Ground-speed and Air-speed according to Flock-size in Migrating Birds.

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(Med et dansk resumé: Flugthastighed og flokstørrelse.)

During earlier visits to the West coast of Jutland, Denmark, we had observed that the Oystercatchers (*Haematopus ostralegus*) on their autumn migration strictly followed the coast line which runs almost straight N–S. They dit not fly over the dunes at times as did the other waders, but followed the beach. As moreover all the Oystercatchers flew south we realized that they would be an ideal object for the speed-records which we had planned.

It must be mentioned, however, that in August 1955 some few speed-records were made during a camp held by the field committee of D.O.F. near Blåvandshuk. They were published in D.O.F.T. **50**, 1956, p. 299. In 1957 we had improved our methods and increased the effectivity of the records.

On the beach proper one kilometer was carefully measured out by means of a tape. This line, which was parallel to the coastline and hence to the direction of the movements of the Oystercatchers, was used as a basis for the speed-records. At each end of the basis were placed two sticks constituting a visible line at a right angle to the basis. Behind the sticks a combined radio and observation station was etablished. Each station consisted of at least two persons. One of them observed, counted and identified the passing birds. The other, who was in charge of the wireless set, pressed a stop-watch at the moment when the flock passed the line between the two sticks. He called the other post over the wireless, told them about the flock, made sure that they were properly informed and finally turned to listening in order to press the stopwatch at the moment when the other station informed him that the flock passed the line at the other end of the basis.

Simultaneously measurements of the strength and direction of the wind were taken. The strength was measured with a wind-meter (cf. fig. 1) which indicated how many meters of

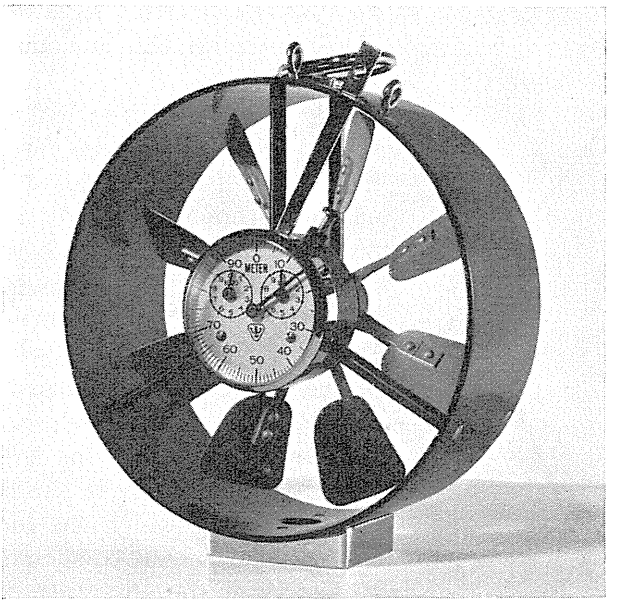

Fig. 1. The wind-meter used for the measurements.
Den til målinger anvendte vindmåler.

wind passed through the meter in the time measured. From this the strength in meters per second could be calculated. The direction of the wind was measured by a weather-cock and a compas.

In this way we had measurements of both the speed of flight of the birds and the direction and strength of the wind, and thus a correction for the air-speed of the birds was possible. These corrections were made by means of mathematical and not by the more complicated aerodynamic principles. Fig. 2 shows how the corrections were carried out.

For the calculation of the air-speed "a" we have the following formular:

$$a^2 = b^2 + c^2 \div 2\,bc \cos A\,.$$

In table 1 all results from the measurements concerning the Oystercatchers are recorded and the calculated air-speeds are added. Table 2 gives the strength of the wind and its angle to the direction of the migrating flocks. On August the 1st, 8th

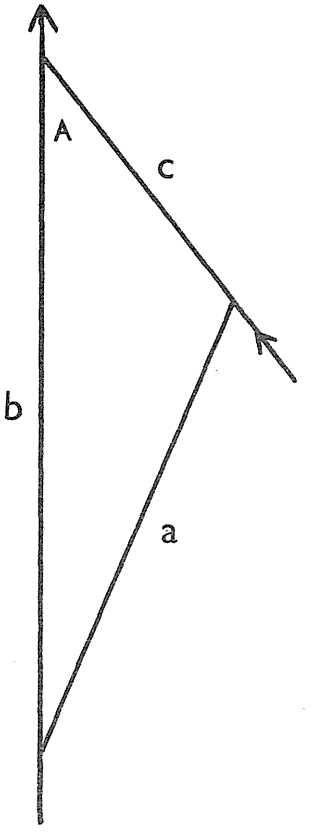

Fig. 2. Diagram showing method of calculating air-speed. a = Air-speed; b = Ground-speed; c = Velocity of wind; A = The wind's angle to the direction of the birds.

Diagram visende hvordan egenhastighederne er beregnede. a = *Egenhastighed;* b = *Den målte hastighed;* c = *Vindstyrke;* A = *Vindretningens vinkel på trækretningen.*

and 9th the measurements were made at Grærup, on the 3rd and 4th at Blåvand.

By the term "air-speed" we mean the speed at which the birds would have flown if they had used the same energy without any wind. It must be emphasized, however, that this term is purely theoretical. Moreover, it must be added that the measurements of the wind were taken two meters above the beach; this means that the calculations are not quite precise, since the strength of the wind supposedly is not quite the same in this height as at the level at which the birds were flying. We have not tried to eliminate this error as the observations of the height of the flocks are rather unprecise and as a certain error is introduced when calculating the strength of the wind at another level than at that at which it has been measured.

While carrying out the measurements we found that the Oystercatchers flew higher with fair wind than with headwind. In head-wind the birds flew low over the water while in fair wind they might fly rather high up. These observations agree well with the fact that near the ground the strength of the wind rises with the height. (LYSGAARD 1943, p. 110.) Obviously the birds fly there where optimum conditions are prevailing.

The speed measured is given in fig. 3, the air-speed calculated in fig. 4. The abscissa indicates the number of the individuals in each flock, while the ordinate gives the speed in kilometers per hour.

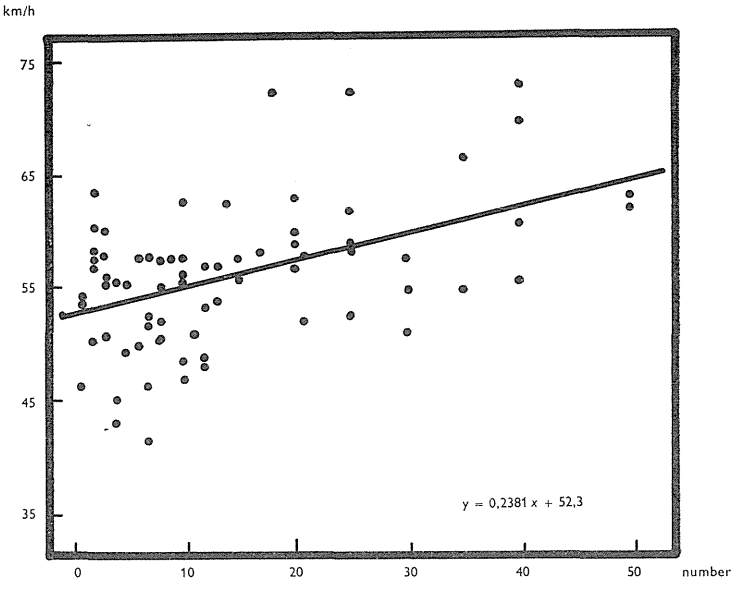

Fig. 3. The speed measured. Each dot represent a flock. Abscissa: numbers of individuals in the flock; ordinate: km/h.

Den målte hastighed. Hver prik angiver en flok. Abscisse: antallet af individer i flokken; ordinat: km/t.

The highest speed measured is 72.9 km/h while the lowest is 41.0 km/h. For the calculated air-speed the corresponding figures are 67.2 km/h and 35.6 km/h.

Concidering fig. 3 it is easily seen that the speed of the flocks rises with the number of individuals. So far this is in full accordance with the theory of MEINERTZHAGEN's (1955, p. 81) that the birds fly faster the bigger the flock.

Considering fig. 4 it looks different. By carring out a linear regression analysis, as for Fig. 3, we got an equation for the average curve by the formular $y = 0.0945\ x + 51.79$ in which y is km/h and x the number of individuals. Moreover t is found to be 1.632. A one-sided t-test gives $0.9 > P > 0.95$[1]). The one-sided t-test was carried out because MEINERTZHAGEN's theory presupposes that the speed increases with the number of individuals.

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[1]) P denotes the probability; $t = \dfrac{\text{Error in mean}}{\text{Standard error of mean}}$.

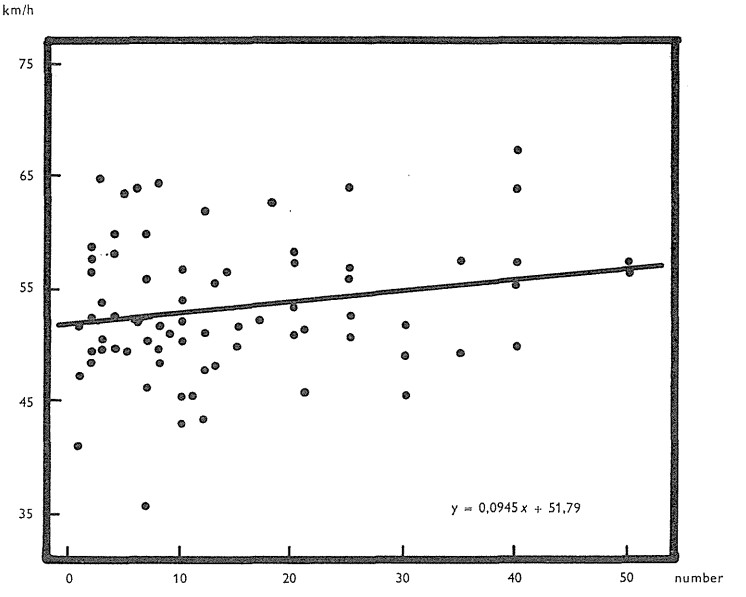

Fig. 4. The air-speed calculated. Each dot represent a flock. Abscissa: numbers of individuals in the flock; ordinate: km/h.

Den beregnede egenhastighed. Hver prik angiver en flok. Abscisse: antallet af individer i flokken; ordinat: km/t.

The significance for P is not absolute, but P is very near to 0.95. The uncernity in P may be increased by the calculations concerning the air-speed, and at the same time the very big spread in y proably influences P.

The results of the regression analysis thus gives, that with the present material we are not able to state with certainty that a rise in speed is correlated with increased size of flocks. However, the size of P indicates with some probability that the size of the flocks is of no influence on the speed. In any case it is not very great as the regressions coefficent is 0.09453.

These attempts may perhaps inspire other students to repeat this investigation in greater scale in order to clarify the problem.

TABEL 1.

The results of the measurements concerning the ground- and air-speed of the Oystercatcher.

Resultaterne af målingerne vedrørende Strandskadernes flugthastigheder.

Date *Dato*	Hour *Klokkeslæt*	Number of birds in the flock *Antal fugle i flokken*	Time in sec. *Tid i sec.*	Km/h *Km/t*	Air-speed *Egenhastighed*
Aug. 1.	07.46	3	62.5	57.6	50.6
"	09.07	1	67.6	53.3	47.1
– 3.	10.39	18	50.0	72.0	62.7
	11.03	2	63.3	56.9	49.3
	–	25	49.9	72.2	64.0
	17.14	3	60.0	60.0	52.5
	17.38	35	54.5	66.1	57.3
– 4.	06.16	40	59.5	60.5	55.1
	06.20	12	74.7	48.2	43.1
	–	12	63.8	56.4	51.0
	–	25	62.3	57.8	52.4
	06.30	8	65.6	54.9	49.6
	06.34	10	74.9	48.1	43.0
	06.35	13	67.2	53.6	48.3
	06.45	20	61.5	58.5	53.1
	06.50	40	51.8	69.5	63.8
	06.50	1	78.3	46.0	41.0
	–	20	64.0	56.3	50.9
	–	2	57.0	63.2	57.7
	07.05	35	66.2	54.4	49.1
	–	30	63.0	57.1	51.7
	07.10	30	70.9	50.8	45.6
	07.10	20	57.4	62.7	57.2
	07.12	11	71.0	50.7	45.5
	–	5	65.4	55.0	49.6
	–	25	58.5	61.5	56.0
	–	30	66.3	54.3	49.0
	–	50	58.2	61.9	56.4
	07.30	15	65.2	55.2	49.8
	07.35	50	57.2	62.9	57.4
	07.40	10	64.7	55.6	50.2
	07.42	12	67.9	53.0	47.7
	–	2	62.3	57.8	52.4
	07.54	15	63.0	57.1	51.7
	07.56	3	65.2	55.2	49.8
	08.02	10	62.6	57.5	52.1
	–	4	65.3	55.1	49.8
	–	17	62.4	57.7	52.3
	08.14	10	57.8	62.3	56.8
	–	40	65.2	55.2	49.8
	–	14	58.0	62.1	56.6
	–	40	49.4	72.9	67.2
	08.24	8	63.0	57.1	51.7
	08.26	6	62.6	57.5	52.1
	17.00	7	87.9	41.0	35.8
	–	7	69.0	52.2	46.3

Date *Dato*	Hour *Klokkeslæt*	Number of birds in the flock *Antal fugle i flokken*	Time in sec. *Tid i sec.*	Km/h *Km/t*	Air-speed *Egenhastighed*
	–	21	69.8	51.7	45.8
	17.35	21	62.6	57.5	51.4
	17.45	9	63.0	57.1	51.0
– 8.	07.47	7	70.2	51.3	50.6
	08.02	2	62.6	57.5	56.6
	–	7	62.8	57.3	55.9
	–	25	68.8	52.3	50.9
	17.13	25	61.7	58.3	56.9
	–	13	63.5	56.7	55.3
	–	10	65.1	55.3	53.9
Aug. 8.	–	1	67.5	53.3	51.9
	–	2	59.8	60.2	58.8
	–	3	65.2	55.2	53.8
	–	20	60.4	59.6	58.2
	19.36	2	72.0	50.0	48.6
	–	10	77.2	46.6	45.2
	20.20	8	71.9	50.1	48.7
– 9.	06.50	12	74.6	48.3	61.8
	–	8	70.0	51.4	64.5
	07.28	7	78.0	46.2	59.9
	07.51	4	84.4	42.7	58.2
	–	6	73.0	49.3	63.8
	08.27	3	71.2	50.6	64.9
	09.32	4	80.4	44.8	59.7
	09.40	5	73.4	49.0	63.3

TABEL 2.

The results of the measurements concerning the force and direction of the wind.

Resultaterne af målingerne vedrørende vindens styrke og retning.

Date *Dato*	Hour *Klokkeslæt*	Time in sec. *Tid i sec.*	The wind's angle to the direction of the birds *Vindretningens vinkel på trækretningen*
1. Aug. 1957.....	08.10	20.3	60°
1. Aug. 1957.....	08.35	17.3	60°
3. Aug. 1957.....	09.00	32.4	60°
3. Aug. 1957.....	11.30	28.5	60°
3. Aug. 1957.....	17.10	22.2	60°
3. Aug. 1957.....	17.45	30.1	60°
4. Aug. 1957.....	08.30	13.5	60°
4. Aug. 1957.....	18.00	16.2	60°
8. Aug. 1957.....	08.10	11.2	80°
8. Aug. 1957.....	20.00	2.2	50°
9. Aug. 1957.....	06.45	31.0	100°
9. Aug. 1957.....	08.15	32.8	100°
9. Aug. 1957.....	09.15	32.5	100°

DANSK RESUMÉ

Flugthastighed og flokstørrelse.

Ved den jyske vestkyst ved Blåvand og Grærup foretog Dansk Ornithologisk Forenings Feltornithologiske Udvalg i august 1957 en serie målinger til belysning af de trækkende fugles hastighed.

Ved hjælp af stopure og transportable radioer blev de forbitrækkende fugles hastighed målt over en strækning af en kilometer. Samtidige målinger af vindstyrken og vindretningen satte os i stand til at foretage beregninger vedrørende fuglenes egenhastighed, d.v.s. den hastighed fuglene ville have haft dersom de med samme kraft var fløjet i vindstille vejr.

I tabel 1 er opført alle målinger vedrørende de forbitrækkende Strandskader (*Haematopus ostralegus*), medens målingerne vedrørende vindens styrke og retning på fuglenes trækretning er opført i tabel 2.

De målte resultater er afbildet grafisk i fig. 3 medens de beregnede egenhastigheder er afbildet i fig. 4. Abscissen angiver antallet af individer i den enkelte flok, medens ordinaten angiver hastigheden i km/t.

Regressionsanalyser viser, at dersom man kun ser på de direkte målte resultater stiger hastigheden med stigende individantal. For egenhastighedernes vedkommende er dette dog ikke med sikkerhed tilfældet. Tværtimod synes beregningerne at vise det modsatte, altså at der ikke er nogen sammenhæng mellem flugthastighed og flokstørrelse. Forskellige usikkerhedsmomenter tillader os dog ikke ud fra det forhåndenværende materiale at udtale os med absolut sikkerhed om problemet.

Statens Almindelige Videnskabsfond, der har ydet økonomisk støtte til indkøb af apparater til målingerne samt dr. phil. F. Søgaard Andersen, der har været os behjælpelig med de matematiske beregninger, beder vi hermed modtage vor bedste tak.

References.

Lysgaard, L. 1943: Lufthav, Vejr og Klima. – København.

Meinertzhagen, R. 1955. The Speed and Altitude of Bird Flight (With notes on other Animals). – Ibis **97**, p. 81–117.