474	wind speed (s)	Group 1 = 0.01
-0.411	rain 07-13hr	Group 2 = -0.26
+0.288	visibility	Group 3 = 0.05
-0.094	temp.	Group 4 = 0.86
+0.022	rain 07hr	

SPARROW HAWK (NOON)

Variable	Correlation Coefficient n = 472	Mean Group 1 n = 218	Group 2 n = 116	Group 3 n = 103	Group 4 n = 35	F^{3}_{468}
Cloud amount (scale 0-8)	-0.21***	5.6	5.5	4.6	3.8	6.9***
Cloud ceiling (scale 0-9)	0.04	5.3	5.4	5.6	5.5	0.4
Convective clouds (scale 0-1)	0.16***	0.35	0.46	0.50	0.63	4.6**
Visibility (scale 0-9)	0.05	7.3	7.3	7.3	7.6	1.0
Rain 0700 hr (scale 0-2)	-0.18***	0.26	0.19	0.04	0.06	4.2**
Rain 0700-1300 hr (scale 0-2)	-0.26***	0.50	0.22	0.08	0.14	12.0***
Relative humidity (%)	0.07	90.7	91.3	91.6	92.1	0.7
Rel. humidity trend (%)	0.02	-0.3	1.0	-1.0	1.3	1.7
Barometric pressure (mb)	0.08	1013.2	1015.2	1015.2	1014.0	1.9
Barom. pressure trend (mb)	0.26***	-1.03	-0.58	0.85	1.35	9.2***
Temperature (°C)	0.05	0.06	0.28	0.49	-0.12	1.1
Temperature trend (°C)	-0.13**	0.09	-0.10	-0.37	-0.51	2.6
Min. temperature (°C)	-0.01	0.04	-0.05	0.18	-0.50	0.6
Min. temp. trend (°C)	-0.19***	0.26	-0.29	-0.50	-0.97	5.1**
Max. temperature (°C)	0.11*	-0.27	0.43	0.41	0.05	2.4
Max. temp. trend (°C)	0.16***	-0.48	0.02	0.07	0.34	3.5*
Surface winds:						
Wind speed (m/s)	-0.23***	7.7	6.0	6.1	5.6	8.8***
Wind speed trend (m/s)	-0.35***	1.2	-0.3	-1.0	-4.7	22.2***
N-wind	0.09	-0.12	-0.24	0.03	0.05	4.6**
N-wind trend	0.10*	-0.05	-0.13	0.18	0.18	4.4**
NE-wind	-0.05	-0.17	-0.24	-0.22	-0.28	0.4
NE-wind trend	0.17***	-0.12	-0.05	0.18	0.31	6.3***
NW-wind	0.16***	-0.00	-0.10	0.27	0.35	7.8***
NW-wind trend	-0.03	0.06	-0.13	0.07	-0.06	1.7
W-wind	0.14**	0.12	0.10	0.34	0.44	3.8**
W-wind trend	-0.13**	0.13	-0.05	-0.07	-0.26	3.5*
High-altitude winds:						
Wind speed (m/s)	-0.17***	10.9	9.5	9.3	8.4	4.1**
Wind speed trend (m/s)	-0.31***	1.4	0.1	-1.2	-5.5	17.6***
N-wind	0.02	-0.08	-0.13	0.01	-0.05	0.9
N-wind trend	0.03	0.02	-0.13	0.13	0.01	3.1*
NE-wind	-0.08	-0.32	-0.38	-0.40	-0.45	0.7
NE-wind trend	0.11*	-0.05	-0.07	0.13	0.14	3.2*
NW-wind	0.10*	0.21	0.19	0.41	0.38	3.2*
NW-wind trend	-0.06	0.08	-0.11	0.06	-0.13	2.9*
W-wind	0.13**	0.38	0.40	0.57	0.59	3.4*
W-wind trend	-0.13**	0.09	-0.03	-0.05	-0.19	2.9*

Multiple regression equation n = 472

R = 0.59

+0.467	W-wind (s)	p < 0.001
-0.288	W-wind trend (s)	p < 0.001
-0.258	N-wind (h)	p < 0.001
-0.224	wind speed (h)	p < 0.001
-0.221	wind speed trend (s)	p < 0.001
-0.187	rain 07-15hr	p < 0.001
+0.142	barom.pr.trend	p < 0.01
+0.110	convective clouds	p < 0.01
+0.101	NE-wind trend (h)	p < 0.05
-0.081	cloud amount	p < 0.05

Multiple regression equation incl. days of delay n = 399

R = 0.64

+0.444	W-wind (s)	p < 0.001
-0.262	W-wind trend (s)	p < 0.001
+0.241	barom.pr.trend	p < 0.001
+0.230	days of delay -2	p < 0.001
-0.150	N-wind (h)	p < 0.01
-0.146	wind speed (h)	p < 0.01
-0.141	rain 07-13hr	p < 0.001
-0.140	wind speed trend (s)	p < 0.01
-0.123	wind speed trend (h)	p < 0.05
-0.116	cloud amount	p < 0.05
+0.088	max temp.	p < 0.05

Multiple discriminant function n = 472

R_c = 0.56

Mean of standardized discriminant score

Group 1=-0.50 Group 2=0.03 Group 3=0.57 Group 4=1.31

+0.576	NW-wind (s)	p < 0.001
-0.559	NE-wind (h)	p < 0.001
-0.422	wind speed trend (s)	p < 0.001
-0.322	W-wind trend (h)	p < 0.01
-0.321	rain 07-13hr	p < 0.001
-0.288	W-wind trend	p < 0.05
-0.240	wind speed (h)	p < 0.05
+0.221	convective clouds	p < 0.01
-0.154	cloud amount	p < 0.05
-0.101	wind speed (s)	p < 0.05

Multiple discriminant function incl. days of delay n = 399

R_c = 0.59

Mean of standardized discriminant score

Group 1=-0.51 Group 2=-0.02 Group 3=0.61 Group 4=1.51

-0.452	NE-wind (h)	p < 0.001
+0.411	NW-wind (s)	p < 0.001
-0.311	W-wind trend (h)	p < 0.01
+0.304	days of delay -2	p < 0.001
-0.303	wind speed trend (h)	p < 0.01
-0.300	wind speed trend (s)	p < 0.01
-0.256	rain 07-13hr	p < 0.001
+0.247	barom.pr.trend	p < 0.05
-0.216	cloud amount	p < 0.01

SPARROW HAWK (TOTAL)

Variable	Correlation Coefficient n = 478	Mean Group 1 n = 82	Group 2 n = 165	Group 3 n = 167	Group 4 n = 64	F^{3}_{474}
Cloud amount (scale 0-8)	-0.23***	6.3	5.4	4.9	4.3	7.7***
Cloud ceiling (scale 0-9)	0.18***	4.6	5.6	5.7	5.4	6.1***
Convective clouds (scale 0-1)	0.07	0.46	0.33	0.46	0.55	3.7*
Visibility (scale 0-9)	0.17***	7.0	7.3	7.4	7.6	4.6**
Rain 0700 hr (scale 0-2)	-0.37***	0.63	0.15	0.05	0.00	26.3***
Rain 0700-1300 hr (scale 0-2)	-0.38***	0.79	0.32	0.17	0.06	22.1***
Relative humidity (%)	0.05	90.9	90.5	91.4	91.9	0.9
Rel. humidity trend (%)	-0.02	-0.0	0.2	-0.4	-0.0	0.1
Barometric pressure (mb)	0.21***	1009.2	1015.1	1015.9	1013.1	12.3***
Barom. pressure trend (mb)	0.26***	-2.28	-0.40	0.31	0.60	11.1***
Temperature (°C)	0.02	0.37	0.02	0.25	0.25	0.5
Temperature trend (°C)	-0.12**	0.32	-0.01	-0.34	-0.24	3.2*
Min. temperature (°C)	-0.07	0.49	0.03	-0.21	-0.13	1.3
Min. temp. trend (°C)	-0.17***	0.49	0.13	-0.60	-0.48	5.9***
Max. temperature (°C)	0.14**	-0.85	0.23	0.32	0.13	4.0**
Max. temp. trend (°C)	0.12*	-0.71	-0.11	-0.12	0.20	3.0*
Surface winds:						
Wind speed (m/s)	-0.31***	9.7	6.7	5.9	6.3	21.0***
Wind speed trend (m/s)	-0.28***	2.3	0.2	-0.6	-2.2	14.6***
N-wind	0.10*	-0.28	-0.07	-0.04	-0.14	3.2*
N-wind trend	0.09	-0.20	0.07	0.01	0.07	2.9*
NE-wind	0.06	-0.44	-0.09	-0.15	-0.38	6.9***
NE-wind trend	0.16***	-0.25	-0.03	0.06	0.18	4.9**
NW-wind	0.06	0.05	-0.01	0.10	0.18	1.4
NW-wind trend	-0.04	-0.04	0.13	-0.05	-0.09	2.0
W-wind	0.01	0.35	0.06	0.18	0.40	4.5**
W-wind trend	-0.14**	0.15	0.11	-0.08	-0.19	3.8*
High-altitude winds:						
Wind speed (m/s)	-0.29***	13.5	10.1	8.9	9.5	14.5***
Wind speed trend (m/s)	-0.27***	2.7	0.4	-0.4	-2.5	11.1***
N-wind	0.02	-0.13	-0.06	-0.02	-0.15	0.9
N-wind trend	0.04	-0.08	0.04	0.04	-0.03	0.8
NE-wind	0.01	-0.54	-0.25	-0.32	-0.55	6.9***
NE-wind trend	0.12**	-0.17	-0.01	0.07	0.05	3.2*
NW-wind	0.02	0.36	0.17	0.29	0.34	2.2
NW-wind trend	-0.05	0.06	0.07	-0.02	-0.10	1.3
W-wind	0.00	0.64	0.29	0.43	0.63	8.5***
W-wind trend	-0.12**	0.17	0.06	-0.07	-0.11	3.6*

Multiple regression equation n = 478

R = 0.59

+0.249	NE-wind trend (s)	p < 0.001
-0.232	rain 07-13hr	p < 0.001
-0.230	NE-wind trend (s)	p < 0.001
-0.225	rain 07hr	p < 0.001
-0.168	wind speed (s)	p < 0.01
+0.166	visibility	p < 0.001
-0.147	wind speed (h)	p < 0.01
+0.090	rel.humidity	p < 0.05

Multiple regression equation incl. days of delay n = 436

R = 0.66

+0.413	W-wind (s)	p < 0.001
-0.281	W-wind trend (s)	p < 0.001
+0.254	days of delay -2	p < 0.001
-0.209	rain 07-13hr	p < 0.001
-0.202	wind speed (s)	p < 0.01
-0.198	rain 07hr	p < 0.001
-0.164	wind speed (h)	p < 0.01
-0.157	NW-wind (h)	p < 0.01
+0.128	visibility	p < 0.01
+0.109	barom.pr.trend	p < 0.01

Multiple discriminant function n = 478

R_c = 0.56

Mean of standardized discriminant score

Group 1=-1.10 Group 2=-0.07 Group 3=0.36 Group 4=0.65

-0.465	wind speed (s)	p < 0.001
-0.424	rain 07hr	p < 0.001
-0.368	rain 07-13hr	p < 0.001
-0.355	W-wind trend (h)	p < 0.001
+0.343	W-wind (h)	p < 0.001
+0.262	visibility	p < 0.01
-0.161	wind speed trend (s)	p < 0.01
-0.135	NW-wind (h)	p < 0.05
+0.026	convective clouds	p < 0.05

Multiple discriminant function incl. days of delay n = 436

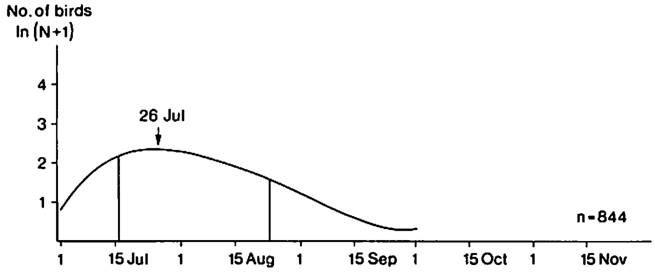
R_c = 0.61

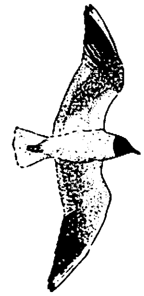
Mean of standardized discriminant score

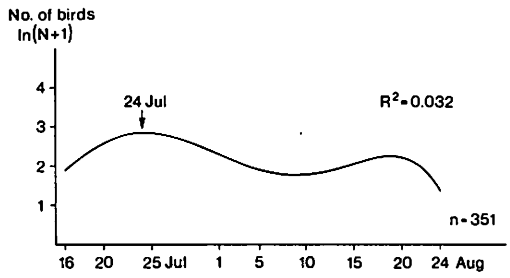
Group 1=-1.10 Group 2=-0.19 Group 3=0.40 Group 4=0.85

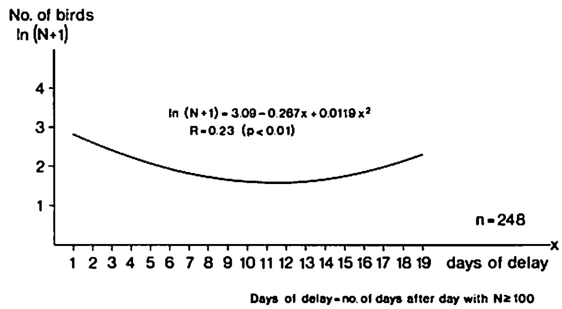
+0.389	days of delay -2	p < 0.001
-0.358	wind speed (s)	p < 0.001
-0.343	rain 07hr	p < 0.001
-0.334	rain 07-13hr	p < 0.001
-0.322	W-wind trend (h)	p < 0.001
+0.284	visibility	p < 0.001
+0.266	W-wind (h)	p < 0.001
-0.192	wind speed trend (s)	p < 0.01

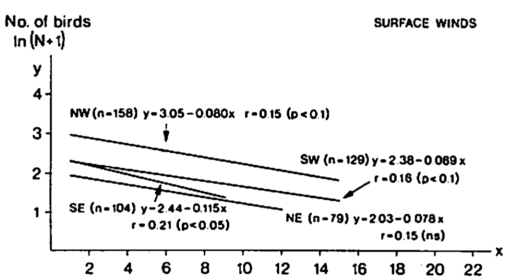
BLACK-HEADED GULL
Larus ridibundus

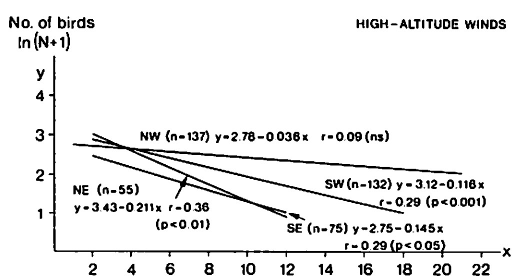












BLACK-HEADED GULL

Variable	Correlation Coefficient n = 326	Mean Group 1 n = 166	Group 2 n = 80	Group 3 n = 64	Group 4 n = 16	F^{3}_{322}
Cloud amount (scale 0-8)	-0.17**	5.2	4.6	4.4	3.0	3.6*
Cloud ceiling (scale 0-9)	0.16**	5.6	6.2	6.3	6.1	2.5
Convective clouds (scale 0-1)	0.12*	0.46	0.54	0.55	0.88	3.6*
Visibility (scale 0-9)	0.15**	7.5	7.6	7.6	7.9	2.5
Rain 0700 hr (scale 0-2)	-0.10	0.16	0.14	0.06	0.00	1.0
Rain 0700-1300 hr (scale 0-2)	-0.05	0.31	0.35	0.28	0.00	1.3
Relative humidity (%)	0.01	87.5	85.3	88.0	87.1	2.3
Rel. humidity trend (%)	0.03	0.5	-1.6	1.5	0.4	2.0
Barometric pressure (mb)	0.15**	1011.6	1013.3	1013.0	1015.5	2.8*
Barom. pressure trend (mb)	0.15**	-0.17	0.18	0.34	2.09	3.7*
Temperature (°C)	-0.07	0.20	0.24	-0.12	-0.29	0.9
Temperature trend (°C)	0.02	-0.01	-0.05	0.11	-0.16	0.3
Min. temperature (°C)	-0.10	0.05	0.07	-0.38	-0.38	0.9
Min. temp. trend (°C)	-0.10	0.19	-0.31	-0.09	-0.19	1.2
Max. temperature (°C)	0.02	-0.03	0.41	-0.09	0.46	0.5
Max. temp. trend (°C)	0.12*	-0.21	-0.08	0.20	0.81	1.4
Surface winds:						
Wind speed (m/s)	-0.09	6.4	6.2	4.8	6.9	3.1*
Wind speed trend (m/s)	-0.16**	0.6	-0.0	-1.2	-1.1	2.9*
N-wind	0.14*	-0.07	0.08	0.10	0.49	4.8**
N-wind trend	0.09	-0.05	0.02	0.03	0.33	1.6
NE-wind	-0.00	-0.14	-0.08	-0.09	-0.19	0.3
NE-wind trend	0.16**	-0.09	0.08	0.10	0.18	2.6
NW-wind	0.18**	0.04	0.19	0.24	0.88	7.1***
NW-wind trend	-0.01	0.02	-0.05	-0.07	0.29	1.0
W-wind	0.12*	0.13	0.19	0.24	0.75	3.4*
W-wind trend	-0.11*	0.08	-0.09	-0.12	0.08	1.7
High-altitude winds:						
Wind speed (m/s)	-0.19***	9.7	8.1	7.4	8.2	4.3**
Wind speed trend (m/s)	-0.19***	0.7	-0.5	-1.4	-2.7	3.3*
N-wind	0.11*	-0.11	-0.05	0.00	0.50	5.0**
N-wind trend	0.08	-0.04	-0.01	0.06	0.28	1.3
NE-wind	0.00	-0.27	-0.22	-0.21	-0.11	0.4
NE-wind trend	0.18**	-0.13	0.13	0.18	0.12	5.2**
NW-wind	0.14*	0.11	0.15	0.22	0.82	5.1**
NW-wind trend	-0.06	0.07	-0.14	-0.09	0.28	3.0*
W-wind	0.09	0.27	0.27	0.30	0.66	1.4
W-wind trend	-0.16**	0.14	-0.19	-0.19	0.11	6.6***

Multiple regression equation — n = 326, R = 0.40

-0.260	W-wind trend (h)	$p < 0.001$
+0.226	W-wind (h)	$p < 0.001$
+0.181	cloud ceiling	$p < 0.001$
+0.170	NW-wind (s)	$p < 0.01$
-0.158	wind speed (h)	$p < 0.05$

Multiple regression equation incl. days of delay — n = 232, R = 0.46

+0.250	days of delay -2	$p < 0.001$
+0.242	NE-wind trend (h)	$p < 0.001$
-0.174	wind speed (h)	$p < 0.01$
+0.170	W-wind (h)	$p < 0.01$
+0.147	visibility	$p < 0.05$
-0.132	cloud amount	$p < 0.05$

Multiple discriminant function — n = 326, $R_c = 0.37$

Mean of standardized discriminant score

Group 1=-0.35 Group 2=-0.26 Group 3=0.42 Group 4=0.65

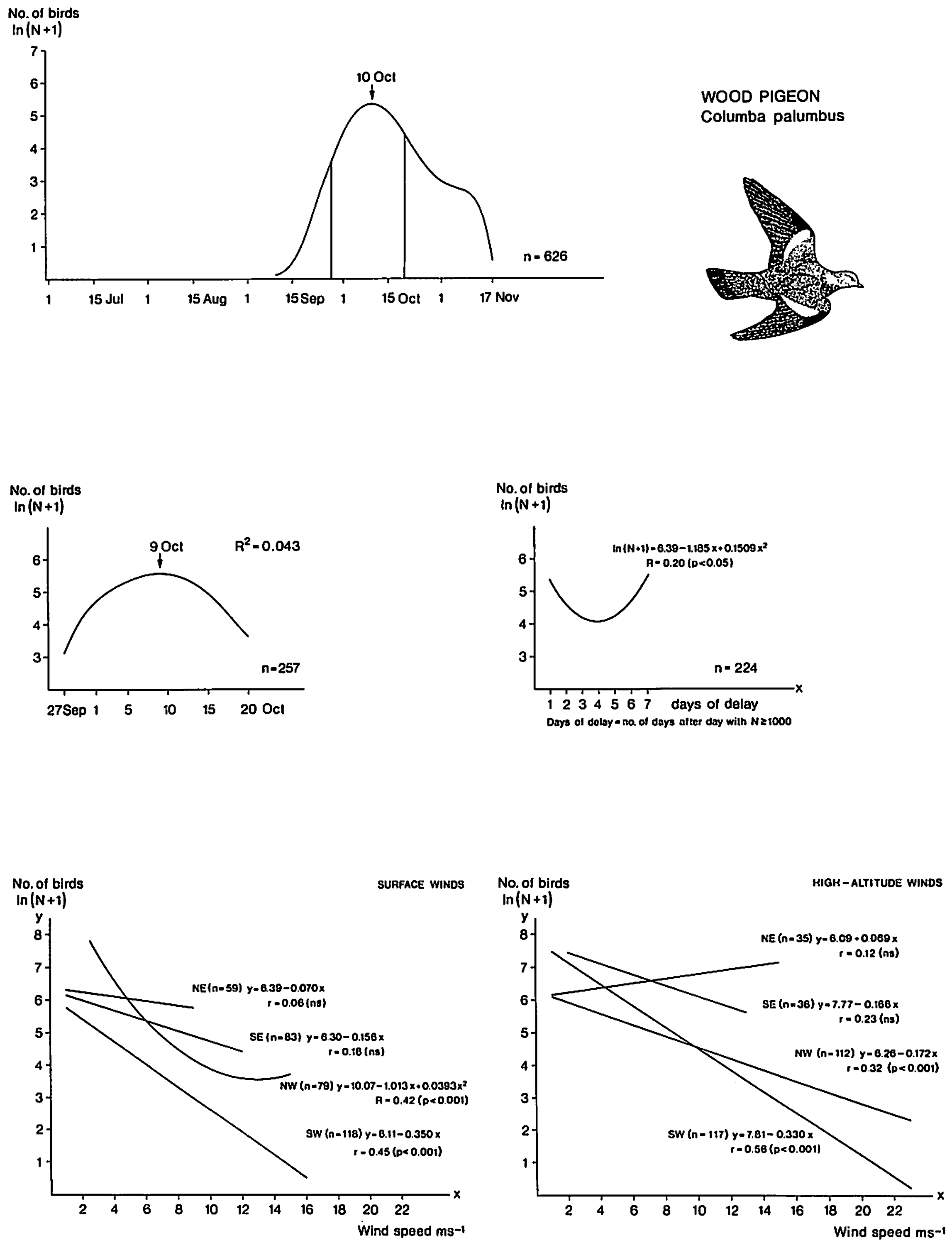
+0.802	NW-wind (s)	$p < 0.001$
-0.653	W-wind trend	$p < 0.001$
+0.412	cloud ceiling	$p < 0.05$
-0.238	wind speed (s)	$p < 0.05$

Multiple discriminant function incl. days of delay — n = 232, $R_c = 0.45$

Mean of standardized discriminant score

Group 1=-0.42 Group 2=0.24 Group 3=0.43 Group 4=1.18

+0.551	days of delay -2	$p < 0.001$
+0.537	NW-wind (s)	$p < 0.001$
+0.438	cloud ceiling	$p < 0.01$
+0.427	NE-wind trend (h)	$p < 0.01$
-0.167	wind speed (s)	$p < 0.05$


No. of birds ln(N+1)
10 Oct
n = 626
1
15 Jul
1
15 Aug
1
15 Sep
1
15 Oct
1
17 Nov
WOOD PIGEON
Columba palumbus
No. of birds ln(N+1)
9 Oct
R² = 0.043
n=257
27Sep 1 5 10 15 20 Oct
No. of birds ln(N+1)
ln(N+1) = 6.39 − 1.185 x + 0.1509 x²
R = 0.20 (p<0.05)
n = 224
1 2 3 4 5 6 7 days of delay
Days of delay = no. of days after day with N≥1000
No. of birds ln(N+1)
SURFACE WINDS
NE (n=59) y = 6.39 − 0.070x
r = 0.06 (ns)
SE (n=83) y = 6.30 − 0.156x
r = 0.16 (ns)
NW (n=79) y = 10.07 − 1.013x + 0.0393x²
R = 0.42 (p<0.001)
SW (n=118) y = 6.11 − 0.350x
r = 0.45 (p<0.001)
Wind speed ms-1
No. of birds ln(N+1)
HIGH-ALTITUDE WINDS
NE (n=35) y = 6.09 + 0.069x
r = 0.12 (ns)
SE (n=36) y = 7.77 − 0.166x
r = 0.23 (ns)
NW (n=112) y = 6.26 − 0.172x
r = 0.32 (p<0.001)
SW (n=117) y = 7.81 − 0.330x
r = 0.56 (p<0.001)
Wind speed ms-1

WOOD PIGEON

Variable	Correlation Coefficient n = 232	Mean Group 1 n = 87	Group 2 n = 30	Group 3 n = 88	Group 4 n = 27	F^{3}_{228}
Cloud amount (scale 0-8)	-0.36 ***	7.1	5.6	4.5	5.9	16.6 ***
Cloud ceiling (scale 0-9)	0.28 ***	4.5	5.4	5.6	5.6	5.7 **
Convective clouds (scale 0-1)	0.10	0.28	0.57	0.39	0.30	3.1 *
Visibility (scale 0-9)	0.27 ***	6.9	7.3	7.4	7.6	5.2 **
Rain 0700 hr (scale 0-2)	-0.33 ***	0.45	0.10	0.02	0.07	9.3 ***
Rain 0700-1300 hr (scale 0-2)	-0.30 ***	0.55	0.10	0.13	0.22	8.0 ***
Relative humidity (%)	-0.23 ***	92.7	90.1	90.4	86.6	6.3 ***
Rel. humidity trend (%)	-0.07	0.9	-1.5	0.0	-2.4	1.3
Barometric pressure (mb)	0.26 ***	1011.9	1012.9	1016.9	1016.4	5.4 **
Barom. pressure trend (mb)	0.32 ***	-2.24	0.24	0.43	1.12	9.0 ***
Temperature (°C)	-0.24 ***	0.85	-0.61	-0.61	-0.31	6.1 ***
Temperature trend (°C)	-0.27 ***	0.68	-0.08	-0.15	-1.45	9.8 ***
Min. temperature (°C)	-0.28 ***	0.94	-0.76	-0.89	-0.48	6.9 ***
Min. temp. trend (°C)	-0.35 ***	0.80	0.13	-0.66	-1.52	9.6 ***
Max. temperature (°C)	0.01	0.10	-0.61	-0.11	0.43	0.8
Max. temp. trend (°C)	0.03	-0.34	0.60	-0.26	-0.41	1.9
Surface winds:						
Wind speed (m/s)	-0.40 ***	9.0	6.8	5.7	5.6	13.1 ***
Wind speed trend (m/s)	-0.35 ***	1.9	0.6	-1.3	-2.2	9.6 ***
N-wind	0.22 ***	-0.27	-0.03	0.05	-0.04	4.4 **
N-wind trend	0.08	-0.07	-0.05	0.09	0.11	0.9
NE-wind	0.42 ***	-0.59	-0.03	0.05	0.08	18.2 ***
NE-wind trend	0.23 ***	-0.19	-0.11	0.19	0.35	6.3 ***
NW-wind	-0.15 *	0.20	-0.01	0.02	-0.13	2.0
NW-wind trend	-0.11	0.09	0.04	-0.06	-0.20	1.2
W-wind	-0.36 ***	0.55	0.02	-0.02	-0.15	12.8 ***
W-wind trend	-0.24 ***	0.20	0.11	-0.17	-0.39	6.3 ***
High-altitude winds:						
Wind speed (m/s)	-0.43 ***	13.5	10.3	8.1	8.5	16.4 ***
Wind speed trend (m/s)	-0.35 ***	2.8	-0.3	-1.6	-2.4	9.9 ***
N-wind	0.03	-0.04	0.01	0.06	-0.16	0.8
N-wind trend	-0.00	-0.03	-0.05	0.08	-0.20	1.4
NE-wind	0.26 ***	-0.53	-0.11	-0.20	-0.21	6.1 ***
NE-wind trend	0.13 *	-0.09	-0.03	0.10	0.05	1.5
NW-wind	-0.21 **	0.47	0.12	0.28	-0.01	5.0 **
NW-wind trend	-0.12	0.05	-0.04	0.02	-0.34	2.7 *
W-wind	-0.35 ***	0.71	0.16	0.33	0.14	12.3 ***
W-wind trend	-0.19 **	0.10	-0.00	-0.05	-0.28	2.9 *

Multiple regression equation n = 232 R = 0.68

-0.274	wind speed (h)	p < 0.001
-0.244	W-wind (h)	p < 0.001
-0.192	min temp.trend	p < 0.001
-0.182	wind speed trend (s)	p < 0.001
-0.181	cloud amount	p < 0.001
-0.163	rain 07-13hr	p < 0.01
-0.114	rel.hum.trend	p < 0.05

Multiple regression equation incl. days of delay n = R =

Multiple discriminant function n = 232 R_c = 0.66

Mean of standardized discriminant score

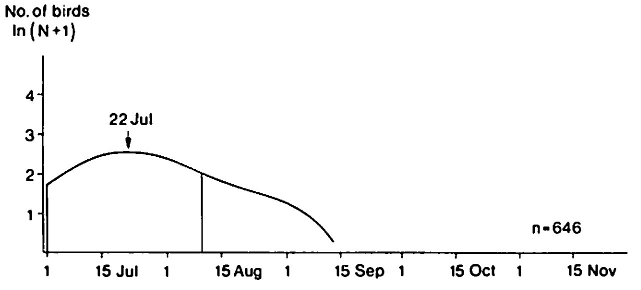
Group 1=-1.09 Group 2= 0.37 Group 3=0.71 Group 4=0.76

-0.513	wind speed (h)	p < 0.001
-0.408	cloud amount	p < 0.001
-0.341	rain 07-13hr	p < 0.01
+0.338	NE-wind (s)	p < 0.01
-0.338	NW-wind (h)	p < 0.001
-0.279	min temp.trend	p < 0.01
+0.176	convective clouds	p < 0.05
-0.173	rel.humidity	p < 0.05
+0.068	NE-wind trend (s)	p < 0.05

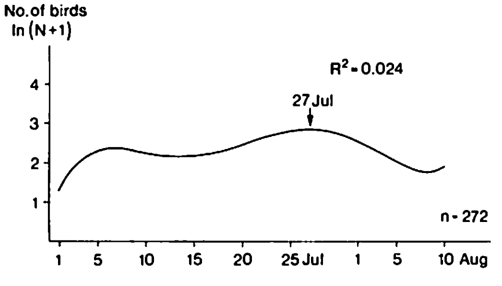
Multiple discriminant function incl. days of delay n = R_c=

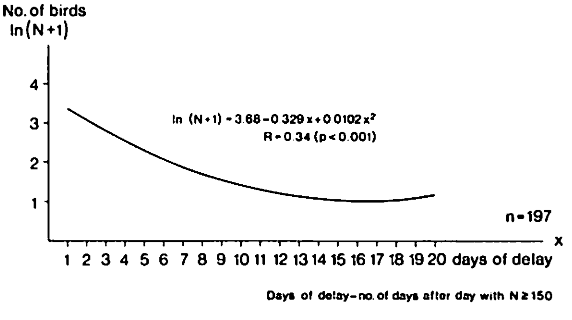
Mean of standardized discriminant score

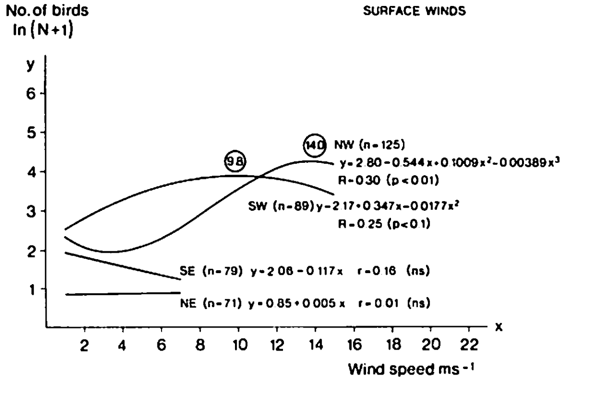
Group 1= Group 2= Group 3= Group 4=

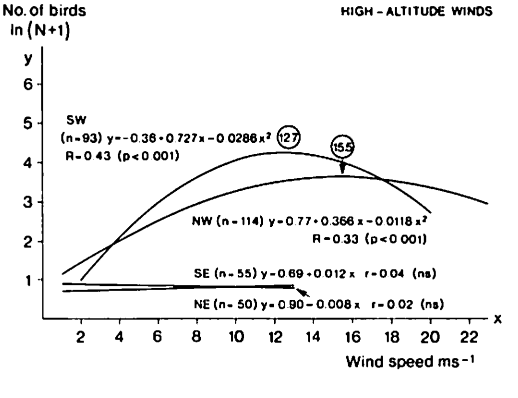


SWIFT
Apus apus









SWIFT

Variable	Correlation Coefficient n = 247	Mean Group 1 n = 151	Group 2 n = 39	Group 3 n = 25	Group 4 n = 32	F^{3}_{243}
Cloud amount (scale 0-8)	0.10	4.5	4.8	5.0	5.2	0.7
Cloud ceiling (scale 0-9)	-0.19**	6.4	5.8	5.3	5.3	4.1**
Convective clouds (scale 0-1)	-0.03	0.58	0.54	0.72	0.53	0.9
Visibility (scale 0-9)	-0.01	7.6	7.6	7.7	7.7	0.2
Rain 0700 hr (scale 0-2)	-0.03	0.11	0.10	0.16	0.09	0.1
Rain 0700-1300 hr (scale 0-2)	0.08	0.32	0.36	0.40	0.44	0.3
Relative humidity (%)	0.03	84.5	86.1	84.0	85.2	0.5
Rel. humidity trend (%)	-0.02	0.3	2.2	-0.6	-1.2	1.0
Barometric pressure (mb)	-0.12	1013.5	1011.7	1013.9	1011.2	2.2
Barom. pressure trend (mb)	0.03	0.11	-0.49	1.12	0.78	2.3
Temperature (°C)	-0.32***	0.69	-0.08	-0.48	-1.03	12.0***
Temperature trend (°C)	-0.09	0.10	0.23	-0.41	-0.33	2.1
Min. temperature (°C)	-0.06	0.25	-0.08	0.45	-0.30	1.2
Min. temp. trend (°C)	0.06	-0.10	0.38	0.32	-0.06	0.9
Max. temperature (°C)	-0.33***	1.07	-0.51	-0.96	-1.53	11.8***
Max. temp. trend (°C)	-0.08	0.32	-0.44	-0.88	0.25	2.5
Surface winds:						
Wind speed (m/s)	0.27***	5.1	6.6	7.4	8.3	7.9***
Wind speed trend (m/s)	0.01	-0.2	0.8	-0.5	0.1	0.5
N-wind	-0.15*	0.18	-0.05	0.13	0.01	1.7
N-wind trend	0.03	-0.02	-0.19	0.19	0.12	1.9
NE-wind	-0.45***	0.18	-0.35	-0.31	-0.53	19.0***
NE-wind trend	-0.07	0.07	-0.23	0.01	0.04	2.4
NW-wind	0.23***	0.08	0.28	0.49	0.55	5.7**
NW-wind trend	0.09	-0.09	-0.04	0.26	0.13	1.8
W-wind	0.43***	-0.07	0.44	0.56	0.77	18.7***
W-wind trend	0.11	-0.11	0.13	0.18	0.06	2.0
High-altitude winds:						
Wind speed (m/s)	0.18**	8.4	10.4	12.1	10.5	4.6***
Wind speed trend (m/s)	-0.03	-0.1	1.3	-0.7	-0.7	0.8
N-wind	-0.04	0.04	-0.07	0.16	0.03	0.7
N-wind trend	0.05	-0.02	-0.07	0.20	0.08	1.1
NE-wind	-0.42***	0.03	-0.49	-0.43	-0.53	14.0***
NE-wind trend	-0.10	0.07	-0.19	-0.02	0.04	2.0
NW-wind	0.35***	0.02	0.40	0.66	0.58	12.6***
NW-wind trend	0.16*	-0.11	0.09	0.31	0.07	3.2*
W-wind	0.49***	-0.01	0.62	0.77	0.79	23.9***
W-wind trend	0.18**	-0.13	0.20	0.24	0.02	4.2**

Multiple regression equation — n = 247, R = 0.52

+0.346	W-wind (h)	p < 0.001
-0.225	NE-wind (s)	p < 0.01

Multiple regression equation incl. days of delay — n = 182, R = 0.57

-0.272	NE-wind (s)	p < 0.001
+0.256	W-wind (h)	p < 0.001
+0.213	days of delay -2	p < 0.001

Multiple discriminant function — n = 247, R_c = 0.55

Mean of standardized discriminant score

Group 1=-0.42 Group 2=0.38 Group 3=0.85 Group 4=0.86

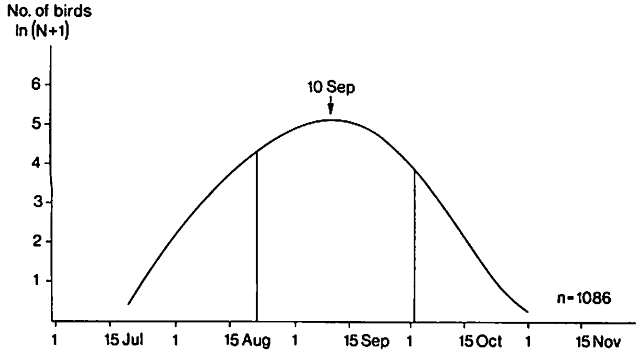
-0.757	temp.	p < 0.001
+0.677	W-wind (h)	p < 0.001
+0.559	min. temp.	p < 0.001

Multiple discriminant function incl. days of delay — n = 182, R_c = 0.61

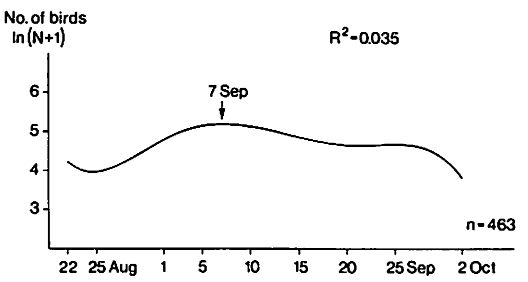
Mean of standardized discriminant score

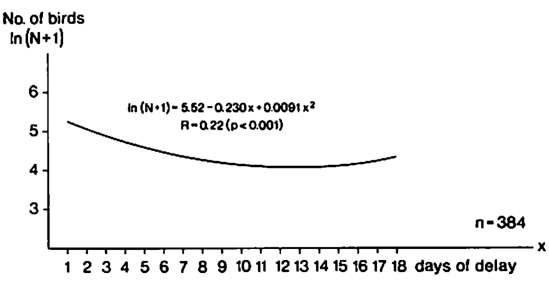
Group 1=-0.49 Group 2=0.45 Group 3=0.86 Group 4=0.90

-0.685	temp.	p < 0.001
+0.529	min temp.	p < 0.001
-0.474	NE-wind (s)	p < 0.001
+0.356	days of delay -2	p < 0.01
+0.272	W-wind trend (h)	p < 0.05

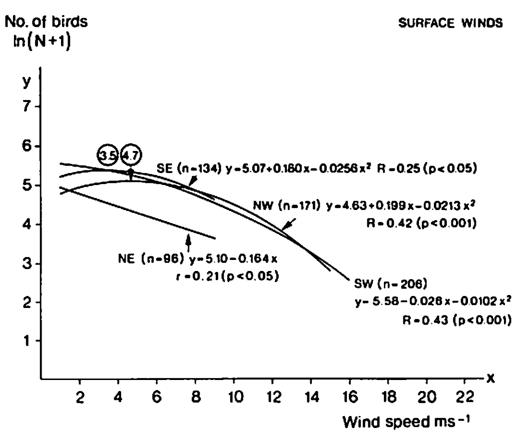


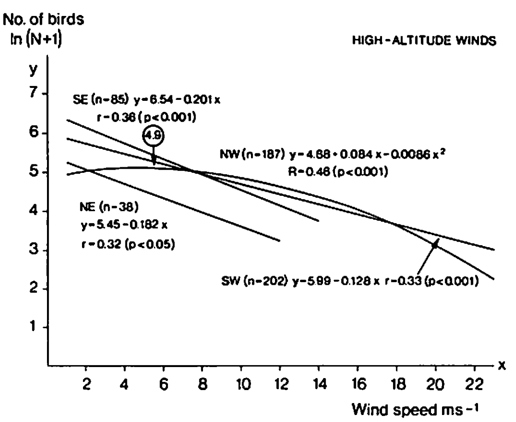
SWALLOW
Hirundo rustica





Days of delay = no. of days after day with N≥500





SWALLOW

Variable	Correlation Coefficient n = 409	Mean Group 1 n = 125	Group 2 n = 122	Group 3 n = 133	Group 4 n = 29	F^{3}_{405}
Cloud amount (scale 0-8)	-0.22***	5.7	5.1	4.2	4.5	7.0***
Cloud ceiling (scale 0-9)	0.19***	5.0	5.4	6.0	5.7	5.5**
Convective clouds (scale 0-1)	0.03	0.47	0.46	0.47	0.52	0.1
Visibility (scale 0-9)	0.11*	7.4	7.3	7.5	7.7	1.6
Rain 0700 hr (scale 0-2)	-0.24***	0.31	0.19	0.10	0.07	3.5*
Rain 0700-1300 hr (scale 0-2)	-0.23***	0.52	0.30	0.20	0.17	5.7**
Relative humidity (%)	0.15**	89.3	90.8	92.0	92.8	4.9**
Rel. humidity trend (%)	0.07	-1.0	-0.1	0.9	2.0	1.9
Barometric pressure (mb)	0.27***	1011.0	1012.8	1015.8	1014.6	8.3***
Barom. pressure trend (mb)	0.04	-0.25	-0.22	0.05	-0.22	0.2
Temperature (°C)	0.10*	0.06	0.28	0.76	-0.32	3.3*
Temperature trend (°C)	0.05	-0.13	-0.24	0.03	-0.10	0.6
Min. temperature (°C)	-0.07	0.37	0.13	0.20	-0.80	1.7
Min. temp. trend (°C)	-0.05	0.14	-0.34	-0.28	-0.07	1.3
Max. temperature (°C)	0.24***	-0.86	-0.11	0.84	-0.03	8.5***
Max. temp. trend (°C)	0.09	-0.52	-0.25	0.11	0.17	2.8
Surface winds:						
Wind speed (m/s)	-0.35***	8.7	6.8	5.7	5.0	18.2***
Wind speed trend (m/s)	-0.20***	1.3	0.1	-1.1	-1.3	7.2***
N-wind	-0.09	-0.01	-0.02	-0.17	-0.24	2.8*
N-wind trend	-0.08	0.03	0.06	-0.02	-0.30	2.4
NE-wind	-0.03	-0.23	-0.20	-0.26	-0.18	0.3
NE-wind trend	0.04	-0.11	-0.00	0.06	0.03	1.4
NW-wind	-0.08	0.22	0.17	0.03	-0.15	3.3*
NW-wind trend	-0.14**	0.15	0.09	-0.09	-0.45	6.4***
W-wind	-0.03	0.32	0.26	0.21	0.02	1.4
W-wind trend	-0.12*	0.19	0.07	-0.11	-0.34	5.3**
High-altitude winds:						
Wind speed (m/s)	-0.33***	12.3	9.4	8.7	8.6	13.8***
Wind speed trend (m/s)	-0.20***	1.5	0.1	-1.3	-0.1	6.1***
N-wind	-0.08	-0.00	-0.10	-0.20	-0.13	2.3
N-wind trend	-0.12*	0.09	0.09	-0.09	-0.19	3.6*
NE-wind	-0.08	-0.34	-0.42	-0.44	-0.42	0.8
NE-wind trend	-0.03	-0.01	-0.01	0.03	-0.09	0.3
NW-wind	-0.04	0.34	0.27	0.15	0.24	1.5
NW-wind trend	-0.13**	0.14	0.14	-0.15	-0.18	6.8***
W-wind	0.02	0.47	0.48	0.42	0.47	0.3
W-wind trend	-0.08	0.11	0.11	-0.13	-0.06	4.5**

Multiple regression equation n = 409 R = 0.55

-0.284	NE-wind (s)	$p < 0.001$
-0.187	wind speed (s)	$p < 0.01$
-0.182	W-wind trend (s)	$p < 0.001$
+0.178	barom.pressure	$p < 0.001$
-0.166	wind speed (h)	$p < 0.01$
-0.157	cloud amount	$p < 0.001$
+0.139	visibility	$p < 0.01$
-0.132	rain 07hr	$p < 0.01$
-0.104	N-wind (h)	$p < 0.05$
+0.104	rel.humidity	$p < 0.05$

Multiple regression equation incl. days of delay n = 336 R = 0.55

-0.314	NE-wind (s)	$p < 0.001$
-0.252	wind speed (s)	$p < 0.001$
-0.236	W-wind trend (s)	$p < 0.001$
+0.233	days of delay -2	$p < 0.001$
-0.190	wind speed (h)	$p < 0.01$
-0.175	cloud amount	$p < 0.001$
-0.118	rain 07hr	$p < 0.05$

Multiple discriminant function n = 409 $R_c = 0.54$

Mean of standardized discriminant score

Group 1=-0.68 Group 2=-0.10 Group 3=0.61 Group 4=0.55

-0.825	N-wind (s)	$p < 0.001$
+0.443	NW-wind (s)	$p < 0.01$
+0.383	NE-wind trend (s)	$p < 0.01$
-0.382	cloud amount	$p < 0.001$
-0.341	wind speed (s)	$p < 0.05$
+0.307	barom. pressure	$p < 0.01$
-0.293	wind speed (h)	$p < 0.01$
+0.235	rel.humidity	$p < 0.05$
+0.234	visibility	$p < 0.01$
+0.160	temp.	$p < 0.05$

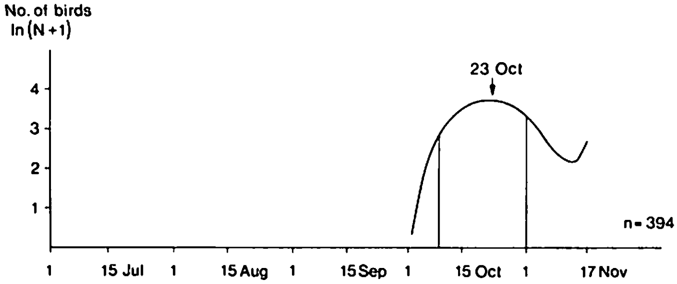
Multiple discriminant function incl. days of delay n = 336 $R_c = 0.58$

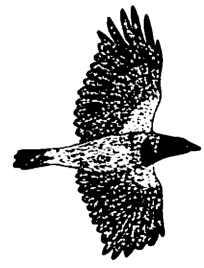
Mean of standardized discriminant score

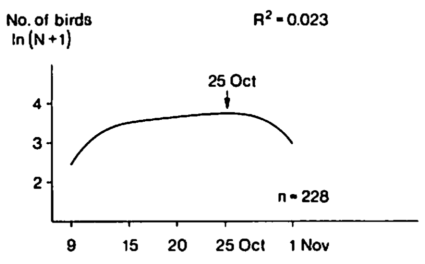
Group 1=-0.74 Group 2=-0.23 Group 3=0.61 Group 4=0.76

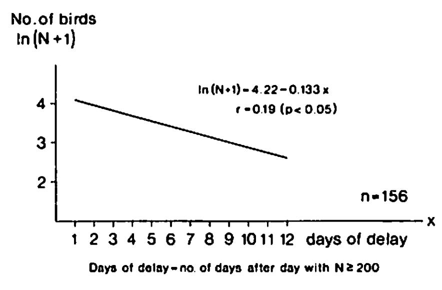
-0.528	NE-wind (s)	$p < 0.001$
+0.496	days of delay -2	$p < 0.001$
-0.388	wind speed (s)	$p < 0.01$
-0.383	W-wind trend (s)	$p < 0.01$
-0.355	cloud amount	$p < 0.001$
-0.245	NW-wind trend (h)	$p < 0.05$
+0.188	max temp.	$p < 0.05$
-0.179	wind speed (h)	$p < 0.05$

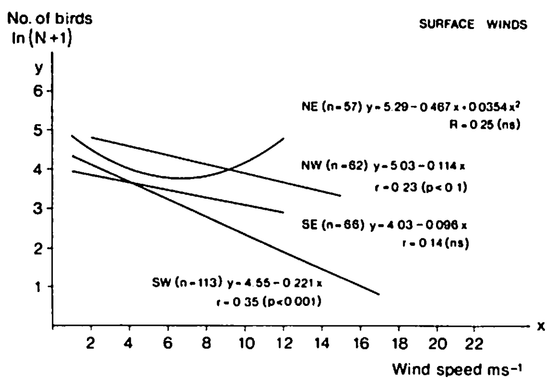
HOODED CROW
Corvus cornix

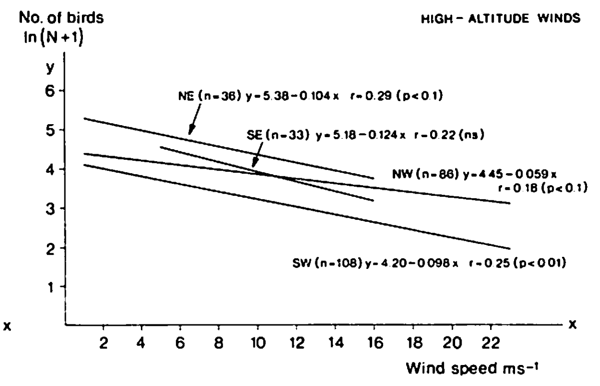












HOODED CROW

Variable	Correlation Coefficient n = 196	Mean Group 1 n = 69	Group 2 n = 46	Group 3 n = 64	Group 4 n = 17	F^{3}_{192}
Cloud amount (scale 0-8)	-0.39***	7.2	6.3	5.1	5.1	9.9***
Cloud ceiling (scale 0-9)	0.23**	4.3	5.2	5.6	4.8	5.0**
Convective clouds (scale 0-1)	0.13	0.17	0.35	0.34	0.35	2.2
Visibility (scale 0-9)	0.28***	6.7	7.0	7.4	7.6	5.9***
Rain 0700 hr (scale 0-2)	-0.36***	0.52	0.24	0.06	0.06	6.3***
Rain 0700-1300 hr (scale 0-2)	-0.27***	0.70	0.39	0.13	0.59	6.5***
Relative humidity (%)	-0.11	92.2	88.5	90.7	88.6	2.8*
Rel. humidity trend (%)	-0.01	0.7	-2.0	1.7	-2.2	1.7
Barometric pressure (mb)	0.11	1011.0	1017.1	1014.1	1012.5	4.1**
Barom. pressure trend (mb)	0.40***	-3.03	0.13	0.38	0.90	10.2***
Temperature (°C)	-0.28***	1.24	-0.62	-0.64	-0.29	7.4***
Temperature trend (°C)	-0.29***	0.59	-0.07	-0.71	-0.48	5.8***
Min. temperature (°C)	-0.28***	1.47	-0.72	-0.60	-0.52	8.4***
Min. temp. trend (°C)	-0.26***	0.75	-0.41	-0.75	-0.47	5.4**
Max. temperature (°C)	-0.08	0.61	-0.35	0.20	-0.14	1.4
Max. temp. trend (°C)	0.02	-0.28	-0.11	-0.18	0.00	0.1
Surface winds:						
Wind speed (m/s)	-0.30***	9.3	6.1	5.7	8.0	14.1***
Wind speed trend (m/s)	-0.33***	2.1	0.0	-1.2	-1.8	7.3***
N-wind	0.25***	-0.31	-0.01	0.05	-0.05	4.6**
N-wind trend	0.18*	-0.09	-0.03	0.14	0.07	1.3
NE-wind	0.34***	-0.62	0.01	0.10	-0.29	15.0***
NE-wind trend	0.27***	-0.19	-0.02	0.21	0.13	4.1**
NW-wind	-0.05	0.18	-0.02	-0.03	0.22	1.7
NW-wind trend	-0.02	0.06	-0.02	-0.01	-0.03	0.2
W-wind	-0.26***	0.56	-0.02	-0.09	0.36	11.2***
W-wind trend	-0.19**	0.18	0.00	-0.16	-0.11	2.4
High-altitude winds:						
Wind speed (m/s)	-0.27***	14.6	10.1	10.1	11.6	8.2***
Wind speed trend (m/s)	-0.27***	2.1	0.5	-1.6	-2.6	5.3**
N-wind	0.13	-0.15	0.07	-0.03	0.03	1.3
N-wind trend	0.12	-0.09	0.04	-0.02	0.10	0.6
NE-wind	0.25***	-0.58	-0.08	-0.22	-0.23	6.8***
NE-wind trend	0.22**	-0.15	0.06	0.06	0.19	2.3
NW-wind	-0.08	0.36	0.18	0.18	0.27	1.1
NW-wind trend	-0.06	0.03	-0.02	-0.09	-0.05	0.4
W-wind	-0.23**	0.66	0.18	0.28	0.35	6.4***
W-wind trend	-0.20**	0.13	-0.66	-0.11	-0.17	2.2

Multiple regression equation n = 196, R = 0.62

-0.212	cloud amount	p < 0.001
-0.210	wind speed trend (s)	p < 0.001
-0.209	W-wind (s)	p < 0.001
-0.194	rain 07hr	p < 0.01
+0.159	barom.pr.trend	p < 0.05
+0.137	visibility	p < 0.05

Multiple regression equation incl. days of delay n = 130, R = 0.70

+0.308	visibility	p < 0.001
-0.275	wind speed trend (s)	p < 0.001
+0.274	barom.pr.trend	p < 0.001
+0.274	max temp.	p < 0.01
-0.244	cloud amount	p < 0.001
-0.202	days of delay -1	p < 0.01
-0.198	W-wind (h)	p < 0.05

Multiple discriminant function n = 196, R_c = 0.61

Mean of standardized discriminant score
Group 1=-1.02 Group 2=0.36 Group 3=0.86 Group 4=-0.07

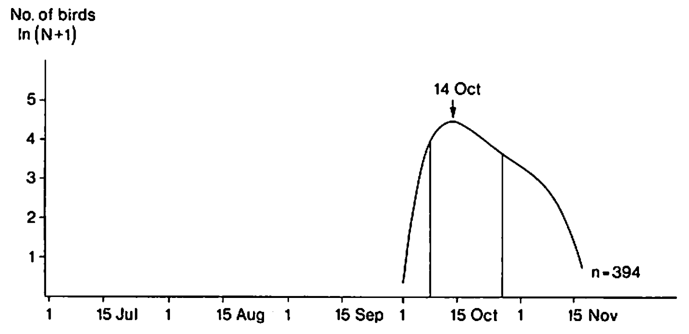
+0.659	NE-wind (s)	p < 0.001
-0.514	wind speed (s)	p < 0.01
-0.477	rain 07-13hr	p < 0.01
-0.366	cloud amount	p < 0.01
-0.145	wind speed trend (s)	p < 0.05

-0.528	wind speed trend (s)	Group 1 = -0.03
+0.451	wind speed (s)	Group 2 = -0.18
-0.392	cloud amount	Group 3 = 0.03
+0.180	rain 07-13hr	Group 4 = 0.50
-0.092	NE-wind (s)	

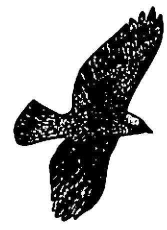
Multiple discriminant function incl. days of delay n = 130, R_c = 0.68

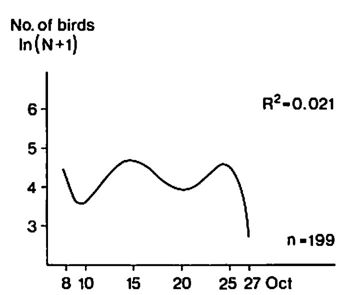
Mean of standardized discriminant score
Group 1=-0.95 Group 2=-0.15 Group 3=0.66 Group 4=0.74

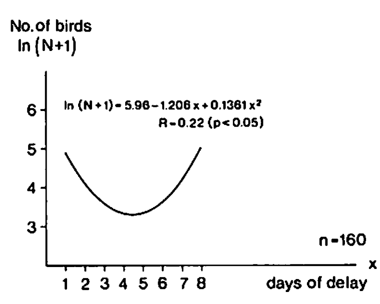
+0.724	visibility	p < 0.001
-0.430	days of delay -1	p < 0.01
+0.387	max temp.	p < 0.01
-0.380	min temp.trend	p < 0.01
-0.327	wind speed (s)	p < 0.001
-0.316	wind speed trend (s)	p < 0.01



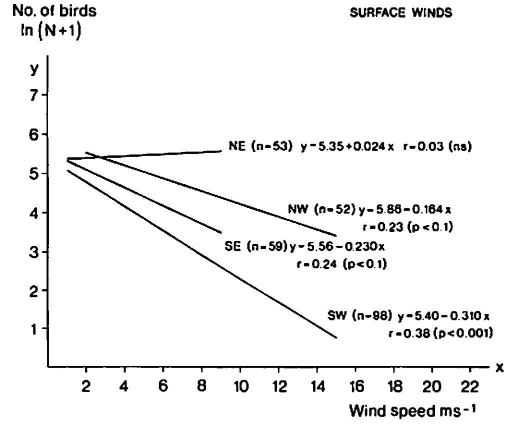
JACKDAW
Corvus monedula

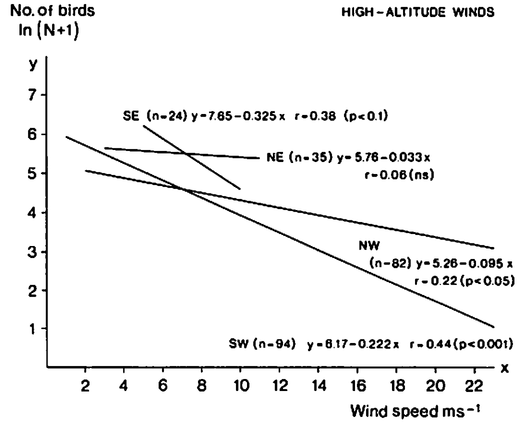






Days of delay=no. of days after day with N≥500





JACKDAW

Variable	Correlation Coefficient n = 177	Mean Group 1 n = 61	Group 2 n = 35	Group 3 n = 54	Group 4 n = 27	F^{3}_{173}
Cloud amount (scale 0-8)	-0.50***	7.5	6.4	5.3	3.6	21.4***
Cloud ceiling (scale 0-9)	0.37***	4.2	4.6	5.6	6.1	8.6***
Convective clouds (scale 0-1)	0.11	0.23	0.34	0.33	0.26	0.7
Visibility (scale 0-9)	0.30***	6.7	7.2	7.1	7.7	6.1***
Rain 0700 hr (scale 0-2)	-0.41***	0.57	0.11	0.04	0.00	10.6***
Rain 0700-1300 hr (scale 0-2)	-0.37***	0.70	0.31	0.09	0.19	8.4***
Relative humidity (%)	-0.13	91.2	89.3	90.4	88.5	0.9
Rel. humidity trend (%)	-0.03	0.6	-2.2	1.2	-0.6	1.0
Barometric pressure (mb)	0.25***	1011.1	1014.2	1017.9	1016.4	5.4**
Barom. pressure trend (mb)	0.40***	-3.07	-0.68	0.57	1.33	10.6***
Temperature (°C)	-0.32***	0.99	0.27	-0.89	-0.47	5.4**
Temperature trend (°C)	-0.38***	0.74	-0.10	-0.49	-1.08	7.3***
Min. temperature (°C)	-0.31***	1.14	0.20	-0.92	-0.54	6.0***
Min. temp. trend (°C)	-0.31***	0.87	-0.51	-0.26	-1.41	7.3***
Max. temperature (°C)	-0.04	0.39	-0.05	0.14	0.49	0.3
Max. temp. trend (°C)	-0.03	-0.05	-0.51	-0.11	-0.19	0.5
Surface winds:						
Wind speed (m/s)	-0.40***	9.1	7.0	5.1	6.5	12.2***
Wind speed trend (m/s)	-0.34***	2.0	0.1	-1.2	-1.7	7.5***
N-wind	0.27***	-0.29	-0.01	0.02	0.02	3.4*
N-wind trend	0.19*	-0.16	0.09	0.11	0.12	2.1
NE-wind	0.42***	-0.56	-0.26	0.17	-0.03	11.2***
NE-wind trend	0.29***	-0.25	0.02	0.14	0.24	4.4**
NW-wind	-0.13	0.15	0.25	-0.14	0.06	3.2*
NW-wind trend	-0.03	0.02	0.10	0.02	-0.07	0.3
W-wind	-0.36***	0.50	0.36	-0.21	0.07	10.3***
W-wind trend	-0.22**	0.19	0.06	-0.09	-0.22	2.3
High-altitude winds:						
Wind speed (m/s)	-0.36***	14.4	10.8	9.2	9.7	8.4***
Wind speed trend (m/s)	-0.24***	1.8	0.2	-0.9	-1.9	3.0*
N-wind	0.11	-0.10	0.00	0.08	0.01	0.8
N-wind trend	0.13	-0.09	-0.06	0.14	0.12	1.6
NE-wind	0.25***	-0.49	-0.34	-0.12	-0.20	3.3*
NE-wind trend	0.18*	-0.12	-0.03	0.10	0.17	1.8
NW-wind	-0.10	0.35	0.34	0.24	0.22	0.5
NW-wind trend	0.00	-0.00	-0.06	0.10	0.00	0.5
W-wind	-0.25***	0.59	0.48	0.26	0.30	3.1*
W-wind trend	-0.13	0.09	-0.02	0.00	-0.12	0.7

Multiple regression equation n = 177, R = 0.73

-0.368	wind speed (s)	$p < 0.001$
-0.271	cloud amount	$p < 0.001$
+0.259	visibility	$p < 0.001$
+0.255	NE-wind (s)	$p < 0.001$
+0.227	temp.	$p < 0.01$
-0.219	rain 07-13hr	$p < 0.001$
-0.167	temp.trend	$p < 0.01$

Multiple regression equation incl. days of delay n = 140, R = 0.75

-0.266	cloud amount	$p < 0.001$
-0.244	wind speed trend (s)	$p < 0.001$
-0.221	rain 07-13hr	$p < 0.001$
+0.196	barom.pr.trend	$p < 0.01$
+0.172	NE-wind (s)	$p < 0.01$
-0.166	NW-wind (h)	$p < 0.01$
+0.152	days of delay -2	$p < 0.01$
-0.141	min temp.trend	$p < 0.05$

Multiple discriminant function n = 177, R_c = 0.69

Mean of standardized discriminant score

Group 1=-0.87 Group 2=-0.07 Group 3=0.63 Group 4=0.79

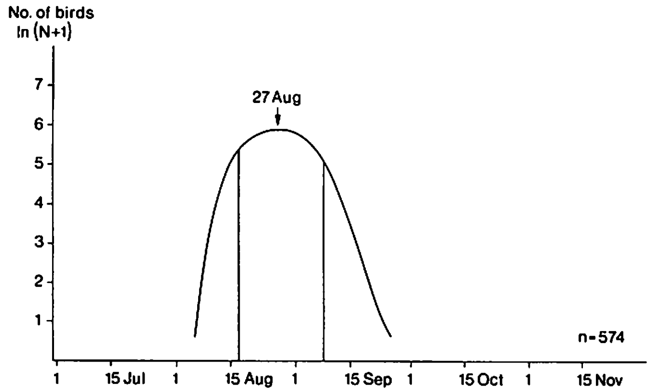
-0.407	cloud amount	$p < 0.001$
-0.356	wind speed (s)	$p < 0.01$
-0.295	rain 07-13hr	$p < 0.01$
-0.287	W-wind (s)	$p < 0.01$
+0.250	barom.pr.trend	$p < 0.05$
+0.208	visibility	$p < 0.05$

Multiple discriminant function incl. days of delay n = 140, R_c = 0.70

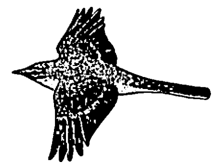
Mean of standardized discriminant score

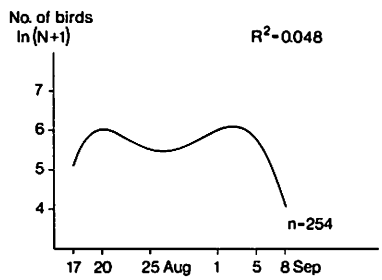
Group 1=-0.86 Group 2=-0.18 Group 3=0.52 Group 4=0.91

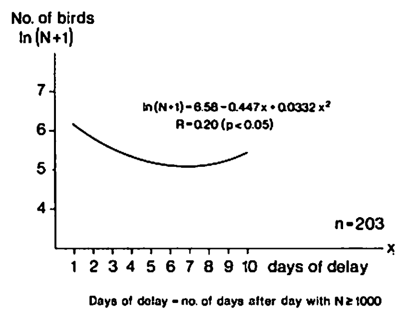
-0.414	cloud amount	$p < 0.001$
-0.322	W-wind (s)	$p < 0.001$
+0.312	barom.pr.trend	$p < 0.01$
-0.304	wind speed trend	$p < 0.05$
-0.245	rain 07-13hr	$p < 0.01$
+0.194	days of delay -2	$p < 0.05$
-0.155	min temp.trend	$p < 0.05$

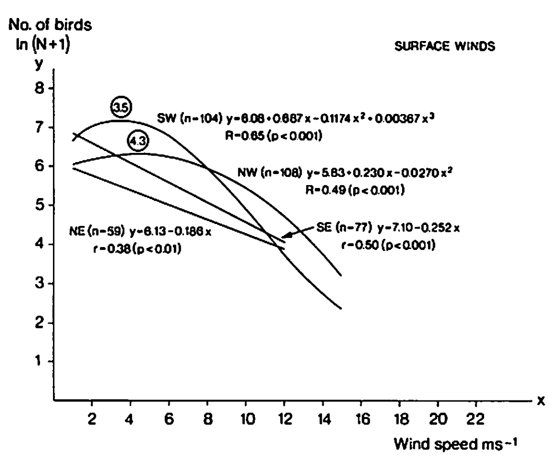


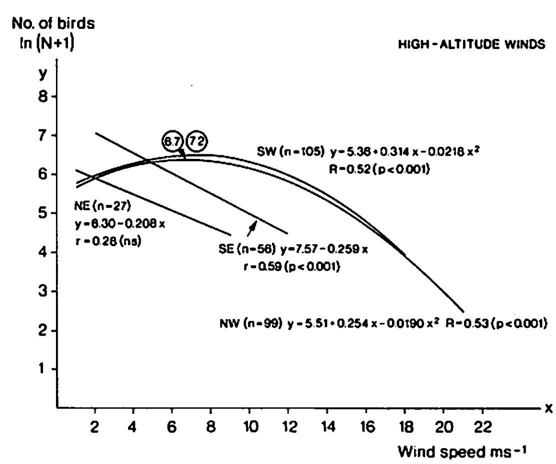
YELLOW WAGTAIL
Motacilla flava











YELLOW WAGTAIL

Variable	Correlation Coefficient n = 226	Mean Group 1 n = 48	Group 2 n = 69	Group 3 n = 90	Group 4 n = 19	F^3_{222}
Cloud amount (scale 0-8)	-0.22***	6.0	5.1	4.0	5.8	6.2***
Cloud ceiling (scale 0-9)	0.19**	5.0	5.8	5.9	5.6	2.2
Convective clouds (scale 0-1)	0.07	0.46	0.43	0.50	0.47	0.2
Visibility (scale 0-9)	0.07	7.3	7.4	7.4	7.4	0.4
Rain 0700 hr (scale 0-2)	-0.23***	0.46	0.19	0.06	0.21	5.2**
Rain 0700-1300 hr (scale 0-2)	-0.27***	0.63	0.32	0.14	0.42	5.6**
Relative humidity (%)	0.11	89.1	88.7	89.8	90.9	0.7
Rel. humidity trend (%)	0.03	0.4	-1.0	0.0	2.1	0.7
Barometric pressure (mb)	0.19**	1010.5	1014.6	1014.4	1012.2	4.1**
Barom. pressure trend (mb)	0.18**	-0.73	0.28	0.26	0.36	1.6
Temperature (°C)	-0.00	0.30	0.62	0.42	-0.18	0.8
Temperature trend (°C)	0.14*	-0.43	-0.10	-0.07	0.43	1.6
Min. temperature (°C)	-0.16*	0.88	0.60	-0.30	-0.11	3.2*
Min. temp. trend (°C)	-0.08	-0.02	0.38	-0.59	0.16	2.9*
Max. temperature (°C)	0.11	-0.80	0.67	0.30	-0.88	2.9*
Max. temp. trend (°C)	0.21**	-0.85	-0.25	0.07	0.47	2.8*
Surface winds:						
Wind speed (m/s)	-0.45***	9.1	6.5	5.4	4.5	14.4***
Wind speed trend (m/s)	-0.41***	2.4	0.9	-1.0	-4.0	15.4***
N-wind	-0.11	0.04	0.19	-0.12	-0.28	5.5**
N-wind trend	-0.11	0.12	0.17	-0.09	-0.19	3.1*
NE-wind	-0.15*	-0.07	0.07	-0.30	-0.57	7.2***
NE-wind trend	-0.02	0.00	0.05	-0.01	-0.00	0.1
NW-wind	0.01	0.12	0.20	0.13	0.18	0.2
NW-wind trend	-0.12	0.17	0.18	-0.12	-0.27	3.3*
W-wind	0.10	0.13	0.09	0.30	0.53	2.1
W-wind trend	-0.07	0.12	0.09	-0.08	-0.19	1.2
High-altitude winds:						
Wind speed (m/s)	-0.34***	11.7	9.0	8.0	8.7	7.4***
Wind speed trend (m/s)	-0.30***	1.2	1.3	-1.0	-3.2	7.3***
N-wind	-0.06	-0.01	-0.18	-0.13	-0.08	0.8
N-wind trend	-0.15*	0.32	-0.10	-0.03	-0.11	4.4**
NE-wind	-0.17*	-0.19	-0.28	-0.44	-0.59	3.4*
NE-wind trend	-0.16*	0.22	-0.05	-0.01	-0.06	2.4
NW-wind	0.06	0.18	0.02	0.26	0.47	2.6
NW-wind trend	-0.06	0.23	-0.09	-0.03	-0.09	2.1
W-wind	0.15*	0.26	0.21	0.49	0.75	4.8**
W-wind trend	0.05	0.00	-0.02	-0.02	-0.02	0.0

Multiple regression equation n = 226 R = 0.58

-0.416	wind speed (s)	$p < 0.001$
+0.251	W-wind (h)	$p < 0.001$
-0.195	wind speed trend (h)	$p < 0.001$
+0.157	temp.trend	$p < 0.01$
-0.154	cloud amount	$p < 0.01$

Multiple regression equation incl. days of delay n = R =

Multiple discriminant function n = 226 R_c = 0.60

Mean of standardized discriminant score

Group 1=-0.80 Group 2=-0.37 Group 3=0.50 Group 4=0.97

-0.752	NE-wind (s)	$p < 0.001$
-0.562	wind speed (h)	$p < 0.001$
-0.442	wind speed trend (s)	$p < 0.001$
-0.350	W-wind trend	$p < 0.01$
-0.187	cloud amount	$p < 0.01$
-0.067	N-wind trend	$p < 0.01$

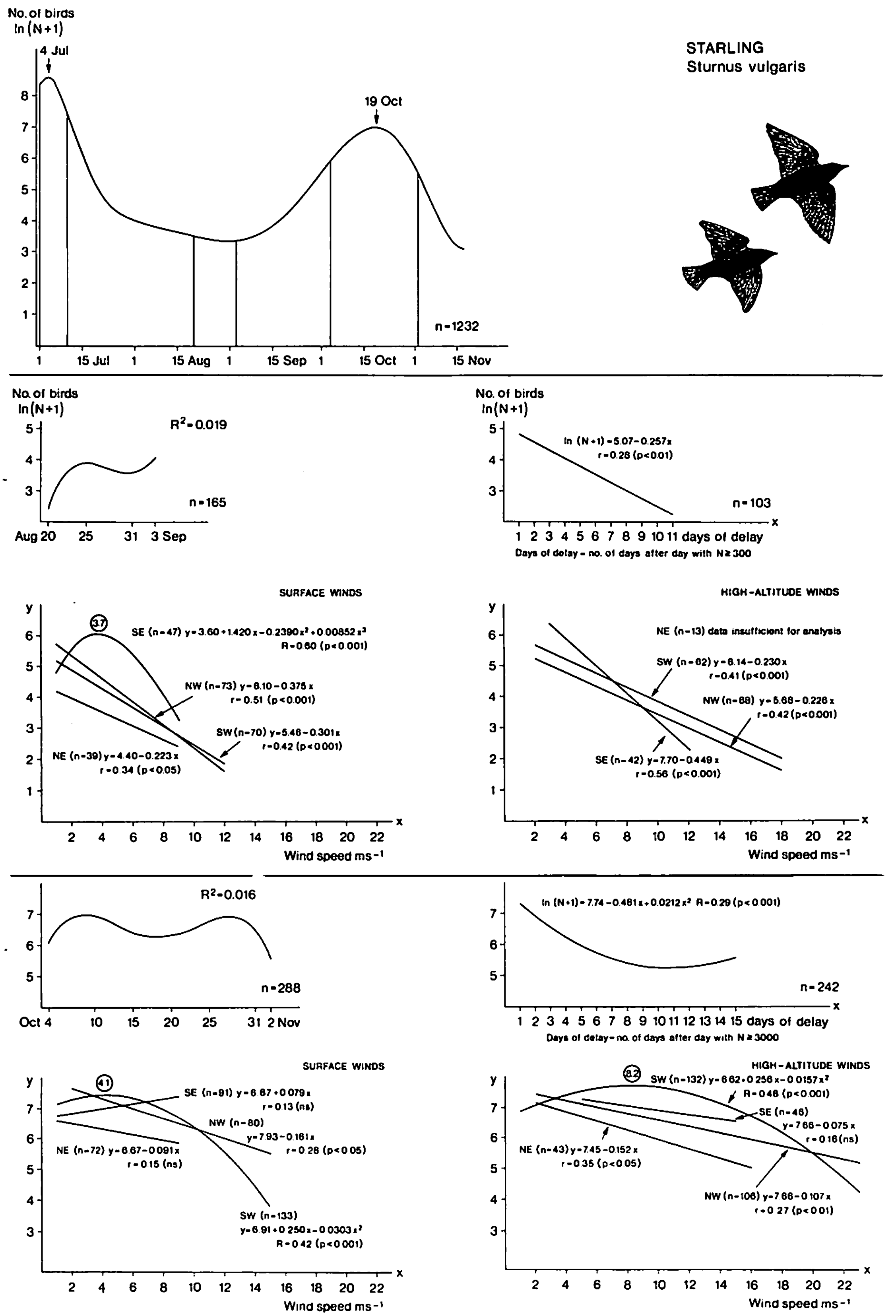
Multiple discriminant function incl. days of delay n = 179 R_c = 0.63

Mean of standardized discriminant score

Group 1=-0.91 Group 2=-0.33 Group 3=0.56 Group 4=0.75

-0.597	NE-wind (s)	$p < 0.001$
-0.444	wind speed (s)	$p < 0.001$
-0.331	wind speed (h)	$p < 0.05$
-0.277	days of delay -1	$p < 0.01$
-0.225	wind speed trend (h)	$p < 0.01$
-0.194	cloud amount	$p < 0.05$

STARLING
Sturnus vulgaris



STARLING (AUGUST)

Variable	Correlation Coefficient n = 151	Mean Group 1 n = 51	Group 2 n = 32	Group 3 n = 38	Group 4 n = 30	F^{3}_{147}
Cloud amount (scale 0-8)	-0.30***	6.1	5.4	5.1	3.6	5.2**
Cloud ceiling (scale 0-9)	0.26**	5.0	5.1	5.1	6.7	7.8***
Convective clouds (scale 0-1)	-0.03	0.47	0.47	0.55	0.33	1.1
Visibility (scale 0-9)	-0.02	7.4	7.3	7.5	7.2	0.9
Rain 0700 hr (scale 0-2)	-0.37***	0.59	0.19	0.03	0.00	8.8***
Rain 0700-1300 hr (scale 0-2)	-0.35***	0.73	0.31	0.13	0.13	7.4***
Relative humidity (%)	0.15	88.5	88.3	91.4	90.3	2.0
Rel. humidity trend (%)	-0.01	0.1	0.2	0.4	-0.8	0.1
Barometric pressure (mb)	0.33***	1009.7	1014.7	1014.6	1015.9	7.9***
Barom. pressure trend (mb)	0.13	-0.46	-0.10	0.14	0.53	0.9
Temperature (°C)	-0.03	0.28	1.29	0.02	0.33	2.5
Temperature trend (°C)	0.18*	-0.30	-0.02	0.11	0.23	1.2
Min. temperature (°C)	-0.18*	0.66	1.16	-0.14	-0.36	2.8*
Min. temp. trend (°C)	-0.06	0.12	-0.06	0.11	-0.37	0.4
Max. temperature (°C)	0.14	-0.80	0.62	-0.15	0.81	2.2
Max. temp. trend (°C)	0.25**	-0.75	-0.09	-0.05	0.73	3.7*
Surface winds:						
Wind speed (m/s)	-0.48***	9.0	6.9	5.3	4.3	14.5***
Wind speed trend (m/s)	-0.28***	1.6	-0.1	-0.3	-2.0	4.2**
N-wind	-0.18*	0.09	0.04	-0.08	-0.17	1.9
N-wind trend	-0.05	0.02	0.04	-0.01	-0.11	0.4
NE-wind	-0.00	-0.22	-0.01	-0.35	-0.12	1.7
NE-wind trend	0.20*	-0.16	-0.02	-0.02	0.22	2.5
NW-wind	-0.18*	0.35	0.08	0.24	-0.13	3.3*
NW-wind trend	-0.23**	0.19	0.07	0.00	-0.37	4.3**
W-wind	-0.11	0.40	0.06	0.42	-0.01	2.8*
W-wind trend	-0.28***	0.25	0.06	0.02	-0.42	6.1***
High-altitude winds:						
Wind speed (m/s)	-0.39***	11.8	9.8	8.3	7.3	8.2***
Wind speed trend (m/s)	-0.23**	1.2	0.3	-0.4	-1.5	2.3
N-wind	-0.21**	-0.02	-0.13	-0.06	-0.48	4.4**
N-wind trend	-0.15	0.06	0.09	0.01	-0.30	2.3
NE-wind	-0.18*	-0.30	-0.25	-0.38	-0.62	3.3*
NE-wind trend	0.00	-0.03	-0.02	0.08	-0.12	0.8
NW-wind	-0.11	0.26	0.06	0.31	-0.06	1.9
NW-wind trend	-0.20*	0.11	0.15	-0.07	-0.30	3.0*
W-wind	0.02	0.40	0.22	0.49	0.39	0.9
W-wind trend	-0.17*	0.10	0.12	-0.10	-0.13	1.9

Multiple regression equation n = 151 R = 0.75

-0.340	max temp.	p < 0.001
-0.304	wind speed (s)	p < 0.001
+0.299	barom.pressure	p < 0.001
-0.269	NE-wind (h)	p < 0.001
+0.242	N-wind trend (h)	p < 0.01
-0.237	W-wind trend	p < 0.001
-0.236	cloud amount	p < 0.001
-0.231	rain 07hr	p < 0.001
-0.212	N-wind (h)	p < 0.05
+0.154	temp.trend	p < 0.05
+0.136	max temp.trend	p < 0.05
+0.121	rel.humidity	p < 0.05

Multiple regression equation incl. days of delay n = 91 R = 0.69

-0.336	wind speed (s)	p < 0.001
-0.285	days of delay -1	p < 0.001
-0.255	W-wind trend (s)	p < 0.01
-0.240	cloud amount	p < 0.01
-0.238	rain 07hr	p < 0.01

Multiple discriminant function n = 151 R_c = 0.68

Mean of standardized discriminant score

Group 1=-0.79 Group 2=-0.16 Group 3=0.39 Group 4=1.02

-0.493	wind speed (s)	p < 0.001
-0.457	NE-wind (h)	p < 0.001
-0.339	rain 07hr	p < 0.01
+0.309	barom. pressure	p < 0.05
-0.306	W-wind trend (s)	p < 0.01
-0.226	temp.	p < 0.01
+0.073	cloud ceiling	p < 0.01

Multiple discriminant function incl. days of delay n = 91 R_c = 0.70

Mean of standardized discriminant score

Group 1=-1.20 Group 2=-0.08 Group 3=0.33 Group 4=0.72

-0.442	rain 07hr	p < 0.01
-0.436	NW-wind trend (s)	p < 0.01
-0.338	wind speed (s)	p < 0.05
+0.333	barom.pressure	p < 0.01
-0.315	days of delay -1	p < 0.01
+0.099	cloud ceiling	p < 0.05
+0.052	convective clouds	p < 0.05

STARLING (OCTOBER)

Variable	Correlation Coefficient n = 253	Mean Group 1 n = 34	Group 2 n = 83	Group 3 n = 94	Group 4 n = 42	F^3_{249}
Cloud amount (scale 0-8)	-0.16*	7.1	6.2	5.9	5.6	2.3
Cloud ceiling (scale 0-9)	0.14*	4.3	4.9	5.1	5.4	2.0
Convective clouds (scale 0-1)	0.09	0.24	0.24	0.31	0.43	1.8
Visibility (scale 0-9)	0.13*	6.6	7.1	7.1	7.2	1.6
Rain 0700 hr (scale 0-2)	-0.23***	0.59	0.20	0.13	0.26	4.6**
Rain 0700-1300 hr (scale 0-2)	-0.17**	0.65	0.37	0.34	0.33	1.5
Relative humidity (%)	0.09	88.9	89.3	91.2	91.5	1.8
Rel. humidity trend (%)	0.09	-1.4	-1.9	1.8	-0.1	2.5
Barometric pressure (mb)	0.01	1012.9	1015.7	1014.3	1010.7	2.6
Barom. pressure trend (mb)	0.19**	-2.82	-0.07	-0.44	-0.46	3.5*
Temperature (°C)	0.09	-0.44	-0.41	0.23	0.73	2.3
Temperature trend (°C)	-0.06	-0.02	-0.21	-0.07	-0.38	0.3
Min. temperature (°C)	0.00	-0.01	-0.06	-0.04	0.35	0.2
Min. temp. trend (°C)	-0.11	-0.09	0.24	-0.37	-0.71	1.9
Max. temperature (°C)	0.08	-0.45	0.04	0.19	0.45	0.7
Max. temp. trend (°C)	-0.01	-0.21	-0.13	-0.22	-0.36	0.1
Surface winds:						
Wind speed (m/s)	-0.28***	9.7	6.6	6.4	7.2	7.3***
Wind speed trend (m/s)	-0.17**	1.1	0.2	-0.4	-0.8	1.2
N-wind	-0.09	0.03	-0.07	-0.11	-0.25	1.4
N-wind trend	0.02	-0.01	0.07	-0.04	0.08	0.4
NE-wind	-0.05	-0.21	-0.02	-0.20	-0.47	3.7*
NE-wind trend	-0.01	-0.01	0.11	-0.03	-0.01	0.7
NW-wind	-0.06	0.25	-0.08	0.04	0.11	2.1
NW-wind trend	0.03	-0.01	-0.01	-0.02	0.11	0.4
W-wind	-0.00	0.32	-0.04	0.17	0.40	4.0**
W-wind trend	0.03	-0.00	-0.09	0.00	0.09	0.6
High-altitude winds:						
Wind speed (m/s)	-0.32***	15.8	10.9	10.0	11.5	8.7***
Wind speed trend (m/s)	-0.14*	0.2	1.1	-0.7	-1.3	2.0
N-wind	-0.13*	0.16	-0.05	-0.12	-0.13	1.7
N-wind trend	0.04	-0.10	0.04	-0.09	0.10	1.2
NE-wind	-0.08	-0.27	-0.17	-0.39	-0.46	2.5
NE-wind trend	0.02	-0.08	0.12	-0.08	0.08	2.0
NW-wind	-0.11	0.49	0.10	0.22	0.27	2.9*
NW-wind trend	0.03	-0.06	-0.06	-0.04	0.06	0.4
W-wind	-0.02	0.53	0.19	0.43	0.51	3.7*
W-wind trend	0.01	0.01	-0.13	0.03	-0.02	1.1

Multiple regression equation $n = 253$, $R = 0.53$

+0.350	temp.	$p < 0.001$
-0.347	wind speed (h)	$p < 0.001$
+0.257	visibility	$p < 0.001$
-0.218	barom.pressure	$p < 0.001$
-0.175	wind speed (s)	$p < 0.05$
-0.148	rain 07hr	$p < 0.05$
+0.147	barom.pr.trend	$p < 0.05$

Multiple regression equation incl. days of delay $n = 207$, $R = 0.60$

-0.368	wind speed (h)	$p < 0.001$
+0.257	visibility	$p < 0.001$
+0.233	days of delay -2	$p < 0.001$
-0.196	wind speed trend (s)	$p < 0.01$
+0.192	temp.	$p < 0.05$
-0.190	rain 07hr	$p < 0.01$
-0.150	NE-wind (s)	$p < 0.05$

Multiple discriminant function $n = 253$, $R_c = 0.55$

Mean of standardized discriminant score

Group 1=-1.30 Group 2=-0.05 Group 3=0.34 Group 4=0.38

-1.079	wind speed (h)	$p < 0.001$
+0.591	temp.	$p < 0.001$
+0.555	barom.pr.trend	$p < 0.001$
+0.466	wind speed trend (h)	$p < 0.001$
+0.441	visibility	$p < 0.01$
-0.426	barom.pressure	$p < 0.01$
+0.250	rel.hum.trend	$p < 0.05$
-0.179	min temp.trend	$p < 0.05$

Multiple discriminant function incl. days of delay $n = 207$, $R_c = 0.54$

Mean of standardized discriminant score

Group 1=-1.17 Group 2=-0.15 Group 3=0.26 Group 4=0.62

-0.734	wind speed (s)	$p < 0.001$
+0.530	visibility	$p < 0.001$
+0.415	days of delay -2	$p < 0.001$
+0.405	temp.	$p < 0.05$
-0.384	NE-wind (s)	$p < 0.01$
+0.286	barom.pr.trend	$p < 0.05$
-0.118	min temp.trend	$p < 0.05$

for the so-called moult migration of males taking place shortly after the breeding period. Possibly the August migrants consist of non-breeding eiders and yearlings which depart towards the Danish and German wintering waters ahead of the adult breeding birds and their remaining young.

Common buzzard, Buteo buteo
18 Sept–21 Oct. Daily total. Group limits: 10, 100, 1000.

Honey buzzard, Pernis apivorus
27 Aug–17 Sept. Daily total. Group limits: 10, 100, 1000. Data from 1955 have been excluded from the analysis.

Sparrow hawk, Accipiter nisus
1) 1 Sept–20 Oct. 05–07 hours (1 Sept –18 Sept) and 06–08 hours (19 Sept–20 Oct). Group limits: 3, 15, 75.
2) 1 Sept–20 Oct. 10–14 hours. Group limits: 3, 15, 75.
3) 1 Sept–20 Oct. Daily total. Group limits: 10, 50, 200.

All results for 1) and 2) are presented, while results for 3) are given only in a page of tables.

Sparrow hawk migration in the morning and around noon were analysed separately in order to distinguish between flapping flight migration (morning) and migration with the aid of thermal currents (noon). For the sparrow hawk (morning) the first discriminant function did not accomplish discrimination of group 4 (intensive hawk migration) but this was done by the second discriminant function, as seen from the tables.

Black-headed gull, Larus ridibundus
16 July–24 Aug. 05–08 hours. Group limits: 10, 50, 200.

Wood pigeon, Columba palumbus
27 Sept–20 Oct. Daily total. Group limits: 50, 500, 5000. Unidentified pigeons (Ulfstrand et al. 1974) are included in these data.

Swift, Apus apus
1 July–10 Aug. 05–09 hours. Group limits: 15, 60, 240.

Swallow, Hirundo rustica
22 Aug–2 Oct. Daily total. Group limits: 50, 250, 1250.

Hooded crow, Corvus cornix
9 Oct–1 Nov. Daily total. Group limits: 20, 100, 500.

The first discriminant function (excl. 'days of delay') did not accomplish discrimination of group 4 (intensive crow migration), but this was done by the second discriminant function as seen from the tables.

Jackdaw, Corvus monedula
8 Oct–27 Oct. Daily total. Group limits: 25, 250, 1500.

Yellow wagtail, Motacilla flava
17 Aug–8 Sept. Daily total. Group limits: 125, 500, 2000.

Tab. 11. Daily number of migrating starlings 1 July to 10 July in relation to weather.

Variable	Correlation Coefficient n = 44	Multiple regression equation		n = 44 R = 0.82
Cloud amount (scale 0-8)	− 0.32 *			
Cloud ceiling (scale 0-9)	0.37 *	-0.489	rain 07hr	p < 0.001
Convective clouds (scale 0-1)	− 0.12	-0.422	wind speed (h)	p < 0.001
Visibility (scale 0-9)	0.18	-0.360	wind speed (s)	p < 0.01
Rain 0700 hr (scale 0-2)	− 0.45 **	-0.347	min temp.	p < 0.001
Rain 0700-1300 hr (scale 0-2)	− 0.12			
Relative humidity (%)	− 0.23			
Rel. humidity trend (%)	− 0.19			
Barometric pressure (mb)	0.44 **			
Barom. pressure trend (mb)	0.21			
Temperature (°C)	0.06			
Temperature trend (°C)	0.34 *			
Min. temperature (°C)	− 0.08			
Min. temp. trend (°C)	− 0.04			
Max. temperature (°C)	0.24			
Max. temp. trend (°C)	0.33 *			
Surface winds:				
Wind speed (m/s)	− 0.60 ***			
Wind speed trend (m/s)	− 0.51 ***			
N-wind	0.14			
N-wind trend	− 0.12			
NE-wind	0.30 *			
NE-wind trend	0.13			
NW-wind	− 0.10			
NW-wind trend	− 0.22			
W-wind	− 0.25			
W-wind trend	− 0.25			
High-altitude winds:				
Wind speed (m/s)	− 0.49 ***			
Wind speed trend (m/s)	− 0.43 **			
N-wind	0.09			
N-wind trend	0.09			
NE-wind	0.15			
NE-wind trend	0.04			
NW-wind	− 0.03			
NW-wind trend	0.09			
W-wind	− 0.12			
W-wind trend	0 05			

Starling, Sturnus vulgaris

1) 1 July–10 July. Daily total. Correlation coefficients and the result from multiple regression analysis are presented in Tab. 11. Seasonal variation accounted for 4.2% (= R^2) of the total variation in daily migratory intensity according to a fifth-degree polynomial regression (n = 50). Data were too scarce for analysing migration in relation to delay, and for grouping into four classes.

2) 20 Aug–3 Sept. Daily total. Group limits: 10, 100, 500.

3) 4 Oct–2 Nov. Daily total. Group limits: 100, 1000, 5000.

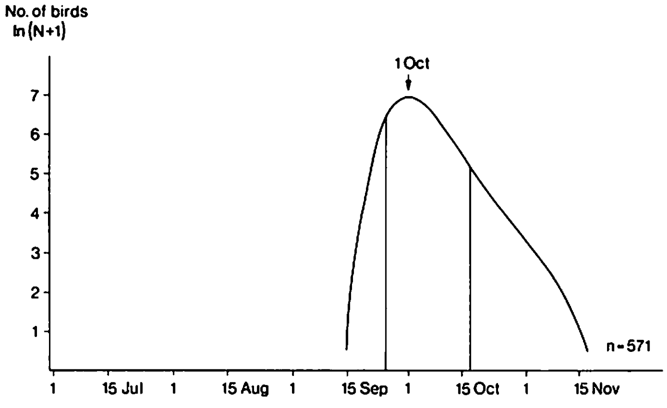
The summer peak of starling migration mainly consists of young birds and also to some extent of non-breeding sub-adults. However, large numbers of yearlings also stay in the north to moult and join the adult breeding birds on migration in October. Records in the Baltic region of the adult: juvenile ratio in migrating starlings during different intervals of time in the autumn have been reviewed by Edelstam (1972).

Chaffinch/brambling, Fringilla coelebs/montifringilla
25 Sept–17 Oct. Daily total. Group limits: 200, 2000, 20000.

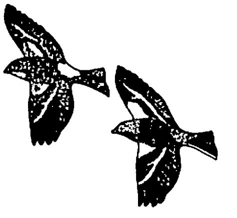
These two species have been analysed together as they usually travel in mixed flocks and they cannot be counted separately by the field observer.

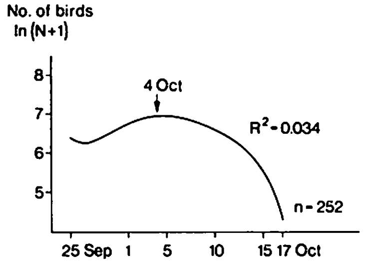
Siskin, Carduelis spinus
16 Sept–16 Oct. Daily total. Group limits: 10, 100, 1000.

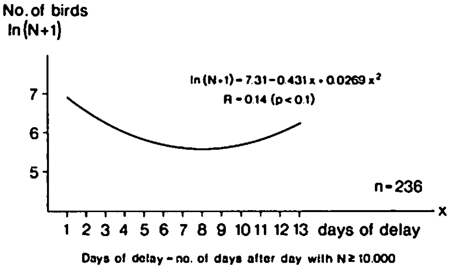
Linnet, Carduelis cannabina
29 Sept–21 Oct. Daily total. Group limits: 50, 500, 2500.

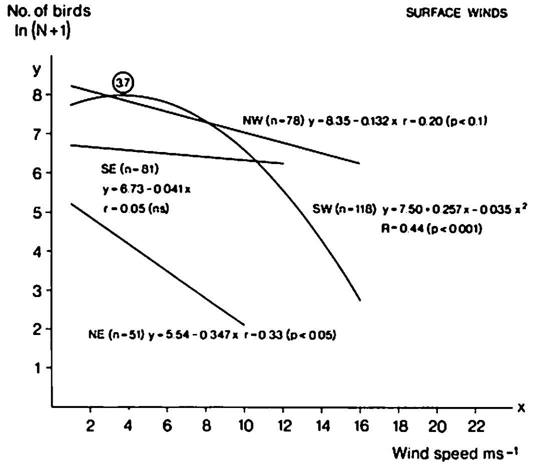


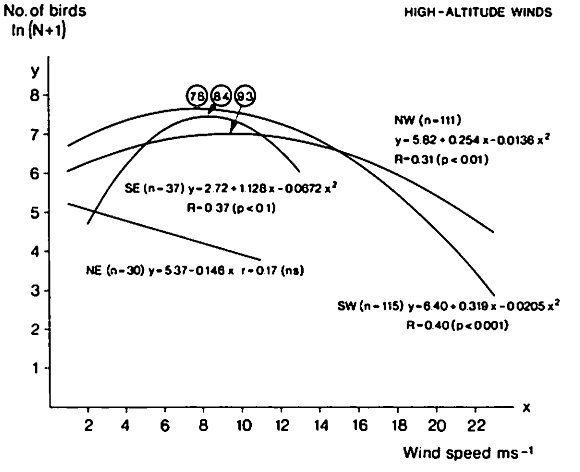
CHAFFINCH / BRAMBLING
Fringilla coelebs / montifringilla











CHAFFINCH/BRAMBLING

Variable	Correlation Coefficient n = 233	Mean Group 1 n = 74	Group 2 n = 62	Group 3 n = 66	Group 4 n = 31	F^3_{229}
Cloud amount (scale 0-8)	-0.09	6.1	4.8	5.6	6.2	2.9*
Cloud ceiling (scale 0-9)	0.16*	4.6	5.8	5.3	5.3	4.1**
Convective clouds (scale 0-1)	-0.04	0.41	0.31	0.38	0.29	0.7
Visibility (scale 0-9)	0.03	7.3	7.1	7.3	7.1	0.5
Rain 0700 hr (scale 0-2)	-0.29***	0.36	0.08	0.09	0.06	4.6**
Rain 0700-1300 hr (scale 0-2)	-0.30***	0.55	0.21	0.17	0.16	5.5**
Relative humidity (%)	0.03	90.4	90.8	91.6	91.2	0.4
Rel. humidity trend (%)	-0.01	-0.4	0.0	0.5	-1.1	0.3
Barometric pressure (mb)	0.19**	1011.0	1017.3	1013.7	1017.4	7.3***
Barom. pressure trend (mb)	0.16*	-1.05	-0.56	0.26	-0.37	1.3
Temperature (°C)	0.27***	-1.11	0.56	0.30	1.31	10.1***
Temperature trend (°C)	-0.12	0.07	-0.06	-0.44	0.02	1.1
Min. temperature (°C)	0.16*	-0.92	0.17	0.00	1.35	4.9**
Min. temp. trend (°C)	-0.22***	0.45	-0.13	-0.76	-0.35	2.8*
Max. temperature (°C)	0.25***	-1.36	1.20	-0.02	0.89	12.5***
Max. temp. trend (°C)	0.07	-0.42	-0.03	-0.12	-0.13	0.5
Surface winds:						
Wind speed (m/s)	-0.20**	8.0	6.2	7.4	6.7	2.3
Wind speed trend (m/s)	-0.25***	1.6	-0.2	-1.6	0.0	5.4**
N-wind	-0.11	0.03	-0.20	-0.11	-0.39	4.1**
N-wind trend	-0.00	0.03	0.11	0.02	-0.17	0.9
NE-wind	-0.23***	-0.01	-0.13	-0.34	-0.74	10.8***
NE-wind trend	-0.05	0.06	0.12	-0.04	-0.27	2.0
NW-wind	0.09	0.06	-0.16	0.19	0.18	3.1*
NW-wind trend	0.04	-0.02	0.04	-0.02	0.04	0.1
W-wind	0.20**	0.05	-0.02	0.37	0.65	8.4***
W-wind trend	0.06	-0.06	-0.05	-0.04	0.22	1.1
High-altitude winds:						
Wind speed (m/s)	-0.23***	12.0	8.9	10.6	9.3	3.9**
Wind speed trend (m/s)	-0.32***	2.7	-0.3	-0.9	-1.8	6.4***
N-wind	-0.09	0.13	-0.22	-0.05	-0.11	3.2*
N-wind trend	0.07	-0.05	0.03	-0.01	-0.01	0.2
NE-wind	-0.19**	-0.12	-0.45	-0.42	-0.53	5.5**
NE-wind trend	0.02	0.02	-0.02	-0.01	0.00	0.0
NW-wind	0.05	0.30	0.15	0.35	0.37	1.3
NW-wind trend	0.08	-0.09	0.06	0.02	-0.02	0.6
W-wind	0.17**	0.30	0.42	0.54	0.63	3.3*
W-wind trend	0.05	-0.08	0.05	0.02	-0.01	0.5

Multiple regression equation — n = 233, R = 0.64

-0.346	NE-wind (s)	$p < 0.001$
-0.275	wind speed (h)	$p < 0.001$
+0.263	min temp.	$p < 0.01$
-0.261	min temp.trend	$p < 0.001$
-0.192	rain 07-13hr	$p < 0.001$
+0.170	barom.pr.trend	$p < 0.01$
-0.147	wind speed trend (h)	$p < 0.05$
+0.130	visibility	$p < 0.05$

Multiple regression equation incl. days of delay — n = , R =

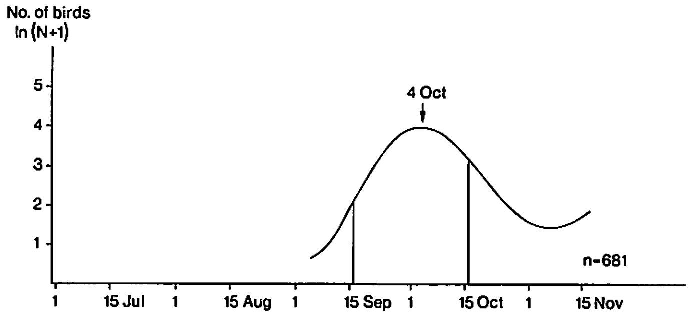
Multiple discriminant function — n = 233, R_c = 0.61

Mean of standardized discriminant score
Group 1=-0.81 Group 2=0.17 Group 3=0.30 Group 4=0.97

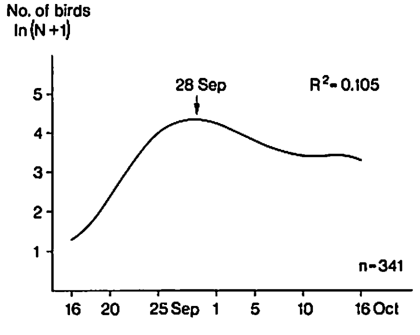
-0.580	NE-wind (s)	$p < 0.001$
-0.457	wind speed trend (h)	$p < 0.001$
-0.350	min temp.trend	$p < 0.01$
+0.347	barom.pressure	$p < 0.01$
+0.305	min temp.	$p < 0.05$
-0.091	NE-wind (h)	$p < 0.05$

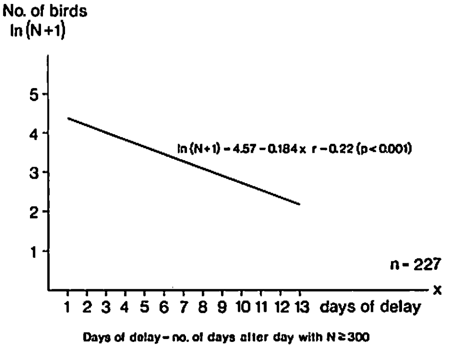
Multiple discriminant function incl. days of delay — n = , R_c =

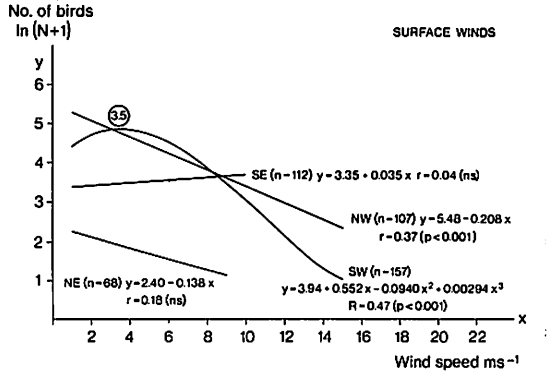
Mean of standardized discriminant score
Group 1= Group 2= Group 3= Group 4=

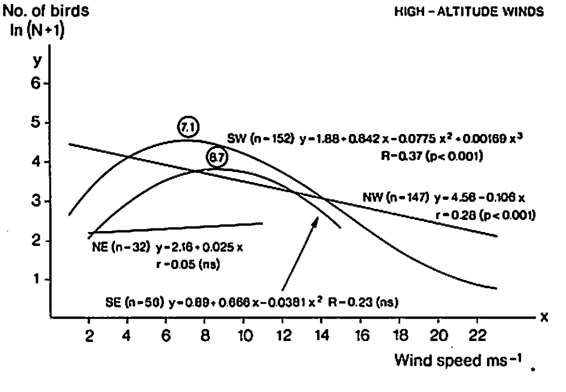


SISKIN
Carduelis spinus









SISKIN

Variable	Correlation Coefficient n = 309	Mean Group 1 n = 101	Group 2 n = 88	Group 3 n = 94	Group 4 n = 26	F^{3}_{305}
Cloud amount (scale 0-8)	0.05	5.5	5.1	5.5	6.2	1.2
Cloud ceiling (scale 0-9)	0.04	5.1	5.1	5.4	5.3	0.3
Convective clouds (scale 0-1)	-0.10	0.47	0.49	0.34	0.31	2.1
Visibility (scale 0-9)	-0.03	7.3	7.5	7.2	7.0	1.6
Rain 0700 hr (scale 0-2)	-0.14*	0.29	0.09	0.13	0.08	2.6
Rain 0700-1300 hr (scale 0-2)	-0.15**	0.43	0.18	0.23	0.19	2.9*
Relative humidity (%)	0.18**	89.7	91.2	91.4	94.1	3.6*
Rel. humidity trend (%)	0.05	-0.9	0.8	0.1	-0.1	0.7
Barometric pressure (mb)	0.14*	1012.2	1013.9	1015.3	1017.0	3.0*
Barom. pressure trend (mb)	0.09	-1.00	0.30	-0.15	-0.46	2.0
Temperature (°C)	0.26***	-0.53	-0.45	0.46	1.92	10.6***
Temperature trend (°C)	0.02	-0.03	-0.40	-0.05	0.21	1.3
Min. temperature (°C)	0.13*	-0.20	-0.72	0.09	1.95	6.7***
Min. temp. trend (°C)	-0.12*	0.39	-0.41	-0.70	0.38	4.3**
Max. temperature (°C)	0.19***	-0.84	-0.32	0.32	0.90	4.9**
Max. temp. trend (°C)	0.08	-0.42	-0.08	-0.01	-0.27	0.8
Surface winds:						
Wind speed (m/s)	-0.20***	8.4	6.7	6.1	6.8	6.2***
Wind speed trend (m/s)	-0.16**	1.4	-0.6	-1.2	0.7	5.9***
N-wind	-0.12*	-0.11	-0.03	-0.20	-0.40	3.1*
N-wind trend	0.02	-0.05	0.13	0.02	-0.29	2.5
NE-wind	-0.20***	-0.12	-0.15	-0.33	-0.58	4.5**
NE-wind trend	-0.07	-0.00	0.08	-0.02	-0.26	1.5
NW-wind	0.04	-0.03	0.12	0.05	0.02	0.7
NW-wind trend	0.03	-0.07	0.11	0.05	-0.16	1.3
W-wind	0.15**	0.07	0.19	0.27	0.43	2.1
W-wind trend	0.07	-0.05	0.02	0.05	0.07	0.3
High-altitude winds:						
Wind speed (m/s)	-0.21***	12.0	10.2	9.3	9.2	4.5**
Wind speed trend (m/s)	-0.21***	1.9	-0.3	-0.9	-0.9	4.4**
N-wind	-0.11	-0.03	0.06	-0.12	-0.34	2.8*
N-wind trend	-0.03	0.00	0.10	-0.01	-0.14	1.1
NE-wind	-0.14*	-0.32	-0.24	-0.42	-0.69	4.5**
NE-wind trend	-0.02	-0.01	0.08	-0.05	-0.12	1.0
NW-wind	-0.02	0.28	0.33	0.25	0.21	0.3
NW-wind trend	-0.02	0.01	0.07	0.03	-0.08	0.3
W-wind	0.08	0.42	0.40	0.48	0.63	1.1
W-wind trend	0.00	0.02	-0.01	0.05	0.03	0.2

Multiple regression equation n = 309, R = 0.49

+0.380	W-wind (s)	$p < 0.001$
+0.242	temp.	$p < 0.001$
-0.222	wind speed (h)	$p < 0.01$
-0.177	NW-wind (h)	$p < 0.05$
-0.163	wind speed (s)	$p < 0.05$
-0.146	min temp.trend	$p < 0.01$
+0.107	barom.pr.trend	$p < 0.05$

Multiple regression equation incl. days of delay n = 208, R = 0.54

+0.363	temp.	$p < 0.001$
-0.245	wind speed trend (h)	$p < 0.001$
+0.218	visibility	$p < 0.01$
-0.191	rain 07-13hr	$p < 0.01$
+0.173	rel.humidity	$p < 0.01$
-0.149	days of delay -1	$p < 0.05$

Multiple discriminant function n = 309, $R_c = 0.44$

Mean of standardized discriminant score

Group 1=-0.57 Group 2=0.00 Group 3=0.45 Group 4=0.60

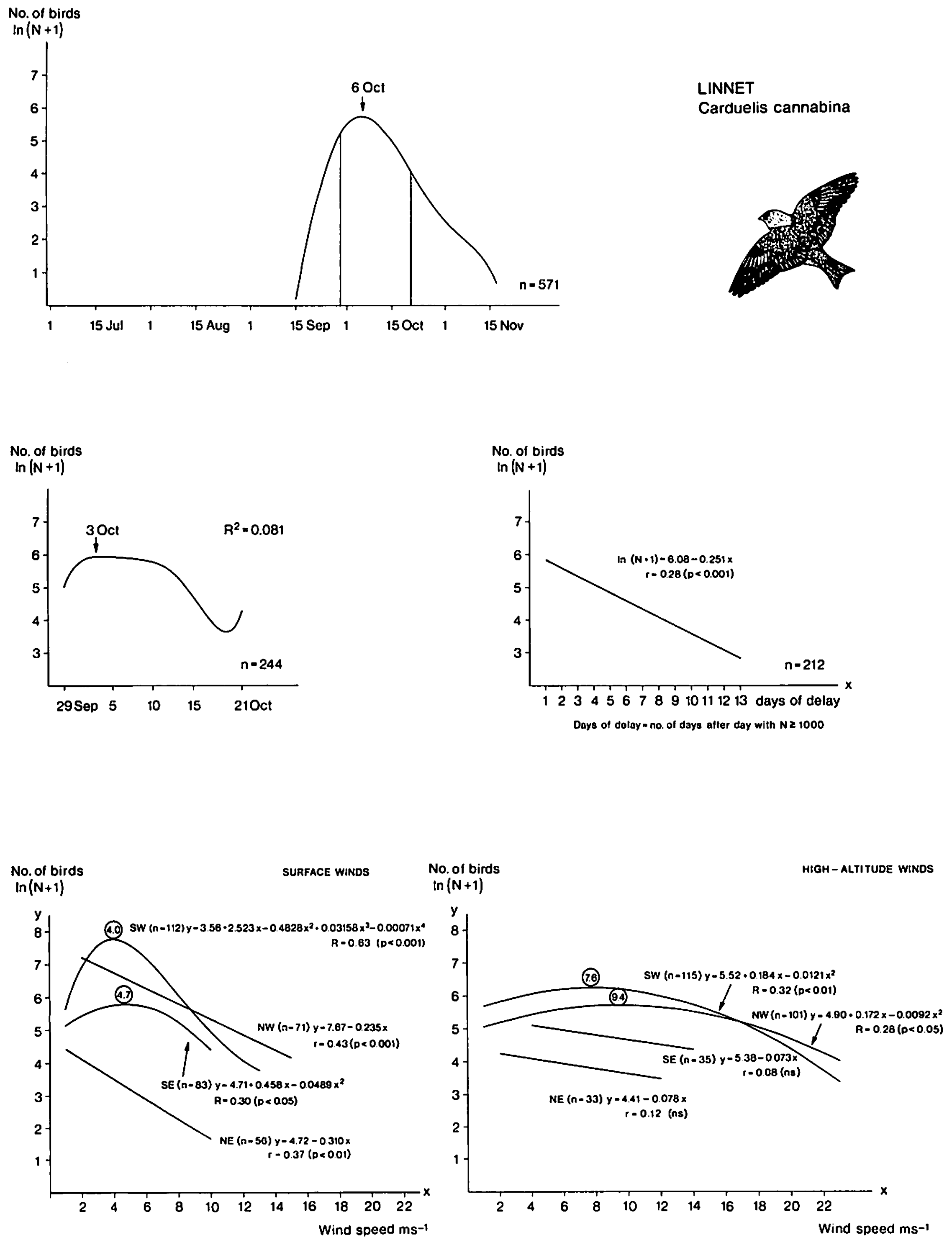
-0.760	wind speed (s)	$p < 0.001$
+0.610	temp.	$p < 0.001$
+0.515	W-wind (s)	$p < 0.01$
-0.402	min temp.trend	$p < 0.01$

Multiple discriminant function incl. days of delay n = 208, $R_c = 0.48$

Mean of standardized discriminant score

Group 1=-0.76 Group 2=-0.06 Group 3=0.32 Group 4=0.70

+0.624	temp.	$p < 0.001$
-0.473	wind speed trend (s)	$p < 0.001$
-0.438	rain 07-13hr	$p < 0.001$
-0.405	days of delay -1	$p < 0.05$


No. of birds
ln (N + 1)
6 Oct
n = 571
1
15 Jul
1
15 Aug
1
15 Sep
1
15 Oct
1
15 Nov
LINNET
Carduelis cannabina
No. of birds
ln (N + 1)
3 Oct
R² = 0.081
n = 244
29 Sep
5
10
15
21 Oct
No. of birds
ln (N + 1)
ln (N + 1) = 6.08 − 0.251 x
r = 0.28 (p < 0.001)
n = 212
1 2 3 4 5 6 7 8 9 10 11 12 13 days of delay
Days of delay = no. of days after day with N ≥ 1000
No. of birds
ln (N+1)
SURFACE WINDS
4.0
SW (n = 112) y = 3.56 + 2.523 x − 0.4828 x² + 0.03158 x³ − 0.00071 x⁴
R = 0.63 (p < 0.001)
4.7
NW (n = 71) y = 7.67 − 0.235 x
r = 0.43 (p < 0.001)
SE (n = 83) y = 4.71 + 0.458 x − 0.0489 x²
R = 0.30 (p < 0.05)
NE (n = 56) y = 4.72 − 0.310 x
r = 0.37 (p < 0.01)
Wind speed ms⁻¹
No. of birds
ln (N + 1)
HIGH-ALTITUDE WINDS
7.6
9.4
SW (n = 115) y = 5.52 + 0.184 x − 0.0121 x²
R = 0.32 (p < 0.01)
NW (n = 101) y = 4.90 + 0.172 x − 0.0092 x²
R = 0.28 (p < 0.05)
SE (n = 35) y = 5.38 − 0.073 x
r = 0.08 (ns)
NE (n = 33) y = 4.41 − 0.078 x
r = 0.12 (ns)
Wind speed ms⁻¹

LINNET

Variable	Correlation Coefficient n = 223	Mean Group 1 n = 54	Group 2 n = 61	Group 3 n = 71	Group 4 n = 37	F^{3}_{219}
Cloud amount (scale 0-8)	-0.06	6.1	5.6	5.9	6.0	0.5
Cloud ceiling (scale 0-9)	0.13*	4.7	5.2	5.1	5.4	0.9
Convective clouds (scale 0-1)	-0.10	0.39	0.43	0.32	0.16	2.7*
Visibility (scale 0-9)	0.03	6.9	7.3	7.2	7.0	1.1
Rain 0700 hr (scale 0-2)	-0.33***	0.56	0.11	0.11	0.05	8.4***
Rain 0700-1300 hr (scale 0-2)	-0.32***	0.63	0.26	0.21	0.08	6.6***
Relative humidity (%)	0.12	90.1	89.0	91.4	92.7	2.4
Rel. humidity trend (%)	0.01	0.3	-1.7	-0.1	1.4	1.0
Barometric pressure (mb)	0.15*	1012.7	1014.7	1015.3	1016.2	1.3
Barom. pressure trend (mb)	0.16*	-1.66	0.28	-0.86	-0.06	2.4
Temperature (°C)	0.18**	-0.54	-0.39	0.43	0.94	3.6*
Temperature trend (°C)	-0.05	0.24	-0.48	-0.07	0.31	2.1
Min. temperature (°C)	0.09	-0.27	-0.70	0.26	0.76	2.3
Min. temp. trend (°C)	-0.16*	0.63	-0.51	0.04	-0.49	2.5
Max. temperature (°C)	0.17**	-0.60	-0.09	0.27	0.92	2.4
Max. temp. trend (°C)	0.01	-0.30	-0.16	-0.37	0.30	1.0
Surface winds:						
Wind speed (m/s)	-0.27***	8.5	6.7	6.3	6.1	4.4**
Wind speed trend (m/s)	-0.32***	2.7	-0.5	-0.9	-1.1	7.9***
N-wind	-0.19**	0.02	0.02	-0.24	-0.37	4.9**
N-wind trend	0.01	-0.06	0.17	-0.01	-0.13	1.4
NE-wind	-0.32***	0.14	-0.06	-0.42	-0.57	12.8***
NE-wind trend	-0.07	0.02	0.21	-0.04	-0.24	3.0*
NW-wind	0.07	-0.11	0.09	0.08	0.05	1.0
NW-wind trend	0.08	-0.09	0.03	0.04	0.05	0.4
W-wind	0.26***	-0.18	0.10	0.35	0.44	7.4***
W-wind trend	0.10	-0.08	-0.13	0.06	0.21	1.8
High-altitude winds:						
Wind speed (m/s)	-0.20**	12.4	10.4	9.4	9.7	3.0*
Wind speed trend (m/s)	-0.30***	3.5	-0.5	-1.2	-1.9	8.7***
N-wind	-0.12	0.01	0.11	-0.12	-0.21	2.2
N-wind trend	0.01	-0.16	0.27	-0.06	-0.19	5.7**
NE-wind	-0.24***	-0.07	-0.28	-0.45	-0.53	5.6**
NE-wind trend	-0.07	-0.02	0.16	-0.07	-0.16	2.6
NW-wind	0.06	0.08	0.43	0.29	0.24	2.8*
NW-wind trend	0.07	-0.21	0.21	-0.02	-0.11	4.3**
W-wind	0.22***	0.11	0.50	0.52	0.54	6.6***
W-wind trend	0.10	-0.14	0.03	0.03	0.04	1.0

Multiple regression equation n = 223, R = 0.68

-0.584	NE-wind (s)	$p < 0.001$
-0.282	wind speed trend (s)	$p < 0.001$
-0.271	wind speed (h)	$p < 0.001$
-0.166	rain 07hr	$p < 0.01$
+0.163	N-wind trend (s)	$p < 0.01$
-0.160	rain 07-13hr	$p < 0.01$
-0.141	min temp.trend	$p < 0.01$

Multiple regression equation incl. days of delay n = 192, R = 0.71

-0.492	NE-wind (s)	$p < 0.001$
-0.292	wind speed trend (s)	$p < 0.001$
-0.267	rain 07hr	$p < 0.001$
-0.266	wind speed (h)	$p < 0.001$
-0.173	days of delay -1	$p < 0.01$
-0.161	rel.hum.trend	$p < 0.01$
-0.147	min temp.trend	$p < 0.01$
-0.132	N-wind (h)	$p < 0.05$
+0.131	NW-wind trend (s)	$p < 0.05$

Multiple discriminant function n = 223, $R_c = 0.67$

Mean of standardized discriminant score
Group 1=-1.13 Group 2=0.07 Group 3=0.45 Group 4=0.66

-0.710	NE-wind (s)	$p < 0.001$
-0.430	wind speed (s)	$p < 0.001$
-0.360	rain 07hr	$p < 0.001$
-0.360	wind speed trend (h)	$p < 0.001$
+0.302	visibility	$p < 0.01$
+0.226	N-wind trend (h)	$p < 0.001$
-0.226	NE-wind (h)	$p < 0.05$

Multiple discriminant function incl. days of delay n = 192, $R_c = 0.69$

Mean of standardized discriminant score
Group 1=-1.14 Group 2=0.01 Group 3=0.49 Group 4=0.71

-0.691	NE-wind (s)	$p < 0.001$
-0.417	rain 07hr	$p < 0.001$
-0.378	wind speed trend (h)	$p < 0.001$
-0.332	wind speed (s)	$p < 0.01$
-0.319	days of delay -1	$p < 0.01$
+0.080	N-wind trend (h)	$p < 0.05$
+0.018	W-wind (h)	$p < 0.05$

APPENDIX B. Weather variables

Weather variables have been measured at different weather stations and times (local time corresponding to GMT + 1 hour), and have been assessed as follows:

Cloud amount (Falsterbo, 07 hour): cloud cover in eights.

Cloud ceiling (Falsterbo, 07 hour): altitude of base of lowermost clouds according to a scale from 0 to 9 used by the Swedish Meteorological and Hydrological Institute (SMHI). 9 refers to a cloud base above 2500 m and is also given when there are no clouds.

Convective clouds (Falsterbo, 07 hour): 0 denotes the absence and 1 the presence of cumulus and/or cumulonimbos clouds.

Visibility (Falsterbo, 07 hour): this variable is given according to a scale from 0 to 9 as defined by SMHI.

Rain 0700 hr (Falsterbo, 07 hour): 0 denotes no rain, 1 rain shower and 2 continuous rain or drizzle.

Rain 0700–1300 hrs (Falsterbo, 13 hour): 0 denotes no rain, 1 rain showers and 2 continuous rain or dizzle during the six-hour period preceding the observation.

Relative humidity (Lund, 07 hour): in %. This variable, as well as a few others (see below) has not been registered at Falsterbo throughout the study period, and records from Lund (Fig. 1) have been used.

Barometric pressure (Falsterbo, 07 hour): in mb.

Temperature (Falsterbo, 07 hour): the difference from the normal temperature in °C. Normal temperatures have been calculated by way of a fourth-degree polynomial regression of temperature from 25 autumns, 1949 to 1973, on date. The same procedure has been used to determine normal minimum and maximum temperatures (cf. below).

Minimum temperature (Lund, 07 hour): the lowest temperature during the night, given in °C as the difference from the normal minimum temperature.

Maximum temperature (Lund, 19 hour): the highest temperature during the day, given in °C as the difference from the normal maximum temperature.

Surface winds have been measured at Falsterbo at 07 hour.

High-altitude winds refer to radiosonde measurements at the 850 mb-level, corresponding to about 1500 m altitude, over Copenhagen at 01 hour.

Wind speed is given in m s^{-1}.

Wind direction has been measured at Falsterbo and Copenhagen to the nearest 10°, and four wind direction variables have been defined as the N-, NE-, NW- and W-component, respectively. By way of example, these four variables attain the following values for a wind from due east: N-wind: 0.00 (cos 90°), NE-wind: 0.71 (cos 45°), NW-wind: −0.71 (cos 135°), and W-wind: −1.00 (cos 180°).

Trends of weather variables refer to the change since previous day (24 hours), except barometric pressure trend, which gives the change during the preceding twelve hours.

In order to illuminate the intercorrelations between weather variables I have carried out factor analysis according to Nie et al. (1975). This analysis consists of two main steps, extraction of principal components (communalities were set to 1) and rotation of the factors to achieve high loadings on some variables and almost zero on others (varimax rotation was used). Factor analysis was carried out for each of the four months July to October on the basis of weather data from the eleven study years. Five factors, accounting for 56 to 58% of the total variance in the thirty-six weather variables, were determined for each month (cf. Sect. 2.2.). Correlation coefficients between original weather variables and factors are presented in the following tables, and correlation coefficients > 0.40 are shown in bold figures.

Weather factors	July. Proportion of total variance = 56.2%. n = 305					August. Proportion of total variance = 57.0%. n = 317					September. Proportion of total variance = 58.1%. N = 303					October. Proportion of total variance = 58.1%. n = 314				
Variable	Factor 1	2	3	4	5	Factor 1	2	3	4	5	Factor 1	2	3	4	5	Factor 1	2	3	4	5
Cloud amount (scale 0–8)	–0.00	–0.07	**–0.69**	–0.04	0.12	0.06	–0.03	0.14	**–0.70**	0.14	0.05	–0.21	–0.28	**0.44**	–0.08	–0.03	0.07	–0.07	0.09	**0.66**
Cloud ceiling (scale 0–9)	–0.20	–0.02	**0.53**	0.31	–0.23	–0.19	0.05	0.13	**0.53**	–0.30	–0.10	–0.15	–0.02	**–0.60**	0.03	–0.12	0.02	0.02	–0.15	**–0.51**
Convective clouds (scale 0–1)	0.20	0.01	0.23	–0.19	–0.03	0.29	–0.00	–0.21	0.20	–0.05	0.17	0.18	**0.47**	0.07	0.01	0.22	–0.16	0.01	0.19	–0.26
Visibility (scale 0–9)	0.11	–0.02	**0.66**	–0.16	0.12	–0.05	0.02	–0.26	**0.54**	0.25	0.11	–0.01	**0.57**	–0.13	0.12	–0.01	**–0.54**	0.04	0.27	–0.33
Rain 0700 hr (scale 0–2)	–0.11	–0.05	**–0.55**	–0.05	0.04	–0.03	0.08	–0.02	**–0.63**	–0.05	–0.23	0.02	–0.15	0.39	–0.11	–0.09	–0.05	–0.08	0.16	**0.63**
Rain 0700–1300 hrs (scale 0–2)	–0.15	0.04	**–0.95**	–0.05	0.13	–0.18	–0.00	–0.01	**–0.58**	0.22	–0.11	–0.11	0.03	**0.49**	0.10	–0.10	–0.02	0.03	0.05	**0.60**
Relative humidity (%)	0.09	0.18	**–0.71**	–0.05	–0.19	–0.03	–0.20	–0.02	**–0.53**	**–0.47**	0.03	–0.06	**–0.46**	0.14	**–0.56**	0.10	0.35	–0.27	–0.29	0.33
Rel. humidity trend (%)	–0.02	0.15	**–0.48**	0.20	–0.31	–0.09	–0.17	–0.00	–0.29	**–0.51**	0.07	–0.11	–0.13	0.04	**–0.63**	0.05	0.08	**–0.41**	**–0.41**	0.13
Barometric pressure (mb)	0.08	–0.03	**0.56**	0.24	–0.24	0.06	0.11	0.23	**0.57**	–0.27	–0.01	–0.05	–0.01	**–0.78**	–0.10	–0.04	–0.22	–0.07	–0.38	–0.22
Barom. pressure trend (mb)	**0.46**	0.11	**0.42**	–0.21	0.02	**0.44**	0.00	–0.18	0.35	–0.19	0.17	0.39	0.30	–0.23	–0.23	0.22	–0.23	**0.44**	–0.28	**–0.43**
Temperature (°C)	–0.12	–0.03	0.27	**0.78**	–0.16	–0.06	–0.06	**0.82**	0.07	0.03	0.23	–0.12	**–0.76**	–0.12	0.08	0.06	**0.86**	–0.06	0.22	0.09
Temperature trend (°C)	–0.28	–0.07	0.03	0.20	**–0.48**	–0.39	–0.09	0.34	0.13	0.07	0.14	**–0.59**	–0.29	–0.15	0.15	0.07	0.13	**–0.56**	0.10	**0.42**
Min. temperature (°C)	0.10	–0.00	–0.04	**0.79**	0.12	0.14	–0.03	**0.74**	–0.21	0.23	0.12	0.02	**–0.84**	0.10	0.24	0.02	**0.83**	0.08	0.18	0.21
Min. temp. trend (°C)	–0.02	–0.02	–0.23	**0.46**	0.06	–0.04	–0.05	**0.46**	–0.10	0.35	0.01	–0.32	–0.38	–0.03	**0.46**	–0.01	0.16	–0.26	0.05	**0.45**
Max. temperature (°C)	–0.12	–0.00	**0.42**	**0.71**	–0.31	–0.04	0.05	**0.70**	**0.42**	–0.29	0.01	–0.02	**–0.56**	**–0.60**	–0.02	–0.06	**0.83**	–0.01	–0.02	–0.11
Max. temp. trend (°C)	–0.09	–0.02	0.27	–0.03	**–0.52**	–0.08	–0.01	–0.06	0.26	**–0.40**	–0.10	–0.08	0.04	–0.35	–0.14	–0.02	0.17	–0.37	–0.08	0.03
Surface winds:																				
Wind speed (m/s)	0.20	0.07	0.00	–0.35	**0.70**	0.10	–0.07	–0.25	–0.17	**0.73**	0.18	0.05	0.15	**0.52**	**0.57**	0.16	0.09	0.02	**0.85**	0.08
Wind speed trend (m/s)	0.09	0.07	0.05	0.14	**0.77**	0.06	0.09	0.17	–0.05	**0.71**	0.15	–0.04	–0.16	0.15	**0.72**	0.01	0.00	–0.07	**0.63**	0.28
N-wind	**0.70**	**–0.40**	0.16	0.15	–0.17	**0.58**	**0.47**	–0.17	0.27	0.06	0.11	**0.62**	**0.42**	–0.31	0.04	0.39	**–0.61**	**0.48**	–0.09	–0.07
N-wind trend	**0.65**	–0.35	–0.08	–0.01	0.09	**0.64**	**0.42**	–0.02	–0.00	0.20	0.18	**0.85**	–0.04	0.00	0.01	**0.41**	0.03	**0.78**	–0.10	0.03
NE-wind	0.03	**–0.71**	0.21	0.39	–0.25	0.03	**0.78**	0.36	0.15	–0.14	**–0.52**	**0.43**	–0.08	**–0.54**	0.04	–0.27	**–0.63**	**0.44**	–0.37	0.06
NE-wind trend	0.03	**–0.71**	–0.02	–0.22	–0.17	–0.06	**0.72**	–0.19	0.04	0.07	**–0.51**	**0.67**	0.05	0.06	–0.14	–0.19	0.00	**0.79**	–0.10	–0.19
NW-wind	**0.82**	0.15	0.01	–0.17	0.01	**0.64**	–0.14	**–0.51**	0.18	0.20	**0.65**	0.34	**0.43**	0.15	0.01	**0.79**	–0.13	0.16	0.27	–0.16
NW-wind trend	**0.77**	0.13	–0.08	0.16	0.24	**0.84**	–0.05	0.12	–0.04	0.19	**0.70**	**0.43**	–0.10	–0.05	0.15	**0.73**	0.04	0.34	–0.05	0.21
W-wind	**0.55**	**0.54**	–0.12	–0.36	0.16	**0.42**	**–0.55**	**–0.55**	0.03	0.21	**0.75**	–0.06	0.23	**0.44**	–0.02	**0.67**	0.33	–0.19	**0.41**	–0.14
W-wind trend	**0.56**	**0.52**	–0.04	0.25	0.28	**0.67**	**–0.47**	0.20	–0.05	0.10	**0.79**	–0.13	–0.10	–0.07	0.19	**0.67**	0.03	–0.28	0.03	0.29
High-altitude winds:																				
Wind speed (m/s)	–0.00	0.16	–0.00	–0.14	**0.66**	–0.02	–0.24	–0.19	–0.22	**0.63**	0.14	0.02	0.02	**0.57**	**0.43**	0.12	0.20	0.03	**0.77**	0.00
Wind speed trend (m/s)	–0.06	0.15	–0.03	0.21	**0.68**	–0.05	–0.16	0.22	–0.07	**0.58**	0.11	–0.08	–0.18	0.15	**0.70**	–0.12	–0.01	–0.10	**0.63**	0.21
N-wind	**0.73**	–0.15	0.22	–0.07	–0.06	**0.61**	0.23	**–0.45**	0.15	0.00	0.28	0.35	**0.71**	–0.08	0.00	**0.56**	**–0.56**	0.21	0.04	–0.22
N-wind trend	**0.72**	–0.17	0.08	–0.05	0.21	**0.79**	0.20	–0.04	–0.16	–0.00	**0.40**	**0.71**	0.11	0.01	0.12	**0.61**	–0.07	**0.59**	–0.06	–0.01
NE-wind	0.35	**–0.62**	0.22	0.32	–0.08	0.27	**0.73**	0.10	0.11	–0.10	–0.22	**0.44**	**0.52**	**–0.44**	0.13	0.02	**–0.81**	0.37	–0.10	0.05
NE-wind trend	0.33	**–0.67**	–0.03	–0.10	0.10	0.30	**0.68**	–0.13	–0.14	0.03	–0.22	**0.80**	0.13	0.07	0.08	0.13	–0.11	**0.82**	0.07	–0.02
NW-wind	**0.62**	**0.40**	0.08	**–0.40**	0.50	**0.51**	–0.33	**–0.62**	0.08	0.08	**0.59**	0.09	**0.52**	0.29	–0.12	**0.74**	0.01	–0.06	0.15	–0.36
NW-wind trend	**0.67**	0.33	0.13	0.02	0.19	**0.79**	–0.33	0.06	–0.09	–0.03	**0.75**	0.22	0.03	–0.04	0.09	**0.75**	0.01	0.07	–0.16	0.01
W-wind	0.20	**0.68**	–0.09	**–0.48**	0.06	0.21	**–0.68**	**–0.51**	–0.01	0.12	**0.60**	–0.23	0.04	**0.53**	–0.18	**0.52**	**0.56**	–0.30	0.17	–0.29
W-wind trend	0.31	**0.69**	0.12	0.08	0.08	**0.40**	**–0.70**	0.14	0.03	–0.04	**0.70**	–0.38	–0.06	–0.08	0.01	**0.48**	0.09	**–0.54**	–0.18	0.02