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A STATISTICAL METHOD FOR DETERMINATION OF FLIGHT SPEEDS OF MIGRATING BIRDS

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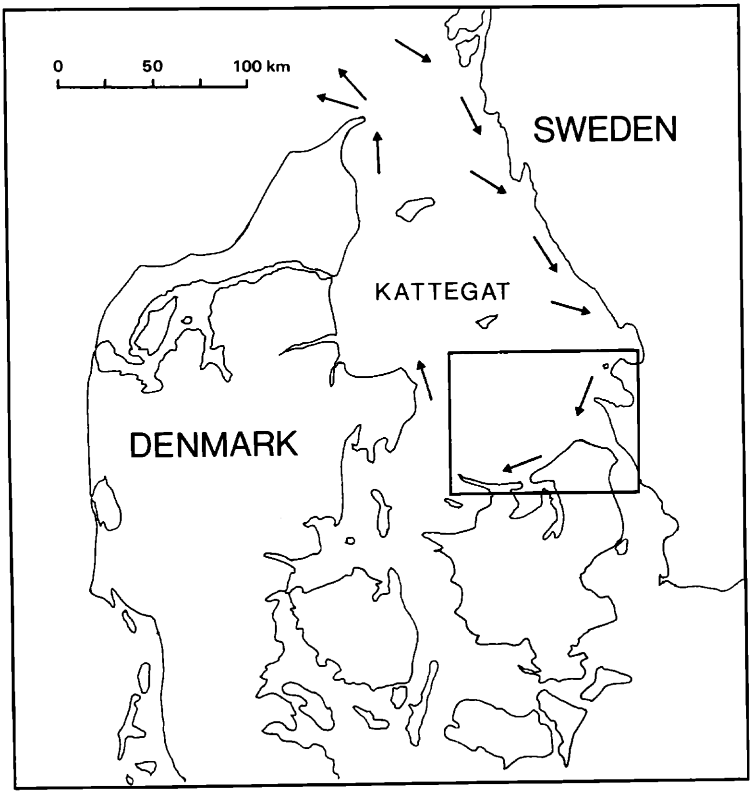
The migratory intensity of birds usually fluctuates during a day. Often, the number of birds leaving an area or passing a watchpoint gradually increases in the early morning, reaches a peak, and then declines. The propagation of the movement can be recognized by ornithologists as the time lag when a distinct peak in the migration intensity appears at adjacent watchpoints. This "lag" can be used to estimate the birds' average flight time between the places.

A more reliable estimation of the flight time is obtained if variations in the entire movement intensity are considered. In the present paper, such a procedure for flight time determinations is described. The method is based upon simple statistics and has been tested upon field data concerning migrating Black-legged Kittiwakes (*Rissa tridactyla*) in the southern Kattegat, southwestern Scandinavia (Fig. 1). Obtained average flight times have been adopted for calculations of groundspeeds and airspeeds for the migrating kittiwakes.

MATERIALS AND METHODS

Field data and study area.—Counts concerning movements of kittiwakes in the southern Kattegat, during the years 1978–1979, were obtained from the Scandinavian Seabird Group (Table 1). Most of the birds followed the main movement pattern of seabirds in the Kattegat (Fig. 1). Birds moving in other directions have been left out of the analysis. During prevailing wind conditions (strong WSW-NW winds, Table 1), movements of kittiwakes are near the sea surface (Götmark 1980, Peterz and Rönnertz 1980).

Method for flight speed determination.—Data have been handled as follows: The time of observation each day was divided into overlapping periods of 30 min (. . . 0900–0930, 0910–0940, 0920–0950 . . .). The corresponding number of counted birds at a watchpoint constitutes a numerical series. Two series from the same day and different watchpoints are related to each other by linear regression analysis and the correlation coefficient r is calculated. By time-displacing the series in relation to each other, new regression analyses can be performed. Revealed values of correlation coefficients for every 10 min displacement are then fitted to a line by a cubic spline function (e.g., Ahlberg et al. 1967). The obtained time t associated with the highest correlation is an estimate of the birds' average flight time between the places in question. Figure 2 shows a typical result concerning the relationship between correlation coefficients and time displacements. Migration data corresponding to Fig. 2 are illustrated in Fig. 3. When the time scale of locale


0 50 100 km
SWEDEN
KATTEGAT
DENMARK

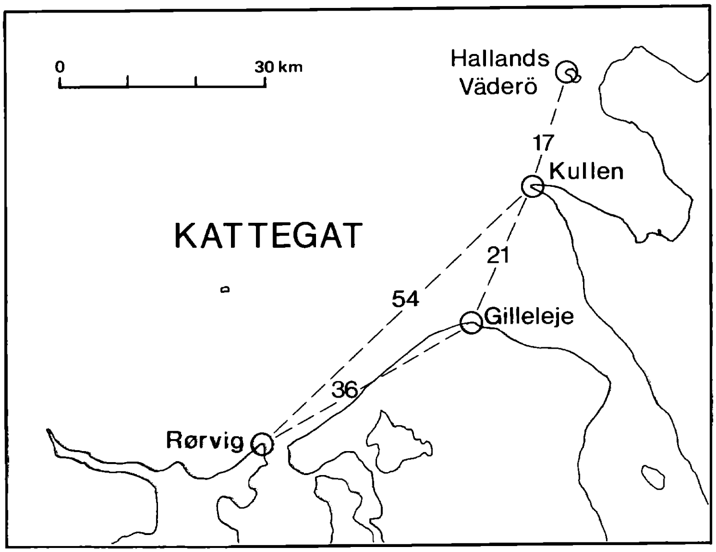

0 30 km
Hallands Väderö
17
Kullen
KATTEGAT
21
54
Gilleleje
36
Rørvig

TABLE 1. Field data concerning movements of kittiwakes in the southern Kattegat, during the years 1978–1979.

Occasion no.	Wind direction	Wind speed (m/s)	α[a]	Watchpoints	Number of birds
1	W	23	116	Kullen Gilleleje	1400 1846
2	W	20	138	Kullen Rørvig	195 209
3	W	13	109	Hallands Väderö Kullen	99 175
4	WSW	14	132	Hallands Väderö Kullen	63 90
5	NW	13	71	Kullen Gilleleje	3350 1391
6	NW	13	93	Kullen Rørvig	3350 1149
7	NW	13	108	Gilleleje Rørvig	1391 1149

[a] α is the angle between wind direction and the straight line connecting the watchpoints (0° = tail wind, 180° = head wind).

B is displaced by a factor t, maxima and minima in the movement intensity at both places will coincide (Fig. 3b).

The speed of movement relative to the earth's surface, groundspeed (V_g), is calculated with knowledge of the flight time. The distance between the watchpoints is measured along the straight line (Fig. 1). By using vector addition of windspeed (V_w) and groundspeed, the birds' speed relative to the airmass, airspeed (V_a), is obtained:

$$V_a^2 = V_g^2 + V_w^2 - 2V_gV_w\cos\alpha, \qquad (1)$$

where α is the angle between the wind direction and the line connecting the watchpoints (0° = tailwind, 180° = headwind). Wind observations for every third hour were obtained from the local weather observatory at Kullen (72 m above sea level).

RESULTS AND DISCUSSION

Flight times and flight speeds of kittiwakes in the southern Kattegat are listed in Table 2. As a consequence of prevailing wind conditions (often strong head winds) the airspeeds generally exceed the ground-

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FIGURE 1. Distances between watchpoints in the southern Kattegat. Arrows denote the main movement pattern of seabirds in the Kattegat area (Pettersson and Unger 1972, Blomqvist and Peterz 1984).

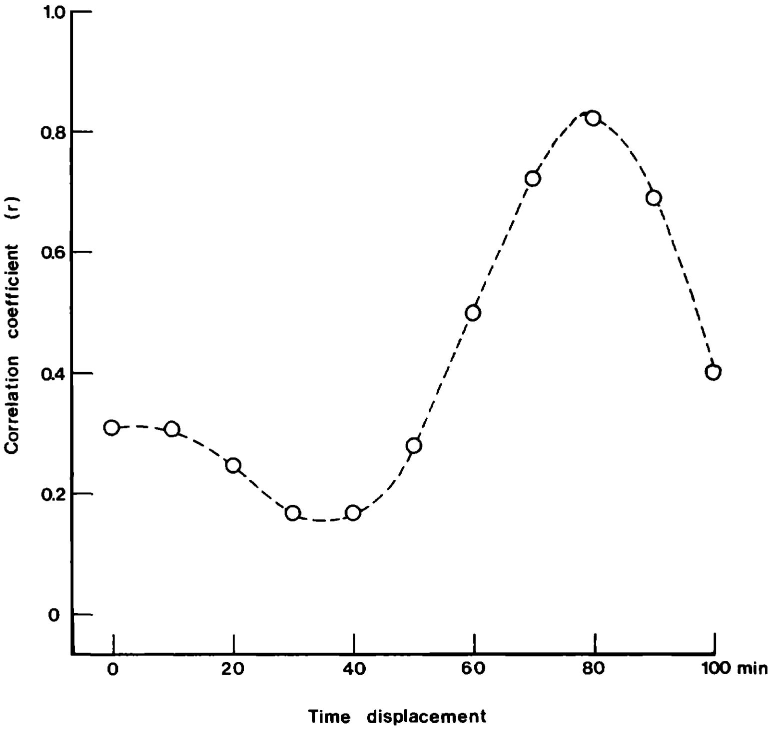

FIGURE 2. Variation of the correlation coefficient by time-displacing numerical series from two watchpoints in relation to each other (occasion No. 2 in Tables 1 and 2). Dotted line shows the cubic spline function.

TABLE 2. Calculated flight times and flight speeds of kittiwakes in the southern Kattegat. Numerals as in Table 1.

Occasion no.	r[a]	n[b]	t[c] (min)	Groundspeed (m/s)	Airspeed (m/s)
1	0.60	18	141	2.5	24.2
2	0.82	18	79	11.4	29.5
3	0.80	22	28	10.1	18.9
4	0.74	9	44	6.4	18.9
5	0.86	21	13	26.9	25.8
6	0.88	28	54	16.7	21.7
7	0.92	22	57	10.5	19.1
Mean				12.1	22.6
Standard deviation				7.87	4.10

[a] Maximum value of the correlation coefficient.
[b] Number of periods used when calculating r.
[c] Average flight time.

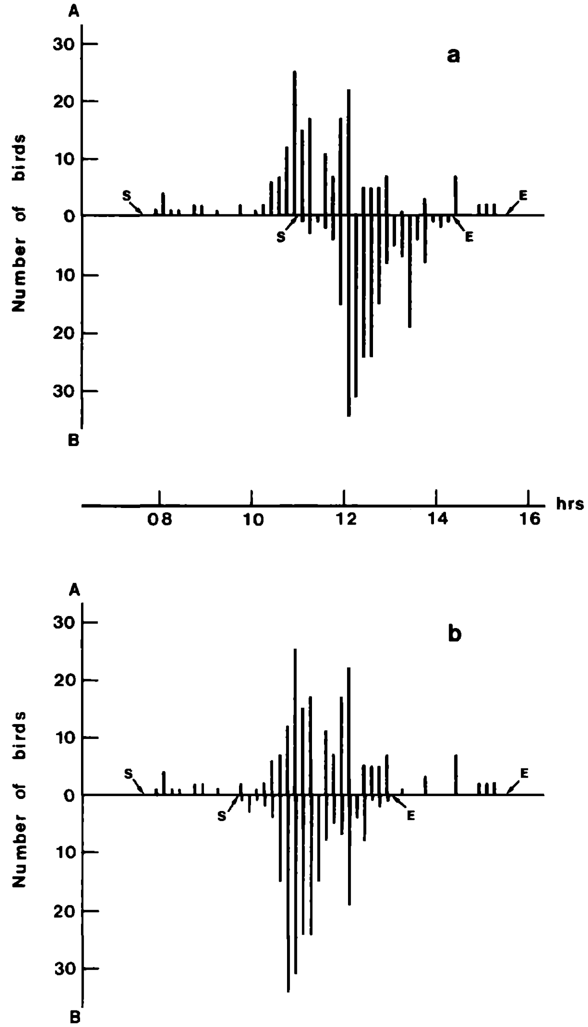

FIGURE 3. a. Counts per 10-min period of migrating kittiwakes at Kullen (A) and Rørvig (B) (occasion No. 2 in Tables 1 and 2). S and E denote start and end of observations, respectively. b. Same as Fig. 3a but time scale of watchpoint B is displaced by 79 min (calculated average flight time).

speeds. The coefficient of variation of airspeeds is logically lower (18%) than of groundspeeds (65%).

A crucial point when calculating airspeeds seems to be the accessibility of accurate wind speed data. The airspeed of the kittiwake, 15 m/s, proposed by Götmark (1980) is calculated using wind speeds which were measured 40 m above sea level and then converted to lower altitudes according to a model of Smedman-Högström and Högström (1977). In accordance, wind speeds measured 72 m above sea level (this study) should be reduced by about 50% to correspond to wind speeds near a rough sea-surface. Such transformation results in a lower average air-speed ($\bar{x}$ = 16.7 m/s, SD = 4.84, n = 7), which is in agreement with Götmark's data.

There are several methods described for estimating flight speeds of birds (e.g., Larkin and Thompson 1980). Most of these methods require extensive field studies to obtain an adequately large sample of measurements. The present method makes it possible, with simple statistics and a restricted amount of field work, to determine the average flight speed of a great number of birds at one time. The method could be improved by the use of more elaborate statistical calculation procedures.

SUMMARY

A method is described for estimating flight speeds of birds by timing passage of flocks between distant observation points. Accurate wind-speed data, flight time, distance between watchpoints, and flock size are needed to allow time displacement of data from two watchpoints to calculate an average flight speed. This study in southwestern Scandinavia resulted in an estimated flight speed of 16.7 m/s for the Black-legged Kittiwake, a figure which compares favorably with estimates derived by other means.

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