POLSKA AKADEMIA NAUK
ZAKŁAD ZOOLOGII SYSTEMATYCZNEJ I DOŚWIADCZALNEJ

ACTA ZOOLOGICA CRACOVIENSIA

Tom XX Kraków, 30. IX. 1975 Nr 13

Stanisław MANIKOWSKI

The Effect of Weather on the Distribution of Kittiwakes and Fulmars in the North Atlantic

[Pp. 489—498]

Rola czynników meteorologicznych w rozprzestrzenianiu mew trójpalczastych i fulmarów na Północnym Atlantyku

Роль метеорологических факторов в распространении трехпалых чаек и глупышей в Северном Атлантическом океане

Abstract. The role of different external factors in the distribution of Kittiwakes and Fulmars was examined on the basis of materials collected during two passages across the Atlantic (8 days, 82 observations) using multivariate statistics. The rise in the number of Kittiwakes during observations correlated with the increase in the wind speed, the state of sea, and southerly winds. The greatest numbers of Kittiwakes were observed in February and then especially in the afternoon. The distribution of Fulmars correlated with the geographical longitude and the passage of occlusions.

I. INTRODUCTION

This paper deals with the influence of environment and mainly weather conditions on the distribution of Kittiwakes *Rissa tridactyla* (LINNAEUS, 1758) and Fulmars *Fulmarus glacialis* (LINNAEUS, 1761) in the area of the Atlantic Ocean. Materials were collected during two passages across the Atlantic on a fishing trawler sailing from Gdynia to the fishing grounds in the region of Newfoundland. Only the observations made far from the coast (in the Atlantic) were elaborated. The days of observations and the positions of the trawler are presented in table I.

Table I

The position of the ship at 12·00 of the local time and days of observations of birds

Day	14. II.	15. II.	16. II.	17. II.	18. II. 1968
Geogr. longitude W Geogr. latitude N	12°45′ 58°24′	21°30′ 57°57′	30°27′ 57°00′	38°30′ 56°21′	46°02′ 54°50′
Day	12. V.	13. V.	14. V.	15. V.	16. V. 1968
Geogr. longitude W Geogr. latitude N	44°26′ 51°05′	37°30′ 52°35′	30°44′ 53°58′	22°24′ 53°53′	14°24′ 57°10′

II. METHOD

Ornithological observations were carried out from the deck of a fishing trawler approximately every $1\frac{1}{2}$ hours from dawn till dusk. A single observation lasted 15 minutes, during which I noted the species and numbers of birds using 11×40 field-glasses for observation.

The numbers of birds observed were analysed with regard to the geographical longitude, wind speed, state of sea, overcast, visibility, air temperature and air pressure at the time of observations. A total of 82 observations were made during the two passages.

Correlations between variables were calculated using multiple correlation statistics. The following coefficients were obtained from the results: R — multiple correlation coefficient, r — correlation coefficient, $\beta \cdot r$ — coefficient representing the contribution of each variable, R^2 — coefficient of multiple determination. The method of calculation and interpretation of coefficients was based on Guilford's (1960) work.

The relations between the weather variables and the numbers of birds are non-linear. The transformations of data are made in order to obtain the proper values for the coefficients. The dependent variable (number of birds) and independent variables are transformed as follows: 1 — untransformed variables (a), 2 — squared variables (a^2), 3 — logarithmed variables (ln a), 4 — 2nd roots of variables ($\sqrt[2]{a}$), 5 — 10th roots of variables ($\sqrt[10]{a}$), 6 — 4th roots of variables ($\sqrt[4]{a}$). The method is similar to that used by Nisbet and Drury (1968).

The relations between the number of birds and the wind direction, the time of day and the month of observation were analysed separately using the t test.

In order to determine the relations between the number of birds and the passage of fronts, lows and highs, the synoptic charts of this region were analysed.

III. RESULTS

A. Kittiwakes

The mean number of birds in an observation was 4·0 ± 6·3. Results of correlations between the variables examined and the numbers of Kittiwakes are presented in Table II. The R coefficients except the 2nd transformation, are statistically significant ($p < 0·01$). The relations between the logarithmed variables are presented in Table III. The relations between the wind speed,

Table II

Values of R coefficient for correlations between numbers of Kittiwakes and Fulmars and variables examined. The values of R coefficient at the level of $p < 0·01$ are underlined

Transformation of variables	R coefficients	
	Kittiwakes	Fulmars
1. untransformated variables (a)	0·583	0·421
2. squared variables (a^2)	0·407	0·400
3. logarithmed variables (ln a)	0·617	0·605
4. 2nd root of variables ($\sqrt[2]{a}$)	0·595	0·541
5. 10th root of variables ($\sqrt[10]{a}$)	0·610	0·607
6. 4th root of variables ($\sqrt[4]{a}$)	0·597	0·591

Table III

The values of r and β·r coefficient for the relations between the number of Kittiwakes and Fulmars during observations, and the variables examined. The values of r coefficient at the level of $p < 0·01$ are underlined. Number of observations N = 82

	Kittiwakes (logarithmed variables)		Fulmars (10th root of variables)	
	r	β·r	r	β·r
Wind speed	+0·419	0·222	+0·020	0·010
State of the sea	+0·467	0·361	+0·084	0·034
Amount of clouds	—0·091	0·012	+0·411	0·032
Visibility	+0·190	0·015	—0·197	0·051
Air temperature	—0·295	0·059	—0·064	0·007
Air pressure	+0·462	0·206	—0·088	0·037
Geographical longitude	+0·046	0·024	+0·492	0·546

the state of sea, the air pressure and the numbers of birds are statistically significant. The β·r index indicates that state of sea and the wind speed are elements of primary importance.

The changes in the values of the elements considered in this calculation explain in 38.1% (R^2 coefficient) the changes in the number of Kittiwakes in the area of the Atlantic. The number of Kittiwakes during observations depends also on the wind direction, the time of day and the month of observation. The greatest number of birds were recorded during southerly winds, in the afternoon and in February.

Table IV

Relations between the number of Kittiwakes and Fulmars during observations and the time of day, month of observation and direction of wind

Hours of observations	7·00—13·00	14·00—19·00		
Kittiwakes	2·5±2·9	6·2±8·9		$t = 2·38$ $p < 0·05$
Fulmars	12·4±11·2	8·14±5·5		$t = 1·90$ $p > 0·05$
Month of observations	February	May		
Kittiwakes	6·3±8·4	1·9±3·3		$t = 2·79$ $p < 0·01$
Fulmars	9·9±10·0	9·4±7·2		$t = 0·29$ $p > 0·05$
Wind directions	N	W	S	Differences between:
Kittiwakes	1·3±2·2	2·8±3·8	9·9±10·9	N and W
				$t = 1·20$ $p > 0·05$
				W and S
				$t = 3·29$ $p < 0·01$
				N and S
				$t = 2·47$ $p < 0·05$
Fulmars	7·2±4·2	8·5±8·2	13·7±9·9	N and W
				$t = 0·62$ $p > 0·05$
				W and S
				$t = 2·05$ $p > 0·05$
				N and S
				$t = 2·15$ $p < 0·05$

B. Fulmars

The mean number of Fulmars in observations was $8{\cdot}9 \pm 9{\cdot}1$. The relations between the variables examined and the number of birds are presented in Table II. The R coefficients in transformations 3 to 6 are statistically significant. The relations between 10th rooted variables are presented in Table III. The correlations between the number of birds and the overcast and the geographical longitude are statistically significant. The $\beta{\cdot}r$ coefficients indicate that the influence of the geographical longitude has a primary effect ($\beta{\cdot}r = 0{\cdot}546$). The influence of the other elements analysed, such as the overcast and the wind speed is 10 times weaker ($\beta{\cdot}r = 0{\cdot}032$). Neither were there any significant differences between the observations made in the morning and those in the afternoon, and between February and May but the greatest number of Fulmars was observed during southerly winds (Table IV).

C. Influence of the fronts

The greatest number of Kittiwakes and Fulmars was noted on 17. 02. 1968. The differences between the average number of birds observed on this day and those observed on other days are significant (for Kittiwakes $F = 7{\cdot}34$; $p < 0{\cdot}01$, for Fulmars $F = 9{\cdot}00$; $p < 0{\cdot}01$). The detailed results of the observations on that day are presented in Table V. On the basis of an analysis of the synoptic

Table V

The number of Kittiwakes and Fulmars and weather conditions measures every 4 hours on 17. 02. 1968 when an occlusion was passing

Hour	Number of birds		Wind direction	Wind speed	Air pressure	Air temperature (in centigrades)	Position of the vessel
	Kittiwakes	Fulmars					
00·00	—	—	NE	4	998	+5	56°30′N 34°30′W
04·00	—	—	SE	4	992	+5	
08·00	—	—	SE	5	989	+5	
09·00	6	40					
10·00	13	40					
11·00	2	30					
12·00	—	—	SSE	5	986	+4	56°21′N 38°30′W
13·00	5	20					
14·00	18	10					
15·00	20	10					
16·00	30	5	SW	7	987	+1	
18·00	19	1					
19·00							
20·00	—	—	SW	7	990	0	55°21′N 42°42′W

chart, it was possible to establish that this day was the only day during two voyages, when the passage of a low system with an occlusion occurred. A detailed analysis of the synoptic charts and local conditions suggests that the occlusion was nearest the vessel at 10·00 to 13·00 of the local time. Then a decrease in number of Kittiwakes was observed.

D. Other species

The other species of birds recorded during the voyage are as follows:

Day	Species	Number of birds observed
14. II 1968	*Larus marinus*	15
	Larus argentatus	2
	Larus sp. imm.	1
15. II	*Larus marinus*	3
18. II	*Larus hyperboreus*	2
12. V 1968	*Larus marinus*	1
	Sula bassana	1
	Stercorarius pomarinus	13
	Uria sp.	1
13. V	*Stercorarius pomarinus*	6
	Numenius sp.	1
15. V	*Larus marinus*	1
16. V	*Phalacrocorax* sp.	1

IV. DISCUSSION OF THE RESULTS

Changes in the number of birds noted on different days of observation in the area of the Atlantic Ocean were reported by several authors. Some of them like Dorst (1958) and Elgmork (1961), stressed the role of weather conditions on the variable number of birds.

According to Dorst (1958), the changes in the number of Kittiwakes during the observations on board a meteorological vessel, depend on the direction of prevailing winds. The rise in the number of birds is generally observed during "stormy weather" (Routh, 1949; Dorst, 1958; Elgmork, 1961). The positive correlations between the increased number of Kittiwakes and the rise in the wind speed, or during southerly winds, confirms these statements.

On the other hand, the study of the effect of weather conditions on changes of the number of Kittiwakes in the fisheries in the North Sea (Manikowski, 1971) reveals that the number of Kittiwakes rises during the days with westerly winds. There were also correlations between the rise in the number of these birds and the increase in the wind speed and the height of sea waves the day before or after the observation of Kittiwakes. In the fisheries in the region of Newfoundland and Labrador, the number of Kittiwakes decreased before the rise of the wind speed. In those fisheries a similar daily pattern of changes in the numbers of Kittiwakes was observed. The greatest number of birds was observed in the afternoon, the smallest in the morning. Probably, the attractiveness of the vessel was responsible for this phenomenon (MANIKOWSKI, 1971).

The differences in the number of Kittiwakes observed in different seasons are confirmed by observations of other authors (RANKIN and DUFFEY, 1948; OORDT, 1959; DORVAL, 1969).

The appearance of Fulmars in the pelagic zone of the Atlantic is more independent of weather conditions. The greatest numbers of these birds observed in the western Atlantic agrees with results presented by WYNNE-EDWARDS (1935), ELGMORK (1966), DORVAL (1966). Very intensive fishing activity in these regions is probably the most important factor determming this distribution. A break in fishing during the Second World War probably caused a more random distribution of Fulmars observed by RANKIN and DUFFEY (1948).

The rise in the number of Kittiwakes in the fisheries in the Atlantic before and after passage of fronts, and the rise in the number of Fulmars during the passage of a weak depression was reported earlier (MANIKOWSKI, 1971). The rise in the number of Fulmars and the changes of weather were reported also by DORST (1958) and ELGMORK (1961). The observations presented in this article generally confirm the previous statements.

The materials collected during two journeys are not sufficient to draw any more certain conclusions, so the main aim of this paper was to draw the attention of others observers to the problem of the role of weather conditions in the distribution and behaviour of sea-birds, and to present some methodological aolutions.

Department of Zoopsychology and Ethology
Jagiellonian University
ul. Krupnicza 50, 30-060 Kraków

REFERENCES

DORVAL M. 1969. Observations ornithologiques en Atlantique Nord durant les années 1964, 1966, 1967 and 1968. Ar Vran **2**: 133—155.

DORST J. 1958. Observations ornithologiques à bord des navires météorologiques français dans l'Atlantique Nord. L'Oiseau RFO, Paris, **28**: 309—323.

ELGMORK K. 1961. Observations on oceanic birds in the North Atlantic. Sterna, Stavanger, **4**: 241—323.

ELGMORK K. 1966. Further observations on birds in the North Atlantic. Sterna, Stavanger, **7**: 241—246.

Guilford J. P., 1960. Podstawowe metody statystyczne w psychologii i pedagogice. Warszawa, 623 pp.

Manikowski S. 1971. The influence of meteorological factors on the behaviour of sea birds. Acta Zool. Cracoviensia, Kraków, **17**: 581—668.

Nisbet I., Drury W. 1968. Short-term Effects of Weather on Bird Migration: a Field Study Using Multivariate Statistics. Animal Beh., London, **16**: 496—530.

Oordt G. J. 1959. Summer records on pelagic birds in the North Atlantic, 1948 and 1958. Ardea, Leiden, **47**: 41—48.

Rankin M. N., Duffey E. A. 1948. A study of the bird life at the North Atlantic. Brit. Birds, London, **41**, suppl.: 1—42.

Routh M. 1949. Ornithological observations in the Antarctic seas. Ibis, London, **91**: 577—606.

Wynne-Edwards V. C. 1935. On the habits and distribution of birds in the North Atlantic. Proc. Boston Soc. Nat. Hist., **40**: 273—346.

STRESZCZENIE

Celem pracy było zbadanie czynników środowiska oceanicznego, wpływających na zmiany liczby mew trójpalczastych *Rissa tridactyla* (L.) i fulmarów *Fulmarus glacialis* (L.) obserwowanych w pobliżu statku. Materiał do pracy zbierano w czasie dwu rejsów przez Atlantyk (tab. I). Związki pomiędzy czynnikami pogodowymi i położeniem statku a zmianami liczby ptaków obliczano za pomocą statystyk wielowartościowych, analizy wariancyjnej i testu t. Wzrost liczby mew trójpalczastych zależy od wzrostu szybkości wiatru, stanu morza i występuje w czasie południowych wiatrów. Zmiany ilości fulmarów wiążą się najsilniej z położeniem geograficznym. Przejście okluzji spowodowało również wzrost liczby ptaków obu gatunków (tab. II, III, IV, V). Listę innych gatunków ptaków obserwowanych w czasie rejsów przedstawiono na str. 494.

РЕЗЮМЕ

Целью работы было исследование факторов океанической среды, влияющих на изменения количества трёхпалых чаек *Rissa tridactyla* (L.) и глупышей *Fulmarus glacialis* (L.), наблюдаемых вблизи судна. Материал к работе собрано во время двух рейсов через Атлантический океан (табл. I). Связь между погодными факторами, расположением судна и изменениями количества птиц подсчитано при помощи многозначных статистик, дисперсионного анализа и теста т. Рост количества трёхпалых чаек завитимый от увеличения скорости ветра, состояния моря и имеет место во время южных ветров. Изменения количества глупышей наиболее сильно связаны из географическим положением. Переход окклюзии вызвал также рост количества птиц обоих видов (табл. II, III, IV, V). Перечень других видов птиц, наблюдаемых во время рейсов представлено на стр. 494.

Redaktor zeszytu: dr Z. Bocheński

PAŃSTWOWE WYDAWNICTWO NAUKOWE — ODDZIAŁ W KRAKOWIE — 1975

Nakład 800+90. Ark. wyd. 0,5. Ark. druk. 10/16. Papier ilustr. kl. III 70×100 80 g.
Zam. 452/75 Cena zł 10, —

DRUKARNIA UNIWERSYTETU JAGIELLOŃSKIEGO W KRAKOWIE