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The influence of meteorological factors on the behaviour of sea birds

[Pp. 581—668, pls IX—XI and 39 text-figs]

Wpływ czynników meteorologicznych na zachowanie się ptaków morskich

Влияние метеорологических факторов на поведение морских птиц

Abstract. The results of a study on changes in numbers and ways of living of sea birds are given. The study was carried out from aboard fishing trawlers in the Atlantic, in the region of Labrador and Newfoundland and that of north-western Africa, and in the North Sea. The study showed relationships of the changes in the numbers of birds with the geographical position, the presence of other trawlers in the fishery and the changes of weather. It was found that the sea bird species under study anticipate unfavourable weather conditions by migrating to other sea areas.

CONTENTS

I. INTRODUCTION

This paper deals with the influence of environmental changes, mainly weather changes on the birds living in the Atlantic Ocean and North Sea. Observations of birds were carried out from aboard the Polish trawlers: s. s. „Hańcza", m. s. „Tasergal", m. s. „Cetus", s. s. „Biała" and s. s. „Przemsza", belonging to the Fishing Enterprises subordinate to the United Fisheries Corporation and the Ministry of Navigation. The investigation covered three main complexes of fisheries, in the North Sea, off the coast of Newfoundland and Labrador in the western North Atlantic, and off the coast of north-western Africa.

The purpose of the work has been to add to our knowledge of the behaviour of birds migrating in the seas and their responses to human activities in fisheries, and also to present material which may prove helpful for interpretation of biometeorological processes.

The execution of the work would not have been possible but for the courtesy of the Ministry of Navigation, United Fisheries Corporation, and Fishing Enterprises, to which I wish to express my heartfelt thanks. I also owe gratitude to the Captains and Crews of the vessels in which I made voyages for their kindness, help and friendliness during my stay on board their vessels. The meteorological data were obtained by courtesy of the State Hydro-Meteorological Institute, or they were kindly provided by the Captains of the vessels.

My thanks go also to Prof. R. WOJTUSIAK, Head of the Department of Psychology and Ethology, Jagiellonian University, and Professor B. FERENS for their help and concern at all the stages of my work.

II. METHOD

1. Collection of observational material

Ornithological observations were carried out from the decks of trawlers, fishing in the North Sea, off Newfoundland and Labrador in the Atlantic Ocean, and off the coast of north-western Africa (Fig. 1). I carried out observations from one of the upper decks, from a place where the range of vision was least limited. While watching the birds, I walked about the deck so as to embrace the full field of vision in my observations. I used 11×40 field-glasses for observation. During one of the voyages to the North Sea and that to the fisheries in the African region I was engaged as a member of the crew and, consequently, the time I had at my disposal to carry out observations was limited. Then I made observations three times a day in the hours 10·00—11·00, 13·00—14·00 and 17·00—18·00 of the local time. During the other voyages observations were conducted every $1^1/_2$ hours from morning (06·00—08·00) till dusk. A single observation lasted 20 minutes, during which the species und numbers of birds were noted. I noted the numbers of birds of particular species following the trawler, those of birds sitting on the sea surface and flying at a distance from the ship, separately. In this last case I also determined the direction of flight. Whenever it was possible, the number and species of birds flying after other trawlers in the fishery were noted. The total of birds counted in one observation consisted of 1) the maximum number of specimens following the vessel directly, 2) the number of birds sitting on the sea surface, and 3) the number of birds flying at a distance from the trawler.

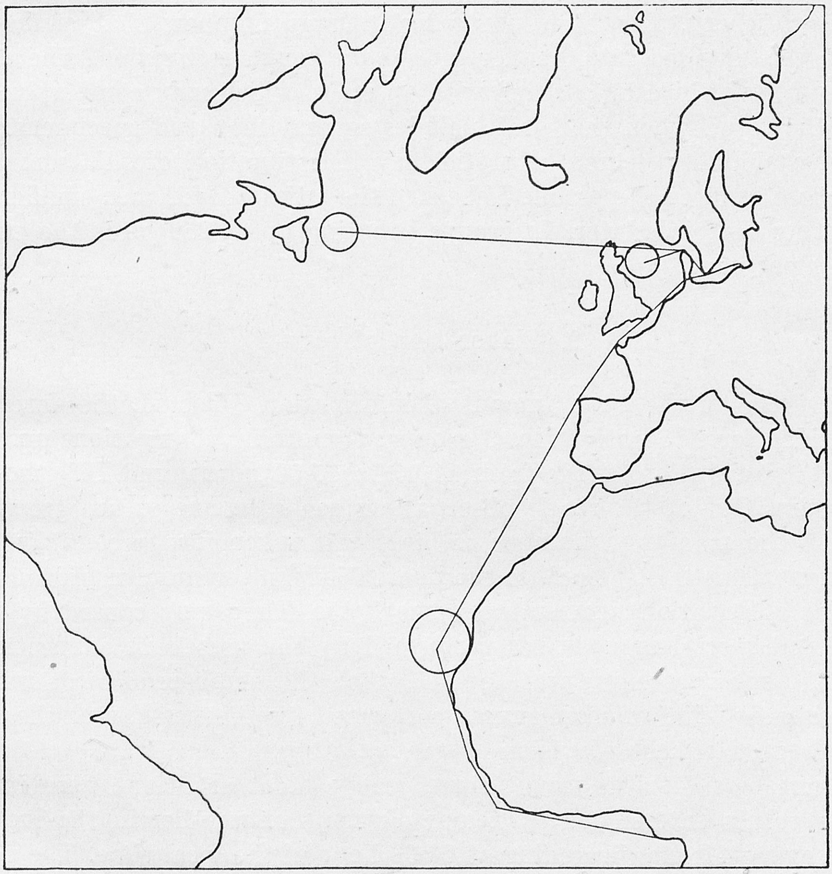

Fig. 1. Itineraries of cruises and situation of fisheries in which observations were made

When it was possible to estimate the numbers of birds following other vessels sufficiently exactly, the largest number of birds observed was included as that of birds following the vessel in the total of specimens of the given species. Each observation covered an area within a radius of 500 m from the trawler. Basing myself on the measurements of the position of the other trawlers in the fishery by means of radar and on the determination of the conditions of observation and identification of individual species I established that this distance was an approximate limit, to which I was able to determine the number and species of birds. As the speed of the vessel at the time of trawling was 4 knots an hour (7·4 km/hr), the birds present in an area of about 2·45 sq.km were counted in a 20-minute observation. In determination of the species and age of birds I used the keys by ALEXANDER and CAMB (1959) and PETERSON, MOUNTFORT and HOLLOM (1961). The age of the Gannet *Sula bassana* was determined on the basis of the publication by KAY (1950). In addition, during my observations I also noted the numbers of vessels fishing in the field of vision and the manoeuvres of these vessels. The manoeuvres of vessels were classified in 4 groups: 1. trawling, 2. casting and pulling out nets, 3. drifting, and 4. passage to another fishery. The birds occurring in large numbers that could not be counted were divided into smaller groups for rough estimation. The estimate of the number of birds is charged with an error, which may come up to 25 per cent of the total, when the total includes several thousand specimens. I tried to achieve a higher degree of proficiency in estimation of this sort and for this purpose as often as possible I checked the estimates for such smaller groups by counting the birds later. In groups counting up to 250 birds the error was about 10 per cent.

2. Elaboration of results

On account of the large amount of information collected, the observations were divided for elaboration into 3 groups: I) morning observations up to 11·00 hours, II) observations made from 11·00 to 15·00 hours, and III) those after 15·00 hours. Out of the single observations made in one of the groups, only that with the maximum number of birds was taken into account in further calculations. This was so because the fluctuations in the number of birds during particular observations were rather remarkable. They were caused by the movement and special manoeuvres performed by the vessels in connection with fishing. No such procedure was applied, when the numbers of birds were compared with the kind of manoeuvres performed by the vessel and the number of vessels in the field of vision.

The numbers of birds in the three groups of observations were compared with the values entered for particular elements of weather in the logbook of the ship every 4 hours beginning at 00·00 hour of the local time. The positions of the vessel at given moments were also rewritten from the logbook. The data concerning the size of catches were obtained for particular vessels from a special information service. Only the results of the Polish vessels fishing in the same fishery were taken into consideration. The entry in the logbook included the wind direction, wind speed according to the Beaufort Scale (Table I), state of the sea (Table II), cloudiness (Table III), kind of precipitation, visibility in sea-miles, atmospheric pressure in millibars, air temperature in degrees Centigrade and temperature of the sea surface in degrees Centigrade.

The numbers of birds of particular species in the three periods of day were compared with the above-mentioned factors. The distribution of observations

Table I

Scale of wind-speed used in log-book entries

Degrees on Beaufort scale	Wind-speed in knots	Wind-speed in m/sec.
0	below 1	0—0.2
1	1—3	0.3—1.5
2	4—6	1·6—3·3
3	7—10	3·4—5·4
4	11—16	5·5—7·9
5	17—21	8·0—10·7
6	22—27	10·8—13·8
7	28—33	13·9—17·1
8	34—40	17·2—20·7
9	41—47	20·8—24·4
10	48—55	24·5—28·4
11	56—63	28·5—52·6
12	64—71	32·7—36·9

Table II

Scale of state of sea used in log-book entries

Degrees of scale	Wave height, in m.
0	0
1	0·0—0·5
2	0·5—1·0
3	1·0—2·0
4	2·0—3·0
5	3·0—4·0
6	4·0—6·0
7	6·0—9·0
8	9·0—14·0
9	above 14

of particular numbers of birds in relation to various values of a weather element was examined using the χ^2 test, regarding the relations between variables as significant, when the value of the zero hypothesis was smaller than 0·05 in agreement with the principles accepted in biology. The use of the χ^2 test was based on the work by GUILFORD (1964).

Following the advice given by SOLLBERGER (1965) and TROMP (1963), in the case of some weather elements their values from before 12, 24 and 48 hours and also those obtained 12, 24 and 48 hours later were compared with the number of birds observed. This procedure was adopted to determine the correlation between the numbers of birds and the weather phenomena preceding or following their counting.

Table III

Scale of cloudiness used in log-book entries

Degrees of scale	Percentage of sky area covered by clouds
0	0
1	25
2	50
3	75
4	100
x	sky invisible for clouds

In order to determine the correlation between the number of birds and the changes in weather I estimated the weather situation on the basis of the synoptic charts made by the State Hydro-Meteorological Institute in Warsaw and for the African region on the basis of the Weather Bulletins of the French „Ministère des Travaux Publice et des Transports, Secrétariat Générale a l'Aviation Civile", which were rendered accessible to me by the aforesaid Institute. The estimation of the weather included the determination what part of the barometric system occurred over the fishery at the time of observation and the determination of the position of the fronts in relation to the place of observation, paying attention to the fact whether a front was approaching (1000—200 km), passing over, or moving away (100—500 km).

Moreover, to complement the complex estimation of the weather a drawing was made, which diagrammatically showed the barometric situation with the position of the fronts and the distribution of the highs and lows. The places of particular observations were plotted on the diagram on the basis of the synoptic charts of the study area so that their situation in relation to and distance from the fronts, highs and lows were preserved. As a result, I obtained a static picture of the distribution of observations relative to the pattern presented by the synoptic diagram. The terms used in descriptions of such synoptic patterns are those commonly accepted in meteorology.

The significance of the correlation between the number of birds and the weather was checked using the analysis of variances. The ratio of the variance between samples to that within samples (F) is given in the tables. When the relation is statistically significant, the level of significance and the arithmetic means from the numbers of birds in particular types of systems are given. As in the case of the χ^2 test, the analyses were based chiefly on the work by Guilford (1964). I consulted Dr. A. Łomnicki as to the purposefulness of these tests and the correctness of their application and I am greatly indebted to him for his valuable remarks.

3. Presentation of results

The results of the investigation are presented in tables and figures, and discussed in further sections of this paper. The tables give the level of significance of the correlations between the changes in the number of birds and the environmental factor examined and the arithmetic means from the numbers of birds related to the prevailing complex of weather factors. Graphs are used to illustrate the statistically significant correlations. In the graphs presenting the relations between the changes in the numbers of birds and those in particular weather factors, the proportions of the total of observations at a given value of the environmental element formed by the observations with quantitatively varying groups of birds are given along the ordinate. In the figures arrows indicate the division into classes of the multipartite table for which the significance was analysed. The distribution of the values of the environmental elements under study, given along the abscissa, is designated according to the classification method presented in Section III. 2. or directly, as in the case of months, air temperature, etc. In the descriptions of figures the explanation of the subject of the graphs is accompanied by the time (N) of the weather factor in question in relation to the time of observation. This information is given in brackets; the figure represents the number of hours, and the signs „+“ and „—“ are used to show that the weather factor followed or preceded the ornithological observation.

The significant correlations or their lack, if it throws some light on the ethology of the bird species under study, are discussed.

III. FISHERIES IN THE REGION OF NEWFOUNDLAND AND LABRADOR

1. Introductory

I made the voyage to the fisheries in the region of Newfoundland and Labrador in the fishing-and-processing vessel m. s. „Cetus“ in the period from 10 February to 20 May 1968. Seventy-two days of this period were spent in the fisheries. Table IV shows when and how long the trawler stayed in particular fisheries. The route of the voyage and the situation of the fisheries are presented in Figs. 1 and 2.

The fish caught was processed in the ship, and scraps and specimens unfit for consumption were cleared away to the sea. Their removal was done in a nearly continuous manner by flushing the deck with a jet of water. The scraps removed overboard and the fishes which got out through the meshes of the nets, while these were being pulled out aboard, were eaten by the birds. Since the abundant catches of fish provided material for processing in excess during the nearly whole voyage, the scraps were removed overboard practically day and night. Irregularities in the work of the processing plant and changes in the amount of scraps have not been taken into consideration because of the difficulties

Table IV

Numbers of days of observation in fisheries in the Labrador and Newfoundland region

Fishery No.	Dates of observations	Numbers of days
1	27 March — 1 April	6
	20—29 April	10
	Total days	16
2	17—19 April	3
	2—4 May	3
	5—9 May	5
	Total days	11
3	19 February—4 March	15
	Total days	15
4	8—13 March	6
	15—24 March	10
	11—16 April	6
	Total days	21
Others	5—7 March	
	14 March	
	23, 26 and 30 April	
	1—2 May. Total days	9
	Total for all fisheries	72

encountered in their quantitative estimation. It has therefore been assumed that the amount of the scraps and the time of their removal overboard are proportional to the weight of fish caught by the crew of the trawler. For this reason the mean output of catches in a fishery was used for comparison with the numbers of birds.

The correlation between the number of birds at the time of single observations and the amount of food for birds thrown away from the ship from which the observations were made was determined by comparing the numbers of birds with the simultaneous manoeuvres of the ship. The passage of the trawler to another fishery was not as a rule accompanied by the processing of fish. A similar technique of processing was used by nearly all the trawlers fishing in this area, not excluding those under foreign flags.

Fishing was done at the slope of the shelf in the region revealing an action of the cold Labrador Current. The trawlers moved among floes and in freely drifting ice, which was rather compact till the beginning of March. As will be seen from the entries in the log-book, in the evening of 2 March the ice surrounding the trawler began to move somewhat apart, leaving fairly large areas of the water surface free from ice. Later, fishing was continued in less compact ice fields. The Labrador Current drifted the ice and the trawlers fishing in free areas amidst it at a speed of about 1 knot southwards (Newfoundland and Labrador Pilot, 1965).

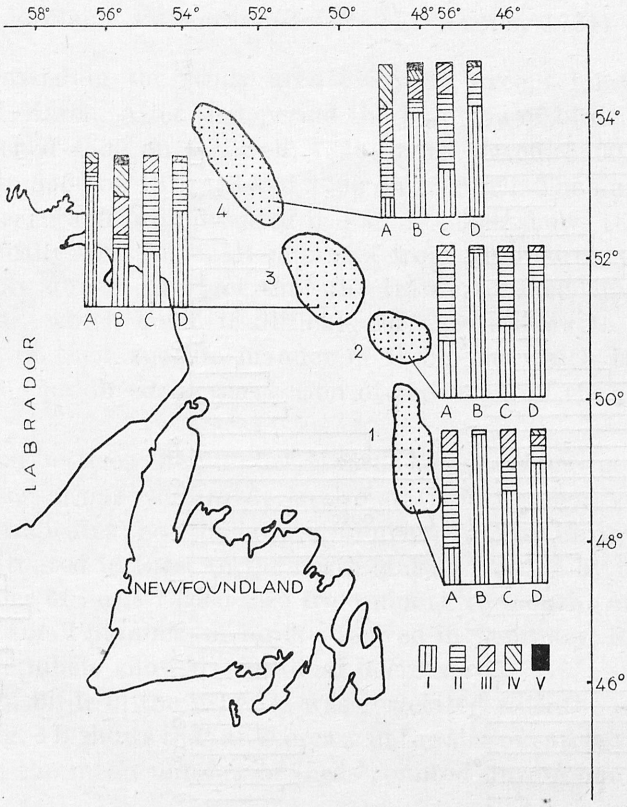

Fig. 2. The distribution of fisheries in the region of Labrador and Newfoundland in the north-western Atlantic. The graphs show percentages of observations with different numbers of birds of the four species examined: A. *Fulmarus glacialis*: I — 0—50, II — 51—400, III — 401—1000, IV — over 1000; B. *Rissa tridactyla*: I — 0—100, II — 101—200, III — 201—500, IV — 501—1000, V — over 1000; C. *Larus hyperboreus*: I — 0, II — 1—20, III — over 20; D. *Pagophila eburnea*: I — 0, II — 1—5, III — 6—20, IV — over 20

The weather fluctuations showed great amplitudes, being characterized by the wind-speed of 1 to 11—12 degrees on the Beaufort scale, the air temperature of —18 to +10°C and the barometric pressure of 959 to 1030 millibars.

The elaboration of the results does not as a rule include the state of the sea, because the waves were markedly suppressed by the ice-floes.

Out of the birds observed in the vicinity of the trawler, Fulmars, Kittiwakes, Glaucous Gulls and Ivory Gulls occurred in fairly large numbers. Only these species were embraced in comparisons carried out between the numbers of birds and the changes in weather. Fulmars and Kittiwakes were more numerous and appeared nearly every day. Consequently, it was possible to obtain information as to what percentages of the total were formed by the birds following the ship, flying at a distance or migrating, and, lastly, sitting on the sea surface, in a fairly large number of observations. In the case of the remaining birds only the total number was taken into account.

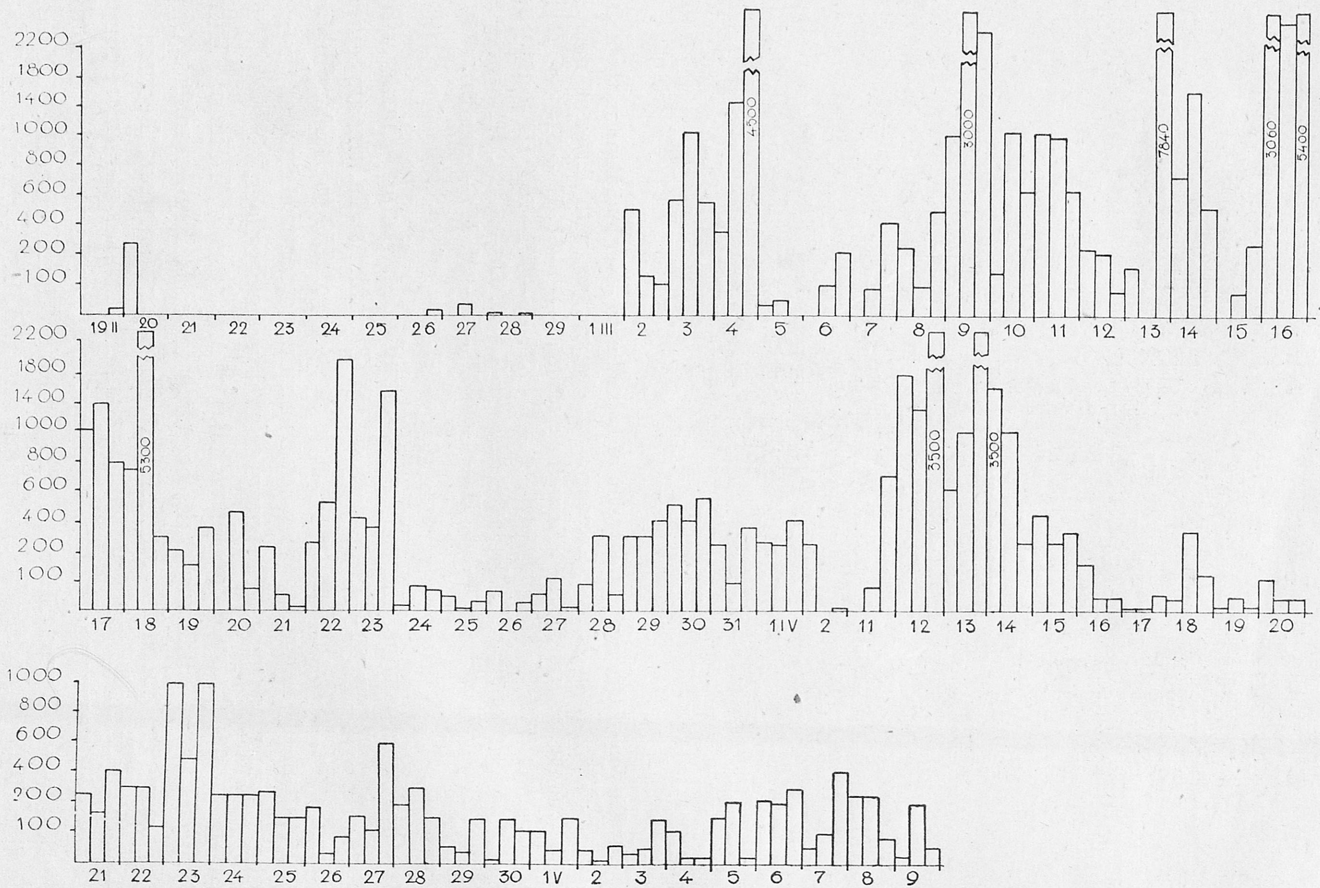

Fig. 3. Maximum numbers of Fulmars *Fulmarus glacialis* in particular observations made in fisheries off Labrador and Newfoundland in the morning, at noon, and in the afternoon from 18 February to 9 May 1968

2. Fulmar *Fulmarus glacialis* (Linnaeus, 1761)

Fulmars appeared in the study area everyday except for a period from 20 February to 1 March. After that period the numbers of birds at the time of observations reached 4500 on 4 March, 7840 on 15 March, 5400 on 16 March, 5300 on 18 March, 3500 on 12 April and 2700 on 13 April. The numbers of birds in particular observations are presented in Fig. 3, which shows that this species occurred sporadically and in small numbers from 19 February to 1 March. This was probably due to the fact that the trawlers fished among large and compact ice-fields, which made it difficult for the fulmars to penetrate the area on account of their specific manner of flying, in which they make use of the air currents produced by the action of the wind on the undulating sea surface.

The correlation between the number of birds and the situation of the fishery in which the observations were made is also statistically significant (Table V, Fig. 2). Figure 2 indicates that the largest numbers of these birds were observed in the fisheries situated farthest to the north and designated by the numerals 3 and 4. The number of birds varied also from month to month (Fig. 4A). Apart from the lack or small numbers of birds observed in February, in March, April and May these numbers showed a gradual decrease.

The number of birds in the fisheries was correlated with the average output of the catches. Fig. 4B shows that an increase in the size of catches was accompanied by a rise in the mean number of birds counted during one day.

Table V

Analysis of significance levels of correlations between the number of Fulmars and the factors examined

	—48	—24	—12	0	+12	+24	+48
Fishery				**0·01**			
Month of observation				**0·01**			
Number of trawlers				0·20			
Size of catches				**0·05**			
Manoeuvres of trawler				0·30			
Time of day				0·10			
Time of day+				0·80			
Wind-speed	0·30	**0·02**	0·30	0·10	0·50	0·70	0·80
Wind direction				0·10			
State of sea				0·30			
Cloudiness	0·20	0·70	0·30	0·80	0·50	0·50	**0·01**
Visibility	**0·01**	0·30	0·20	0·70	0·20	0·98	**0·01**
Barometric pressure	0·70	0·50	**0·05**	0·10	0·20	0·70	0·20
Air temperature	0·30	0·80		0·80		0·80	0·10
Water temperature				**0·01**			

Time of day+ — the relative numbers of birds, during the day, classified in groups of maximum, medial and minimum numbers of birds, were compared between particular times of day.

The abundance of fulmars was related to the following weather factors: the wind-speed 24 hours before the observation (correlation significant at the level of 0·02), the cloudiness 48 hours after the observation (correlation significant at the level of 0·01), the visibility 48 hours before and after the observation (correlations significant at the level of 0·01), the atmospheric pressure 12 hours before the observation (0,05) and the water temperature (0·01). The correlation between the number of birds and the passage of fronts was not significant.

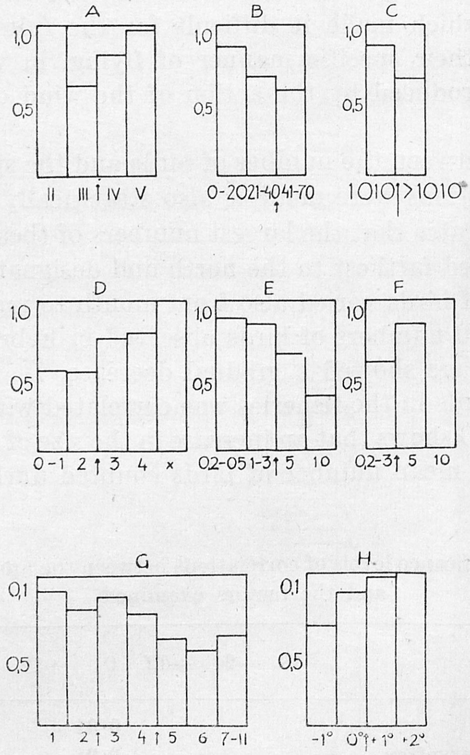

Fig. 4. Changes in the number of Fulmars according to A — month of observations, B — size of catches in fishery expressed in tons per trawler, C — barometric pressure (N = —12), D — cloudiness (N = +48), E, F — visibility (N = +48, —48), G — wind-speed (N = —24), H — sea surface temperature. The blocks represent the quantitative share of observations with 0—400 birds

The number of Fulmars in relation to the wind-speed recorded 24 hours earlier is presented in Fig. 4G, which shows that an increase in the wind-speed caused a rise in the number of birds. Similarly, there was an increase in the number of birds 48 hours after the deterioration of visibility (Fig. 4F) and 12 hours after an increase in the barometric pressure to above 1011 millibars (Fig. 4C). At the same time a rise in the number of birds occurred 48 hours before a decrease in cloudiness and 48 hours before the deterioration of visibility (Fig. 4D and F). A drop in the number of birds was associated with the reverse values

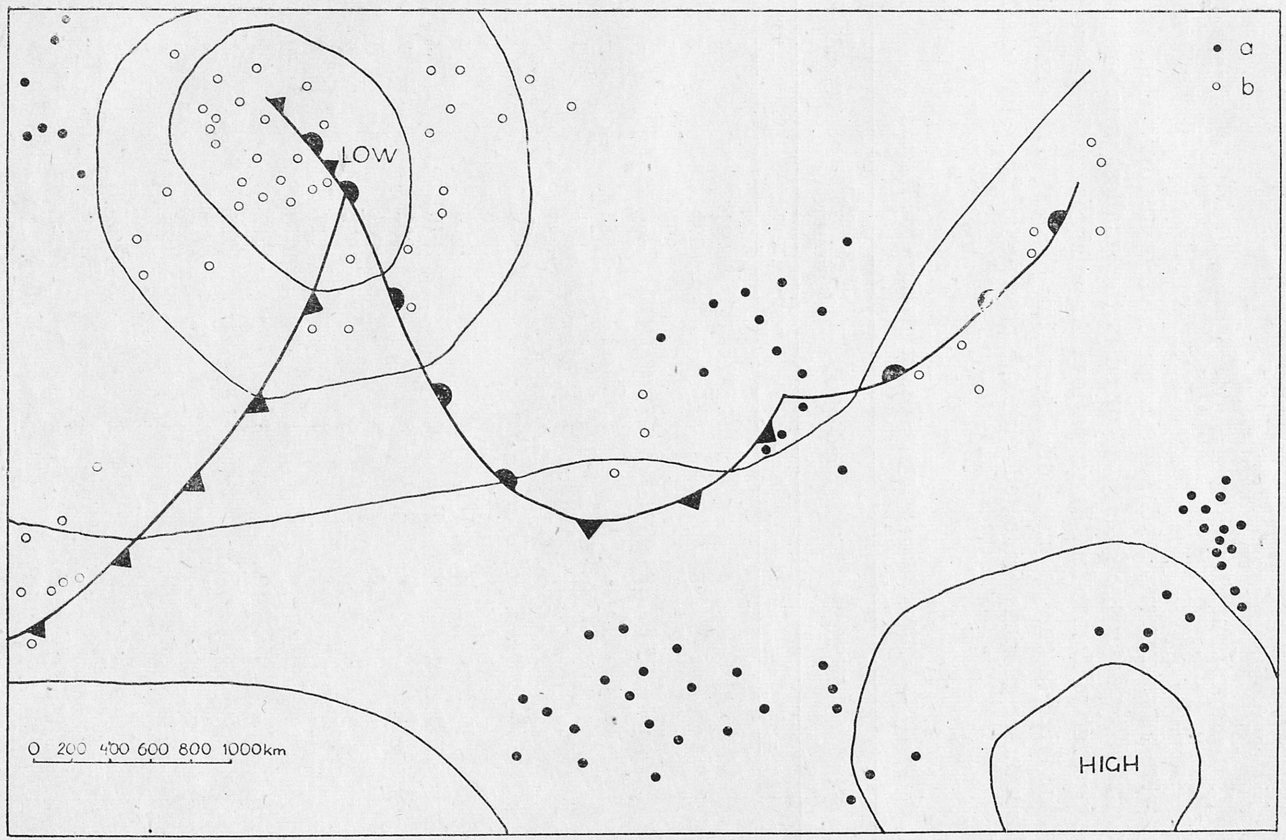

Fig. 5. Correlation between the mean number of Fulmars counted in an observation and the situation of the place of observation plotted on the synoptic diagram. a — mean value higher than 780 birds, b — mean lower than 500 birds

of these weather factors. The weather factors are summarized in Table VI, which facilitates further analysis of the correlations. The correlation between the number of birds and the temperature of the superficial layer of the sea is given in Fig. 4H, which shows the occurrence of large numbers of Fulmars only when this temperature was 0 and —1°C.

Figure 5 is a diagrammatic weather chart with the results of observations plotted on it. As can be seen from the map and from Table VII, the birds of this species were most numerous behind a depression, in an anticyclone or col, and also in a shallow depression. They occurred in the smallest numbers at the time of the passage of fronts and during a low. An analysis of the movement of the high in relation to the place of observation (Table VIII) shows that a rise in the number of birds coincided with the presence of the edge of a high

Table VI

Weather factors accompanying maximum numbers of Fulmars

Date	Visibility		Wind-speed	Barometric pressure	Cloudiness
	—48	+48	—24	—12	+48
3 III	5	5	6	981	4
4 III	2	5	4	993	3
4 III	2	5	4	996	2
9 III	10	10	5	992	1
9 III	10	10	5	983	1
9 III	2	10	5	981	1
10 III	3	2	6	987	4
11 III	2	5	6	1010	1
11 III	5	10	6	1015	1
13 III	10	5	8	1000	4
14 III	2	9	7	1016	4
16 III	1	10	8	992	2
16 III	1	10	8	1001	1
16 III	2	10	8	1002	2
17 III	2	10	3	1017	0
17 III	2	10	4	1015	0
18 III	2	10	3	1012	1
22 III	5	1	6	1015	1
23 III	2	5	6	1015	3
12 IV		10	2	1012	2
12 IV		10	2	1012	2
12 IV		5	2	1011	3
13 IV	1	10	2	1013	3
13 IV	1	10	2	1013	2
14 IV	5	10	3	1011	1
14 IV	15	10	3	1011	1
14 IV	10	10	4	1012	1
23 IV	3	10	4	1017	1
23 IV	3	10	5	1017	1

Table VII

Correlation between the number of Fulmars and the situation of the place of observation plottet on the synoptic diagram

	0—100	101—500	501—1000	above 1000	Mean
1 High and col	11	19	3	10	780
2 Fronts	5	12	1	1	500
3 Depression	12	17	3	3	470
4 Behind depression	1	2	1	3	1200
5 Weak low-pressure system	5	3	2	4	780

$F = 2{\cdot}52$
$p < 0{\cdot}05$

Table VIII

Correlation between the number of Fulmars and the movements of the high in relation to the place of observation

	0—100	101—500	501—1000	above 1000	Mean
1 Approach of high towards place of observation	0	0	0	2	2000
2 High over place of observation	6	12	2	3	632
3 High-pressure ridge obver place of observation	2	6	1	0	455
4 Edge of high over place of observation	2	3	1	3	970

$F = 4{\cdot}34$
$p < 0{\cdot}01$

over the fishery. Fewer birds occurred in the high itself or in a ridge of high pressure. Table IX presents these relations for a low. According to it, the birds are most numerous in a trough of low pressure and least numerous in the peripheral portion of lows. The correlation between the number of birds and the passage of fronts is not significant (Table X).

Fulmars occur more numerously in the northern oceanic areas situated off Labrador and give preference to sea regions with a superficial water temperature of 0 to —1°C. The increase in the number of birds in the period of bigger catches is hard to interpret, because the higher output of fishing was achieved in March and in the fisheries farthest to the north, and these circumstances may have affected the results obtained.

Large flocks of Fulmars were observed when the barometric systems moving over the fishery were transitional between the high and the low, whereas a de-

Table IX

Correlation between the number of Fulmars and the movements of the low in relation to the place of observation

	0—100	101—500	501-1000	above 1000	Mean
1 Approach of low towards place of observation	2	5	1	1	630
2 Centre of low over place of observation	3	5	2	1	620
3 Low moving away from place of observation	2	2		1	640
4 Low-pressure trough over place of observation	3	3	3	3	830
5 Edge of low over place of observation	11	7			255

$F = 2{\cdot}64$
$p < 0{\cdot}05$

Table X

Correlation between the number of Fulmars and the movement of the fronts in relation to the place of observation

	0—100	101—500	501—1000	above 1000
1 In advance of front	9	6	1	1
2 During the passage of front	10	12	2	6
3 Behind front	10	32	4	2

$F = 2{\cdot}54$

crease in their number fell in the high and low themselves. The maximum numbers of birds were seen 48 hours after a spell of poor visibility and heavy winds, and at the same time 48 hours before an improvement in both visibility and cloudiness. Keeping to the peripheries of high-pressure systems and to shallow depressions, these birds avoid stormy weather and periods of poor winds which may happen during a high and make it difficult for them to fly in search of food.

Birds following the trawler

The results concerning the birds flying after the trawler are collected in Table XI, which shows that their percentage was correlated with the wind-speed at the time of observation (significantly at 0.01 level), the cloud-cover 24 hours before the observation (significantly at 0·05 level) and the barometric pressure

24 and 12 hours before and 12 hours after the observation (significantly at 0·02, 0·01 and 0·02 levels, respectively).

The absolute number of birds following the trawler was also correlated with the wind-speed at the time of observation (0·01 level of significance).

Table XII presents the correlation between the percentage of Fulmars following the trawler and the pattern of synoptic situation. It is significant at the 0·01 level.

Table XI

Analysis of significance levels of correlations between the percentage of the Fulmars flying after and feeding at the trawler and the factors examined

	—48	—24	—12	0	+12	+24	+48
Total of birds				0·20			
Time of day				0·70			
Time of day+				0·70			
Wind-speed	0·70	0·20	0·70	**0·01**	0·50	0·70	0·80
Wind direction				0·10			
State of sea				0·30			
Cloudiness	0·99	**0·05**	0·70	0·95	0·90	0·70	0·70
Barometric pressure	0·50	**0·02**	**0·01**	0·20	**0·02**	0·30	0·95
Number of Fulmars following trawler acc. to wind-speed			0·30	**0·01**	0·70		

Table XII

Correlation between the percentage of the Fulmars following the trawler and the synoptic situation pattern

	0—20	21—60	61—100	Mean
1 High and col	10	13	14	58%
2 Fronts	2	1	14	86%
3 Depression	9	4	21	70%
4 Weak low-pressure system	6	1	4	46%

$F = 4{\cdot}15$
$p < 0{\cdot}01$

The percentages of birds flying after the ship at various wind-speeds are given in Fig. 6A. It will be seen from it that an increase in the wind-speed to above 4 degrees on the Beaufort scale caused a rise in the percentage of these birds. As shown in Fig. 6B, the numbers of Fulmars following the ship observed at various wind-speeds behaved similarly.

The relation of the percentage of Fulmars flying after the ship to the cloudiness preceding their count by 24 hours is presented in Fig. 6 C. A rise of the percentage was observed 24 hours after an increase in the cloud-cover. Fig. 6 D, E and F shows the percentage of Fulmars following the ship as related to the barometric pressure 24 and 12 hours before and 12 hours after the observation. A fall of pressure to below 1010—1001 millibars was followed by an increase in the percentage of birds flying after the ship.

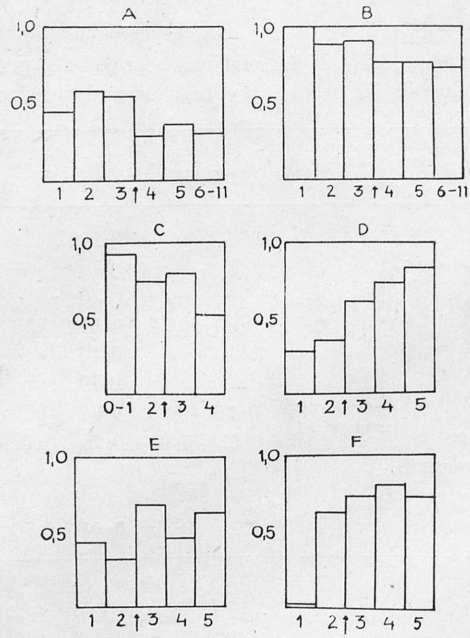

Fig. 6. Changes in the percentage of Fulmars following the trawler according to A — wind-speed (N = 0), B — changes in the total of Fulmars in the neighbourhood of the vessels relative to the wind-speed (N = 0), C — cloudiness (N = —24), D, E, F — barometric pressure (N = —24, —12, +24). The blocks, except in Graph B, represent the quantitative share of observations with 0—40% of birds, those of Graph B observations with 0—400 birds. In Graphs D, E and F the barometric pressure values are 1. 971—990, 2. 991—1000, 3. 1001—1010, 4. 1011—1020, 5. 1021—1030 millibars

Table XII presents the relations between the percentage of Fulmars following the ship and the synoptic situation pattern. The data given in this table show that these birds formed the highest percentage of the total when fronts passed over the fishery and during a depression; on the other hand, the lowest percentage occurred at the time of a high, col and weakly cyclonic weather.

Fulmars flying at a distance from the ship

The results of observations concerning the correlation between the percentage of birds flying at a distance from the ship and the environmental elements examined are given in Table XIII. This correlation appears significant with the wind-speed 24 hours before the observation (0·02 level of significance), the wind-direction at the time of observation (0·02 level) and the cloudiness 24 hours before (0·05 level). In addition, there is a correlation between the number of Fulmars flying at a distance from the ship and the total of these birds from before 48 hours.

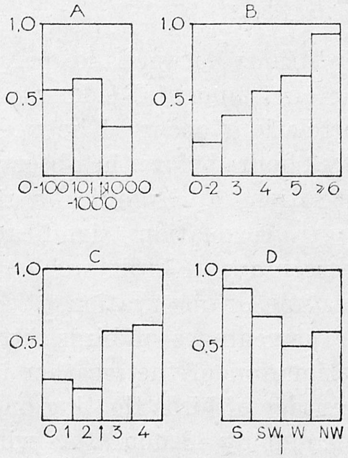

Fig. 7. Changes in the percentage of Fulmars flying at a distance from the trawler according to A — total of Fulmars (N = —48), B — wind-speed (N = —24), C — cloudiness (N = —24), D — wind direction (N = 0). The blocks represent the quantitative share of observations with 0—40% of birds

Table XIII

Analysis of significance levels of correlations between the percentage of the Fulmars flying at a distance from the trawler and the factor examined

	—48	—24	—12	0	+12	+24	+48
Total of Fulmars	**0·05**	0·95		0·30		0·70	0·20
Time of day				0·70			
Wind-speed	0·50	**0·02**	0·60	0·99	0·10	0·30	0·80
Wind direction				**0·02**			
State of sea				0·95			
Cloudiness	0·99	**0·05**	0·70	0·20	0·70	0·20	0·90
Barometric pressure	0·99	0·30	0·10	0·99	0·70	0·30	0·95

No correlation was found between the percentage of Fulmars and the complex estimation of the weather.

Fig. 7A shows the percentage of Fulmars flying at a distance from the trawler in relation to their total number 48 hours earlier. An increase in the percentage occurred 48 hours after a rise in the total of Fulmars.

The correlation between the percentage of Fulmars flying at a distance from the ship and the wind-speed and cloudiness 24 hours before the observation is given in Fig. 7B and C. A decrease in the wind-speed and cloudiness appears to have been responsible for a rise in the percentage of birds. Besides, the rise of the percentage of Fulmars flying at a distance was related to the west winds blowing at the time of observation (Fig. 7D).

Fulmars sitting on the sea surface

An analysis of the correlations between the percentage of Fulmras sitting on the sea surface and the environmental elements examined is presented in Table XIV. Significant correlations occurred between the percentage of birds and the wind-speed 48 and 12 hours before the observation and that at the time of observation. These correlations are significant at the 0·05, 0·05 and 0·01 levels, respectively. Moreover, correlations significant at the 0·01 level have been found between the percentage of birds and both the wind direction and the state of the sea at the time of observation.

The distribution of the percentages of birds sitting on the sea surface in relation to the complex estimation of the weather is not significant.

Fig. 8A shows the percentage of birds floating on the sea surface at various wind-speeds preceding the count by 48 hours. As will be seen from this figure, a rise in the percentage of birds occurred 48 hours after an increase in the wind-speed to above 4 degrees on the Beaufort scale. The effect of the same factor 12 hours before and at the time of the observation is illustrated in Fig. 8B and C. A higher percentage of Fulmars swam on the sea when the force of wind was below 4 degrees on the Beaufort scale.

The south-west winds prevailed when the percentage of birds sitting on the sea surface was on the increase (Fig. 8E). An increase in the percentage of Fulmars occurred also at the time when there were slight waves on the sea (below 3 degrees on the Beaufort scale — Fig. 8D).

Table XIV

Analysis of significance levels of correlations between the percentage of the Fulmars sitting on the sea surface and the factors examined

	—48	—24	—12	0	+12	+24	+48
Total of Fulmars	0·70	0·10		0·10		0·20	0·95
Time of day				0·70			
Time of day +				0·50			
Wind-speed	**0 05**	0·30	**0·05**	**0·01**	0·20	0·20	0·90
Wind direction				**0·01**			
State of sea				**0·01**			
Cloudiness	0·50	0·95	0·70	0·80	0·80	0·80	0·10
Barometric pressure	0·10	0·98	0·90	0·20	0·20	0·50	0·90

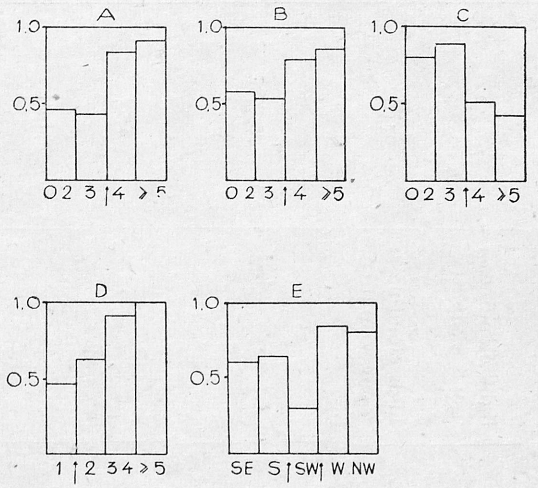

Fig. 8. Changes in the percentage of Fulmars sitting on the sea surface according to A, B, C — wind-speed (N = 0, —12, —48), D — state of sea (N = 0), E — wind direction (N = 0). The blocks represent the quantitative share of observations with 0—40% of birds

Recapitulation of the results of investigation on Fulmars

Table XV summarizes the factors to which the changes in the number and percentages of Fulmars classified according to the three types of their behaviour are related.

An increase in the total of Fulmars was observed during a shallow depression and a high (mainly at its edge), behind a low and in a trough of low pressure on the days following a spell of poor visibility, fast winds, and directly after a rise in barometric pressure. In my observations a decrease in the number of Fulmars occurred when two days of good visibility and slight winds were followed by a fall in barometric pressure, or during a low, at its edge, and at the time of active fronts and a high-pressure wedge. The close correlation with the changes in cloudiness and visibility 48 hours before the observation suggests a rather long duration of a favourable or unfavourable state of weather. An increase in the percentage of Fulmars following the trawler, most of which fed on scraps removed from the deck and organisms thrown to the sea surface by the revolutions of the ship screw, occurred before and after a fall in barometric pressure, 24 hours after an increase in cloudiness, during the passage of a low and fronts, and at the time of a rise in wind-speed.

A fall in the percentage of Fulmars which followed the trawler was recorded before and after a rise in barometric pressure, after a decrease in cloudiness, at the time of a high, shallow depression and subsiding wind.

A comparison of the complexes of weather factors which induced changes in the total number of Fulmars and in the percentage of birds following the trawler reveals that the factors responsible for an increase in the total of Ful-

Table XV

Comparison of meteorological factors with which changes in number and ways of living of Fulmars are associated. I. Total of birds, II. percentage of Fulmars following trawler, III. percentage of birds flying at distance, IV. percentage of birds sitting on sea

	—48	—24	—12	0	+12	+24	+48	Changes in number of birds on the day of observation
I	poor visibility	strong wind	high pressure	weak depression; behind depression; high			light cloudiness; good visibility	rise
	good visibility	light wind	low pressure	low; fronts			high cloudiness; poor visibility	fall
II		high; cloudiness; low pressure	low pressure	fronts; low; strong wind	low pressure			rise
		low; cloudiness; high pressure	high pressure	col; high; weak depression; light wind	high pressure			fall
III	large number of Fulmars	light wind; low; cloudiness		westerly wind				rise
	small number of Fulmars	strong wind; high cloudiness		southerly and south-westerly winds				fall
IV	strong wind		light wind	light wind; light waves; sout-westerly wind				rise
	light wind		strong wind	strong wind; high waves; southerly and westerly winds				fall

mars and a decrease in their percentage following the trawler are very much a like and, vice versa, similar weather factors bring about a decrease in the total of Fulmars and a rise in the percentage of birds flying after the ship.

The rise in the percentage of Fulmars flying at a distance from the trawler or migrating occurs during the weather which favours their gathering in the fishery. This is also true of the birds sitting on the sea surface. In this last case the increase depends chiefly on the local factor, i. e., the state of the sea, but its correlation with the wind-speed 48 hours before the observation suggests that the percentage of Fulmars floating on the sea increases during the weather with mild winds and the gathering of large numbers of Fulmars associated with it. In addition, the percentage of birds sitting on the sea surface increased 48 hours after a rise in the total of birds.

A fall in the percentage of Fulmars sitting on the sea occurred at the time of heavy waves and south or west winds — under circumstances opposite to those described above.

To sum up, it should be stated that Fulmars feed on the scraps removed from the trawler during the weather which causes a fall in the total number of birds (unfavourable factors), whereas they fly up in the air, migrate, or swim on the sea when the weather resembles the situation which brings about the gathering of large numbers of Fulmars, only that these types of behaviour are characterized either by a shift in time in relation to the quantitative maxima or by lack of any direct connections with them.

3. Kittiwake *Rissa tridactyla* (Linnaeus, 1758)

Kittiwakes appeared in the study areas everyday. On some days their number came up to several thousand (7500 — 27 February, 6340 — 29 February, 3150 — 4 March, 2200 — 9 March). The numbers of Kittiwakes on particular days of observation are given in Fig. 9. It shows, among other things, that the number of these birds decreased considerably in the second half of March. The correlation of the number of Kittiwakes with the month in which observation was carried out is significant at the 0·01 level (Table XVI, Fig. 10A).

The number of Kittiwakes was also related to the place of observation, which relation was significant at the 0·01 level. Fig. 2 shows the quantitative share of observations with different numbers of specimens of this species for particular fisheries. It will be seen from this figure that the largest numbers of Kittiwakes occurred in the northernmost fisheries (Nos. 3 and 4).

The number of birds in the vicinity of the trawler changed with manoeuvres performed by her. The numbers of Kittiwakes found in observations at different manoeuvres of the trawler are presented in Fig. 10B. It shows that more birds accompanied the trawler during the feeding and hauling of nets,at the time of trawling and drifting than while she was passing to another fishery. The difference between the numbers of birds accompanying these two groups of manoeuvres is significant at the 0·05 level.

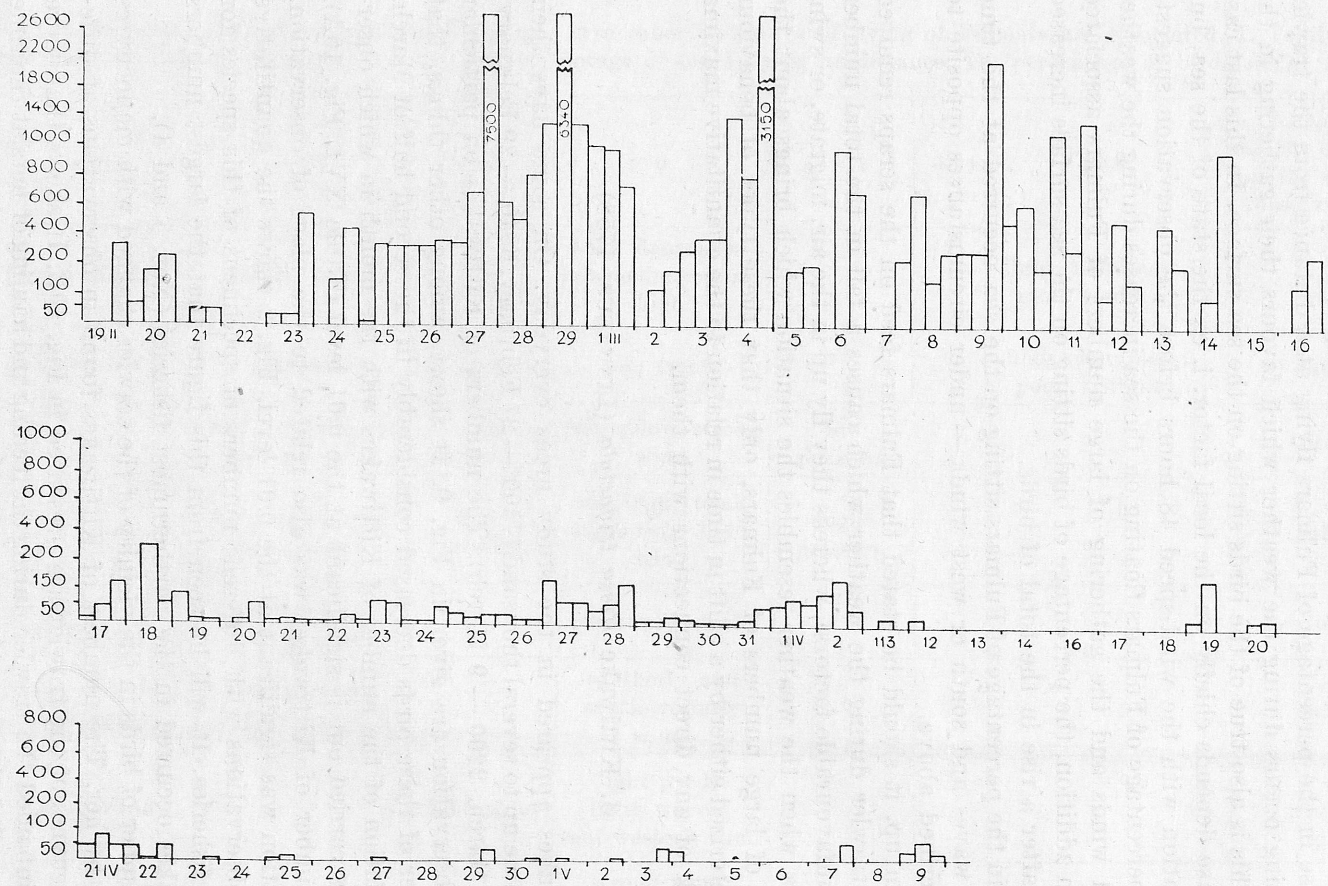

Fig. 9. Numbers of Kittiwakes *Rissa tridactyla* in the observations made in the fisheries off Labrador and Newfoundland in the morning, at noon, and in the afternoon from 19 February to 9 May 1968

Table XVI

Analysis of significance levels of correlations between the number of Kittiwakes and the factors examined

	—48	—24	—12	0	+21	+24	+48
Fishery				**0·01**			
Month of observation				**0·01**			
Number of trawlers				0·50			
Size of catches				0·99			
Manoeuvres of trawler				**0·05**			
Time of day				**0·01**			
Time of day+				**0·01**			
Wind-speed	0·50	0·80	0·50	0·20	**0·01**	**0·02**	0·20
Wind direction				0·50			
Cloudiness	0·80	0·80	0·20	0·20	0·70	0·30	0·70
Visibility	0·95	0·80	0·30	0·10	0·10	0·70	0·30
Rainfall				0·30			
Barometric pressure	0·95	0·70	0·20	0·30	0·10	0·70	0·95
Barometric tendency				0·10			
Air temperature	**0·01**	**0·02**		**0·01**		**0·01**	0·10

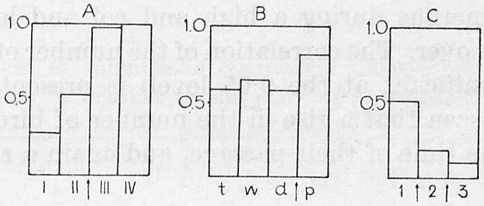

Fig. 10. Changes in the number of Kittiwakes according to A — month of observations, B — manoeuvres of trawler, C — time of day. The blocks represent the quantitative share of observations with 0—100 birds. Designations in Graph B: t — trawling, w — feeding and hauling of nets, d — drifting, p — passage to other areas. Designations in Graph C: 1 — observations made in the morning, 2 — at noon, 3 — in the afternoon

The time of day had a significant effect on the number of Kittiwakes (at 00·1 level). Fig. 10C shows the numbers of these birds observed at particular times of day (morning, afternoon, evening). The correlation between the occurrence of the maximum, medial and minimum numbers of birds and the time of day is given in Fig. 11. Both these figures show that in the morning the birds occurred in the smallest number, being most numerous in the evening.

As regards the weather factors, the number of Kittiwakes is related to the changes in winds-speed 12 and 24 hours after the observation and those in air temperature at the time of observation, 24 and 48 hours before it and 24 hours after. These correlations are significant at the 0·01, 0·02, 0·01, 0·02 and 0·01 levels, respectively. The correlation between the number of birds and the place of observation, as plotted on the synoptic diagram, was significant at the 0·01 level. The relation of the number of birds to the situation of fronts at the time of observation was also significant (at 0·05 level).

Fig. 12A and B shows the changes observed in the number of Kittiwakes in relation to the wind-speed. An increase in wind-speed to above 3—5 degrees on the Beaufort scale followed a fall in the number of birds and, on the contrary, a rise in the number of birds preceded winds the force of which was lower than 3 degrees.

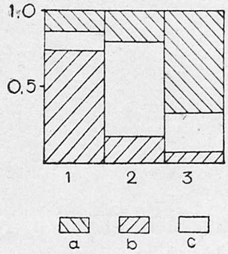

Fig. 11. Correlation between the maximum, minimum and medial numbers of Kittiwakes and the time of day. 1 — morning, 2 — noon, 3 — afternoon, a — maximum numbers, b — medial numbers, c — minimum numbers

The correlation between the number of Kittiwakes and air temperature is illustrated in Fig. 12C, D, E and F. An increase in the number was associated with a fall in temperature.

The diagram of the weather pattern (Fig. 13, Table XVII) shows that Kittiwakes were most numerous during a high and col and least numerous while the fronts were passing over. The correlation of the number of these birds with the passage of fronts (significant at the 0·05 level) is presented in Table XVIII, from which it can be seen that a rise in the number of birds occurred ahead of the fronts, a fall at the time of their passage, and again a rise behind the front.

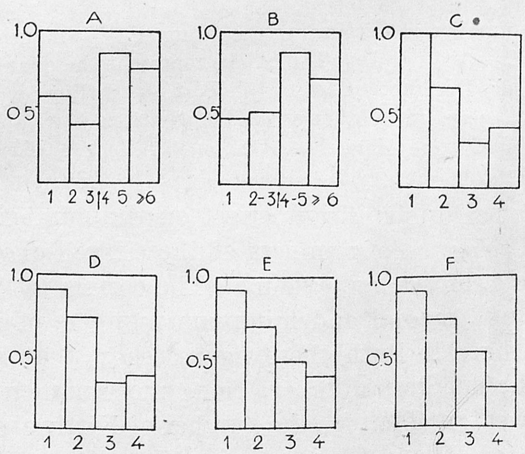

Fig. 12. Changes in the number of Kittiwakes according to A, B — wind-speed (N = +12, +24), C, D, E, F — air temperature (N = −48, −24, 0, +24). The blocks represent the quantitative share of observations with 0—300 birds in Graphs. A and B, and 0—100 in Graphs. C—F. Designations in Graphs. C—F: 1. above 2° C, 2. +1 — −1° C, 3. −2 — −5° C, 4. below −5° C

The significant change in the number of Kittiwakes was not connected with the distribution of highs and lows.

The foregoing observations indicate that Kittiwakes are most numerous in the fisheries situated in latitudes higher than 52°N. This is confirmed by the correlation found between the number of birds and the air temperature, which becomes lower in higher latitudes. The fall in the number of Kittiwakes in the second half of March may have been connected with their migration to the Atlantic regions lying farther to the north or back to their breeding grounds.

Table XVII

Correlation between the number of Kittiwakes and the synoptic situation pattern

	0—100	101—500	501—1000	above 1000	Mean
1 High and col	34	4	5	7	460
2 Fronts	16	3	0	0	162
3 Depression	39	15	7	1	320

$F = 5{\cdot}9$
$p < 0{\cdot}01$

Table XVIII

Correlation between the number of Kittiwakes and the movement of the fronts in relation to the place of observation

	0—100	101—500	501—1000	above 1000
1 In advance of front	0	1	3	1
2 During the passage of front	5	14	0	0
3 Behind front	4	8	6	2

$F = 4{\cdot}70$
$p < 0{\cdot}05$

The relation of the number of Kittiwakes to the sort of manoeuvres performed by the trawler and to the time of day points to the gathering of specimens of this species in the proximity of the fishing vessels. They feed on large amounts of fish scraps thrown overboard. The increase in the number of Kittiwakes in evening hours was probably due to the fact that, having come across a ship, some of them stayed in her neighbourhood till dusk.

Apart from the foregoing factors, the changes in the number of birds observed in the fisheries depended on the meteorological factors associated with the changes in the weather situation on particular days.

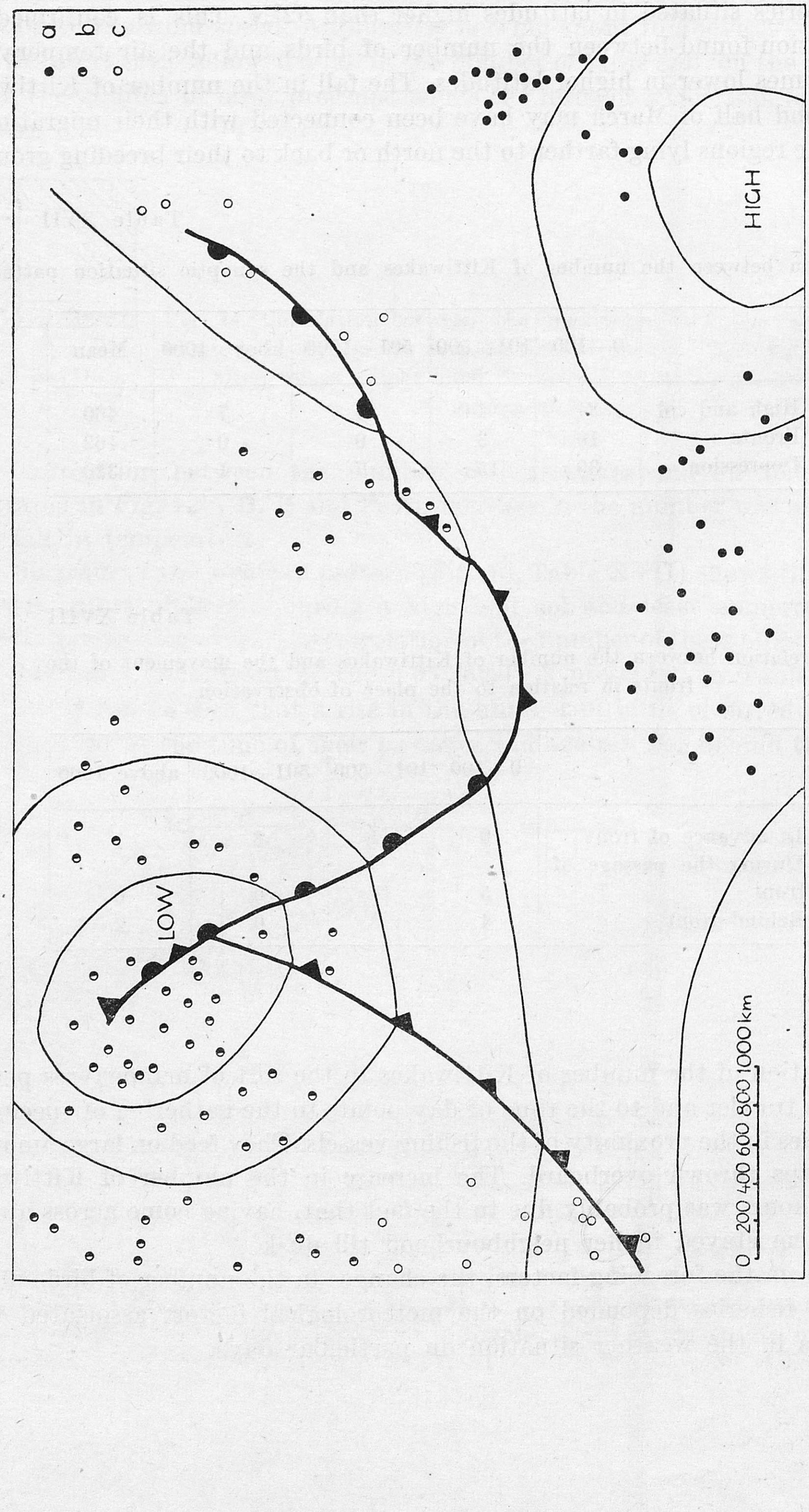

Fig. 13. Correlation between the mean number of Kittiwakes in an observation and the place of observation as plotted on the synoptic diagram. a — 480, b — 320, c — 162 birds

Kittiwakes following the trawler

The results of observations are given in Table XIX. It shows that the percentage of Kittiwakes following the trawler was correlated with the time of day and cloudiness 12 and 24 hours before the observation.

Its correlation with the synoptic pattern of the passing fronts, depressions and highs was below the level of significance.

Fig. 14 A shows the percentage of Kittiwakes flying after the trawler at different times of day; it reaches its maximum in the evening and minimum

Table XIX

Analysis of significance levels of correlations between the percentage of the Kittiwakes flying and feeding at the trawler and the factors examined

	—48	—24	—12	0	+12	+24	+48
Total of Kittiwakes				0·90			
Time of day				0·80			
Time of day+				**0·01**			
Wind-speed	0·30	0·30	0·30	0·50	0·20	0·30	0·30
Wind direction				0·30			
State of sea				0·20			
Cloudiness	0·90	**0·05**	**0·05**	0·70	0·50	0·10	0·70
Barometric pressure	0·20	0·98	0·30	0·30	0·20	0·90	0·99
Air temperature		0·30		0·30		0·80	

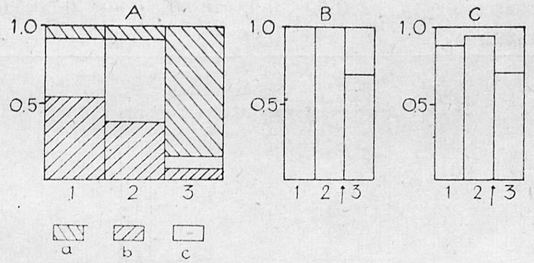

Fig. 14. Changes in the percentage of Kittiwakes following the trawler according to A — time of day, B. C — cloudiness (N = —24, —12). The blocks in Graphs B and C represent the quantitative share of observations with 0—40% birds. Graph A shows the relative percentage value of Kittiwakes. a — maximum numbers, b — medial numbers, c — minimum numbers, 1 — morning, 2 — noon, 3 — evening

in the morning. The quantitative share of observations with different percentages of Kittiwakes following the trawler in relation to the cloudiness 12 and 24 hours before the observation is given in Fig. 14 B and C. It shows that an increase in cloudiness was followed by a rise in the percentage of birds following the trawler.

It may be stated in general on the basis of the material presented in this paper that Kittiwakes, for the most part, feed in the evening and after an increase in cloud-cover.

Kittiwakes flying at a distance from the trawler

Table XX shows the results obtained in this respect. The percentage of birds flying at a distance from the trawler was correlated with the wind-speed at the time of observation (0·05 level of significance) and the cloud-cover 12 hours before the observation (0·02 level of significance). The effect of the pattern of synoptic situation and that of fronts, lows and highs on the percentage of Kittiwakes flying at a distance from the trawler were not significant.

The quantitative share of observations with Kittiwakes flying at a distance from the trawler at various wind-speeds is given in Fig. 15A, which shows that the greatest quantity of these birds occurred at a wind-speed of 2—3

Table XX

Analysis of significance levels of correlations between the percentage of the Kittiwakes flying at a distance from the trawler and the factors examined

	—48	—24	—12	0	+12	+24	+48
Total of Kittiwakes				0·30			
Time of day				0·30			
Time of day+				0·30			
Wind-speed	0·50	0·10	0·50	**0·05**	0·50	0·90	0·10
Wind direction				0·90			
Cloudiness	0·95	0·30	**0·02**	0·70	0·70	0·90	0·50
Barometric pressure	0·50	0·98	0·50	0·80	0·50	0·98	0·50
Air temperature		0·90		0·90		0·20	

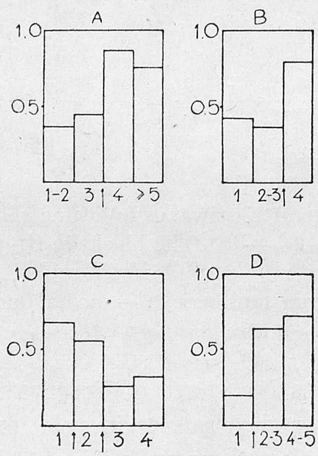

Fig. 15. Changes in the percentage of Kittiwakes flying at a distance from the trawler (A, B), sitting on the sea surface (C, D) relative to A — wind-speed (N = 0), B — cloudiness (N = —12), C — total of Kittiwakes, D — state of sea (N = 0). The blocks in Graphs A, C and D represent the quantitative share of observations with 0—20% of birds, in Graph B those with 0—40%. Designation in Graph C: 1. 0—100, 2. 101—500, 3. 501—1000, 4. over 1000 specimens altogether

degrees on the Beaufort scale. This share in relation to the cloudiness 12 hours before the observation is presented in Fig. 14B. An increase in the percentage of birds flying at a distance took place 12 hours after light cloudiness (1—2).

Kittiwakes sitting on the sea surface

Out of the factors examined, the total number of Kittiwakes at the time of observation and also the state of the sea have an effect on the percentage of specimens sitting on the surface of the sea (Table XXI). The influence of the first of these factors was significant at the 0·05 level and that of the other one at the 0·02 level. The correlation between the percentage of birds floating on the sea and the pattern of synoptic situation and the effect of fronts, lows and highs were significant below the 0·05 level.

Table XXI

Analysis of significance levels of correlations between the percentage of the Kittiwakes sitting on the sea surface and the factors examined

	—48	—24	—12	0	+12	+24	+48
Total of Kittiwakes				**0·05**			
Time of day				0·20			
Wind-speed	0·70	0·10	0·10	0·70	0·10	0·30	0·90
Wind direction				0·70			
State of sea				**0·02**			
Cloudiness	0·98	0·70	0·70	0·10	0·80	0·90	0·90
Barometric pressure	0·20	0·90	0·80	0·10	0·20	0·70	0·70
Air temperature		0·70		0·98		0·98	

Fig. 15C shows a quantitative share of observations with different percentages of Kittiwakes swimming on the sea against the changes in the total numbers of these birds. The number of birds swimming on the sea increased with the rise of the total number of specimens in the vicinity of the ship. The percentage of birds sitting on the sea surface at various states of the sea is illustrated in Fig. 15D. This percentage was higher, when the state of the sea was lower, according to the Beaufort scale, that is, the waves were smaller.

Recapitulation of the results concerning Kittiwakes

The factors statistically associated with the changes in the total number of Kittiwakes and those in the percentages of these birds classified according to the three types of their behaviour are given in Table XXII.

A rise in the number of Kittiwakes occurred in the evening, on the days preceding a decrease in wind-speed. This happened chiefly at the time of a high and col or ahead of and behind fronts. The number of Kittiwakes decreased in the morning, before a rise in wind-speed, and during a low and the passage

Table XXII

Comparison of meteorological factors with which changes in number and ways of living of Kittiwakes are associated. I. Total of birds, II. percentage of birds following trawler, III percentage of birds flying at a distance, IV. percentage of birds sitting on sea

	—48	—24	—12	0	+12	+24	+48	Changes in the number of birds on the day of observation
I	fall in air temperature	fall in air temperature		high; col; ahead of and behind fronts; low air temperature	light wind; fall in air temperature	light wind; fall in air temperature		rise
	rise in air temperature	rise in air temperature		rise in air temperature; passage of fronts; low	strong wind; rise in air temperature	strong wind; rise in air temperature		fall
II		high cloudiness	high cloudiness					rise
		low cloudiness	low cloudiness					fall
III			low cloudiness	light wind				rise
			high cloudiness	strong wind				fall
IV				low waves; large number of Kittiwakes				rise
				high waves; small number of Kittiwakes				fall

of fronts. Besides, fairly large numbers of birds were observed at a low air temperature at the time of observation, on the days preceding and on the day following it. Smaller numbers of birds were seen at the time of an increased air temperature persisting for four days.

The percentage of Kittiwakes flying and feeding in the proximity of the trawler increased 24 and 12 hours after an increase in cloudiness and in evening hours, and a fall in it followed a decrease in cloudiness and occurred in the morning.

The percentage of Kittiwakes swimming on the sea rose when the total of these birds increased and when the waves were lower. A fall in the percentage was recorded when the total of birds decreased and there was a high wave on the sea.

The percentage of Kittiwakes flying at a distance from the trawler (including migrants) rose 12 hours after a decrease in cloudiness and at the time of mild winds.

A fall in the percentage of Kittiwakes flying at a distance from the trawler was observed 12 hours after an increase in cloudiness and at the time when fairly strong winds prevailed.

As in the case of analogous relations in Fulmars, more birds followed the trawler and fed in her proximity when the complex of weather factors resembled that bringing about a fall in the total number of birds.

It may be stated on the basis of the foregoing data that the percentage of migrating Kittiwakes is higher when the weather is similar to that responsible for a rise in the total of birds (decrease in wind-speed).

The occurrence of migration is also associated with low cloudiness. After a spell of increased cloudiness the percentage of Kittiwakes feeding in the vicinity of the trawler was higher.

4. Glaucous Gull *Larus hyperboreus* Gunnerus, 1767

Glaucous Gulls appeared in the study area nearly every day, most often in numbers somewhat exceeding 10 specimens. The maximum numbers observed were 335 on 26 February, 306 on 30 March and 300 on 13 April. The numbers of these gulls counted in the fisheries are given in Fig. 16. They were significantly correlated with the place of observation (fishery) at the 0·02 level (Table XXIII).

Fig. 2 shows the percentage share of observations with different numbers of Gloucous Gulls in 4 fisheries. It will be seen from this figure that the birds were most numerous in fishery 1, situated farthest to the south, and in fishery 4, which was situated farthest to the north.

The number of birds is not correlated with the month in which the observations were made, the number of ships and the output of catches in the particular fishery. It was correlated with the change in wind-speed 24 and 48 hours after the observation and that in cloudiness 24 hours after it (Table XXIII)

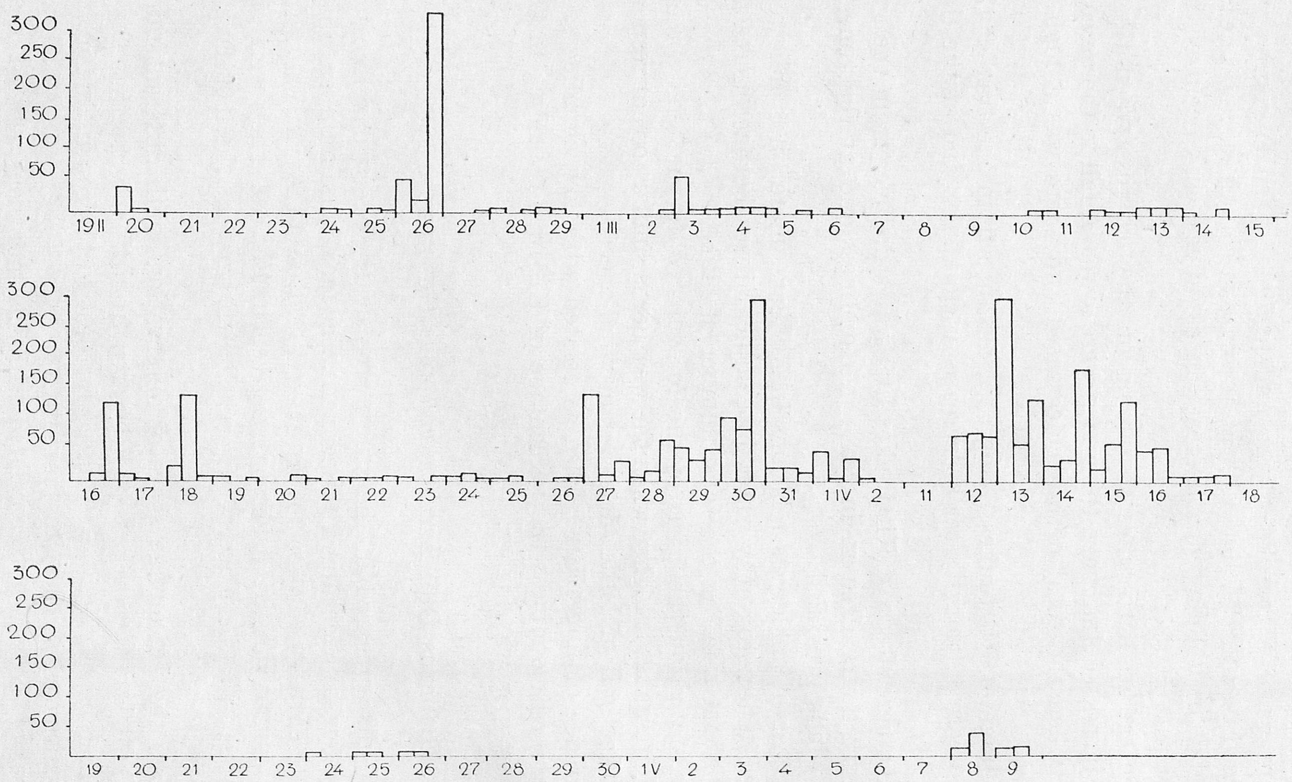

Fig. 16. Numbers of Glaucous Gulls *Larus hyperboreus* in particular observations made in the fisheries off Newfoundland and Labrador in the morning, at noon and in the evening from 19 February to 9 May 1968

Table XXIII

Analysis of significance levels of correlations between the number of Glaucous Gulls and the factors examined

	—48	—42	—12	0	+12	+24	+48
Fishery				**0·02**			
Month of observation				0·99			
Number of trawlers				0·80			
Size of catches				0·95			
Time of day				0·90			
Time of day+				0·30			
Wind-speed	0·20	0·90	0·99	0·70	0·20	**0·01**	**0·05**
Wind direction				0·50			
Cloudiness	0·50	0·50	0·70	0·30	0·20	**0·05**	0·10
Visibility	0·99	0·80	0·20	0·50	0·20	0·70	0·50
Barometric pressure	0·30	0·30	0·90	0·20	0·10	0·10	0·30
Mean air temperature	0·99	0·70		0·20		0·30	0·90
Amplitude of temperature				0·50			

at the 0·01, 0·05 and 0·05 level, respectively. The correlation between the number of birds and the place of observation, as plotted on the synoptic diagram, was significant at the 0·05 level.

The relation of the number of Gloucous Gulls in particular observations to the wind-speed 24 and 48 hours after these observations is presented in Fig. 17A and B. An increase in the number of birds was recorded 24 and 48 hours before a wind of a speed lower than 4—5 degrees on the Beaufort scale. A fall in the number of gulls occurred 24 and 48 hours before a wind blowing at a higher speed.

Fig. 17C shows the quantitative share of observations with gulls at different degrees of cloudiness 24 hours after the observation. A fall in the number

Table XXIV

Correlation between the number of Glaucous Gulls and the synoptic pattern

	0	1—20	above 20	Mean
1 High and col	10	29	12	10
2 Fronts	9	12	1	4
3 Depression	20	17	5	6
4 Behind depression	1	6	1	10
5 Weak low-pressure system	5	9	2	8

$F = 2.94$
$p < 0.05$

of birds occurred before an increase in cloudiness and, vice versa, 24 hours before a decrease in cloud-cover there was a rise in the number of observations in which more than 20 specimens were counted.

The synoptic pattern (Fig. 18, Table XXIV) shows that the largest numbers of Gloucous Gulls were observed in the fisheries during a high and col and after a low. The gulls were least numerous at the time of a low and fronts.

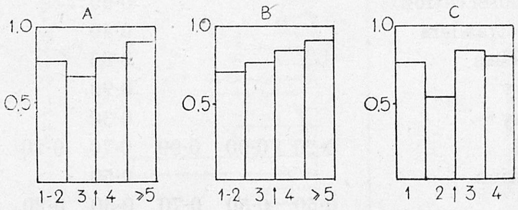

Fig. 17. Changes in the number of Glaucous Gulls according to A, B — wind-speed (N = +24, +48), C — cloudiness. The blocks represent the quantitative share of observations with 0—10 birds

The foregoing observations indicate that Glaucous Gulls give preference to sea areas with light winds, which together with low cloudiness often characterize anticyclonic or col weather (very low pressure gradient). The data presented also show that the occurrence of these birds in particular sea regions is chiefly related to the weather which is to follow.

5. Ivory Gull *Pagophila eburnea* (PHIPPS, 1774)

In the study areas Ivory Gulls appeared in small numbers (maximum numbers being 70 specimens on 4 March, 25 on 18 March and 24 on 30 March). The numbers of birds occurring in the fisheries at the time of particular observations are given in Fig. 19. As can be seen from this figure, Ivory Gulls were as often as not entirely lacking or represented by single specimens. No specimens of this species were observed after 20 April. The birds observed included also specimens marked by juvenile colouration. The quantitative changes found in this species were independent of the place of observation and the month in which it was carried out (Table XXV). Table XXV shows also that there were no significant correlations between the number of Ivory Gulls and the number of trawlers fishing in the place of observation and the average output of fishing in the fishery examined. Out of the remaining factors, the number of birds was correlated with the visibility 12 hours after the observation at the 0·01 level of significance. Its correlation with the place of observation plotted on the synoptic diagram was also significant at the 0·01 level (Table XXVI, Fig. 20).

Fig. 21 shows that a decrease in visibility below 3 occurred 12 hours after a rise in the number of Ivory Gulls from 1 to 5, and, above all, to above 6 specimens.

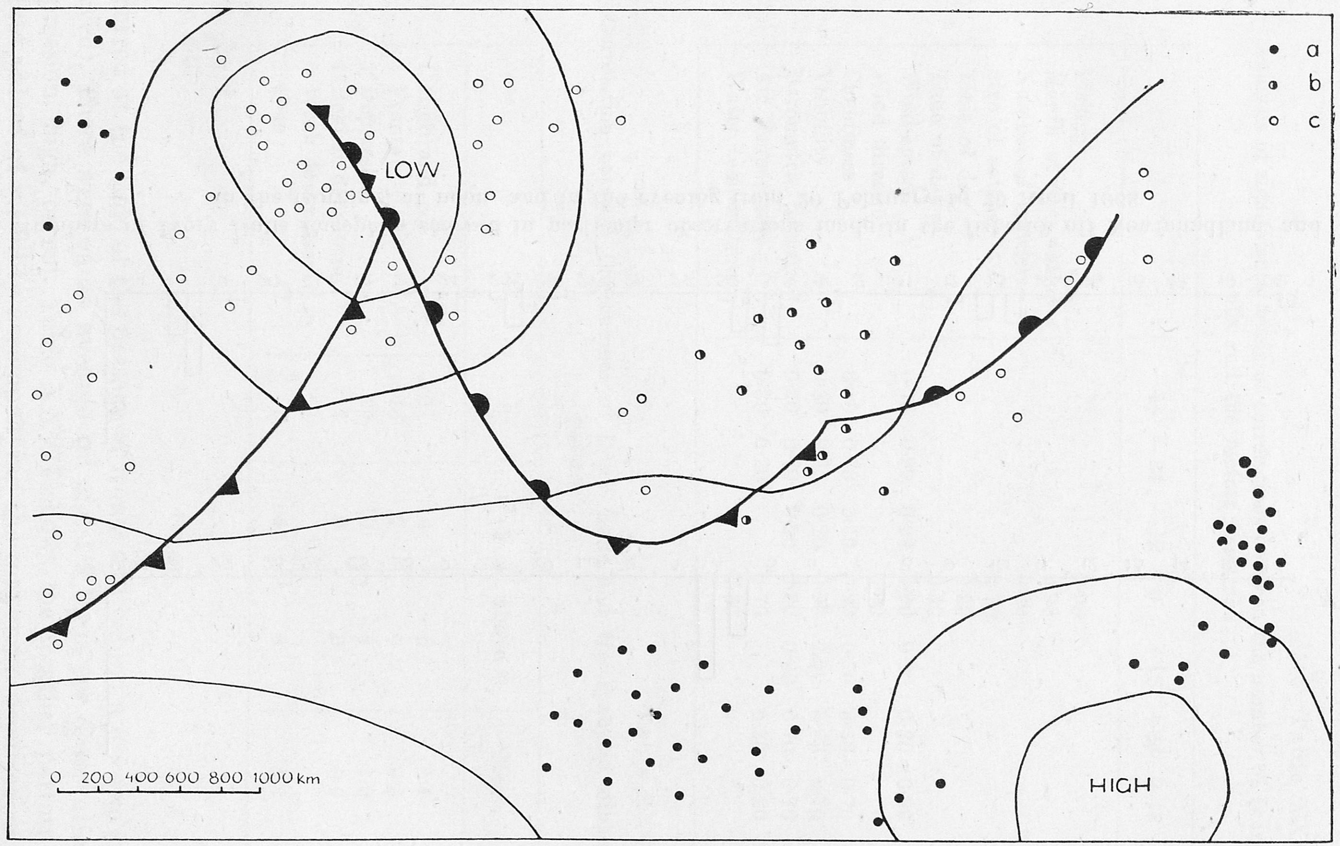

Fig. 18. Correlation between the mean number of Glaucous Gulls in an observation and the situation of the place of observation plotted on a synoptic diagram. a — over 10, b — 8, c — 6 birds

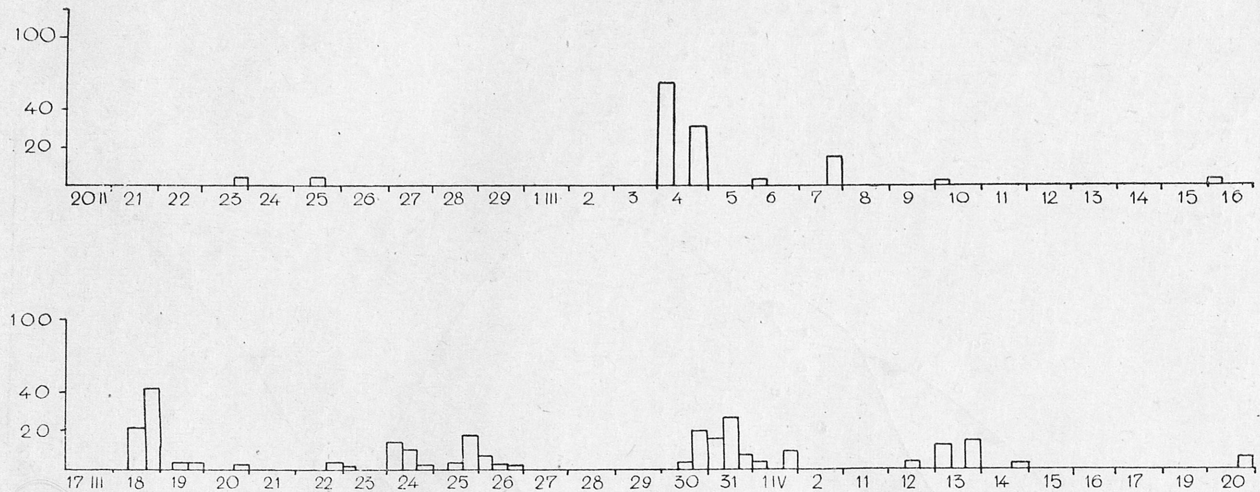

Fig. 19. Numbers of Ivory Gulls *Pagophila eburnea* in particular observations made in the fisheries off Newfoundland and Labrador in the morning, at noon, and in the evening from 20 February to 20 April 1968

The weather diagram (Fig. 20, Table XXVI) shows that an increase in the number of birds took place in an area over which a shallow depression was moving (mean number of birds in an observation was 2·7), whereas a fall in

Table XXV

Analysis of significance levels of correlations between the number of Ivory Gulls and the factors examined

	—48	—24	—12	0	+12	+24	+48
Fishery				0·98			
Month of observation				0·90			
Number of trawlers				0·50			
Size of catches				0·70			
Time of day				0·90			
Time of day+				0·50			
Wind-speed	0·70	0·99	0·99	0·99	0·20	0·30	0·99
Wind direction				0·99			
Cloudiness	0·50	0·70	0·70	0·99	0·70	0·50	0·70
Visibility	0·30	0·95	0·20	0·99	**0·01**	0·99	0·70
Barometric pressure	0·30	0·70	0·20	0·30	0·80	0·70	0·70
Air temperature	0·80	0·20		0·70		0·20	0·20
Water temperature				0·50			

Table XXVI

Correlation between the number of Ivory Gulls and the synoptic situation pattern

	0	1—5	above 6	Mean
1 High and col	31	14	6	1·4
2 Fronts	16	7	0	0·3
3 Depression	25	10	7	1·9
4 Behind depression	7	0	0	0·0
5 Weak low-pressure system	8	4	4	2·7

$F = 5{\cdot}8$
$p < 0{\cdot}01$

it occurred at the time of the passage of fronts and behind a low (no specimens observed). There were on an average 1·4 and 1·9 birds per observation during a depression, high, or col. Table XXVII shows the weather pattern and the absolute values of visibility accompanying the maximum occurrences of Ivory Gulls. In addition, the fall of rain (4 March) and snow (in the remaining cases) is represented in this table by its time compared with the time of observation.

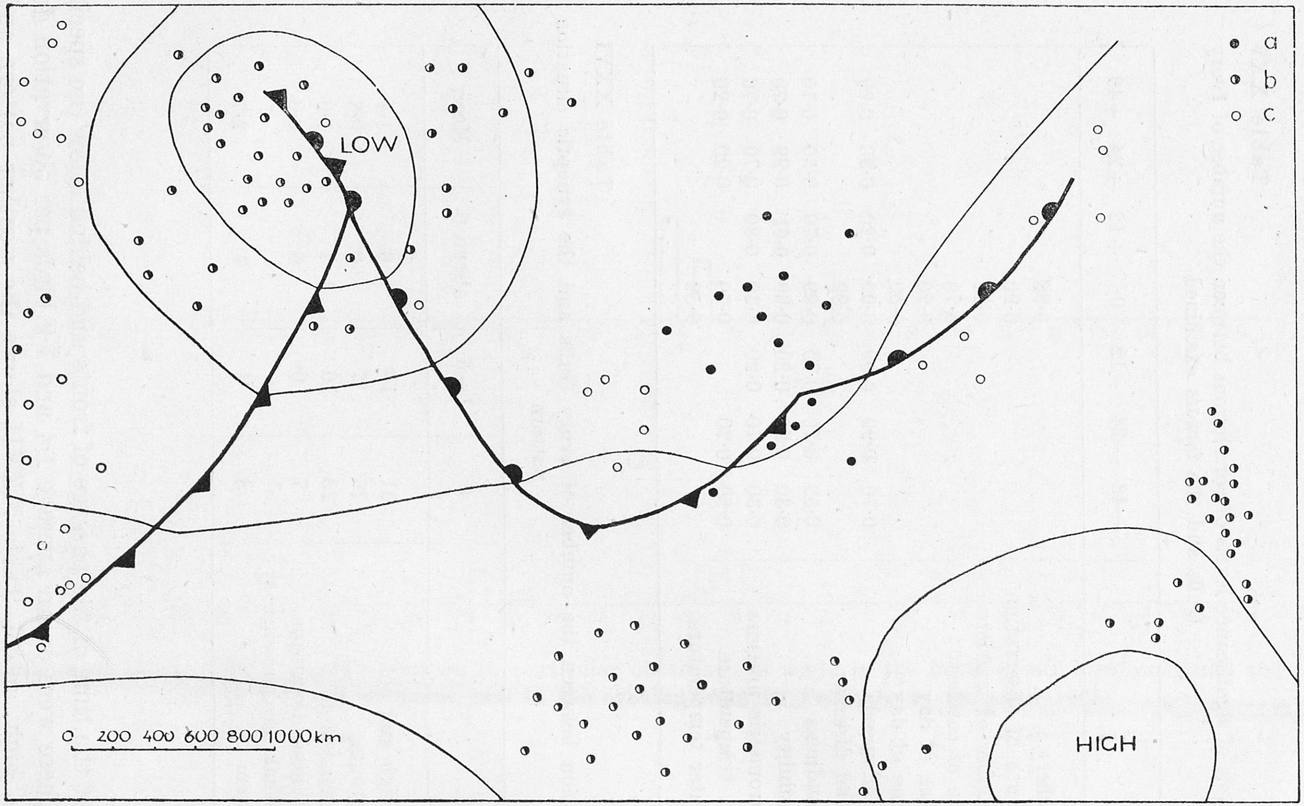

Fig. 20. Correlation between the mean number of Ivory Gulls in an observation and the situation of the place of observation plotted on a synoptic diagram. 0—2·7, 0—1·4 and 1·9, 0—below 0·3 specimens

As will be seen from this table, in all the cases the rise in the number of birds was correlated with the position of the place of observation in relation to the synoptic pattern or with the deterioration of visibility combined with rainfall. In two cases (30 March and 13 April) there was no deterioration in visibility in 12 hours, but there occurred falls of snow after 24 and 8 hours, respectively.

Table XXVII

Weather factors accompanying maximum numbers of Ivory Gulls

Date	Visibility 12 hrs after observation	Occurrence of weak low-pressure system	Rainfall (figures in brackets represent hours after observation)
4 III	0·3		(+12)
4 III	5		(+12)
7 III	2		(+12)
18 III	10	+	
18 III	10	+	
24 III	2		(+12)
24 III	1		(+12)
25 III	2	+	
26 III	6	+	
30 III	5		(+24)
31 III	2		(+12)
31 III	2		(+12)
1 IV	2		(+12)
13 IV	0·5		(+12)
13 V	10		(+8)

Table XXVIII

Levels of significance of correlation between the numbers of particular species examined in fisheries in the Labrador and the Newfoundland region

Fulmarus glacialis	— *Pagophila eburnea*	: 0·99
Fulmarus glacialis	— *Larus hyperboreus*	: **0·02**
Fulmarus glacialis	— *Rissa tridactyla*	: 0·50
Rissa tridactyla	— *Larus hyperboreus*	: 0·95
Rissa tridactyla	— *Pagophila eburnea*	: 0·30
Larus hyperboreus	— *Pagophila eburnea*	: 0·50

The present investigation shows that the occurrence of Ivory Gulls is not associated with a definite area in the region examined, neither does it reveal any connections with the presence of fishing trawlers. The only factor with which the changes in their numbers are correlated are the changes in weather. The birds aggregate in the largest numbers in areas which exhibit a shallow depression, depression, or anticyclone. They appear most rarely at the time of the passage of fronts and behind a low-pressure system. A rise in the number of Ivory Gulls occurred also 12 hours before a deterioration in visibility, always

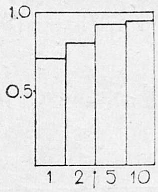

Fig. 21. Changes in the number of Ivory Gulls according to visibility (N = +12). The blocks represent the quantitative share of observations with 0—5 birds

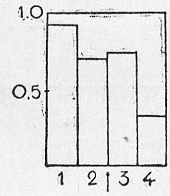

Fig. 22. Relationship between the number of Glaucous Gulls and that of Fulmars. The blocks represent the quantitative share of observations with 0—10 Glaucous Gulls in relation to the quantitative ditribution of Fulmars: 1. 0—50, 2. 51—400, 3. 401—1000, 4. over 1000.

combined with the fall of snow or rain. This fact indicates that they can migrate actively to regions with more favourable atmospheric conditions. They can also acquire information about the approach of poor visibility and rainfall about 12 hours in advance.

6. Relations between the numbers of particular bird species

Levels of significance for the correlations between the numbers of particular species at the time of observation are presented in Table XXVIII. It shows that there was a correlation between the number of Fulmars and that of Glaucous Gulls. Fig. 22 shows the share of the observations with Glaucous Gulls in relation to the number of Fulmars in the fishery. It will be seen from this figure that the increase in the number of Glaucous Gulls accompanied the increase in the number of Fulmars.

IV. FISHERIES IN THE NORTH SEA

1. Introductory

I made cruises to the fisheries in the North Sea in the trawlers s. s. „Hańcza“ from 3 February to 9 March 1964, s. s. „Biała“ from 22 August to 19 September 1968 and s. s. „Przemsza“ from 4 to 25 October 1968. The stay in the fisheries lasted 48 days altogether.

Table XXIX gives the numbers of days and dates of stays in particular fisheries. The itineraries of cruises and the situations of fisheries are presented in Figs. 1 and 23.

The catches were followed by the classification and preservation of the fish caught on board the trawler. The hauling of nets on to the deck was accompanied by a number of manoeuvres performed by the trawler, and for the birds these movements were an indication of the possibility of finding food in the proximity of the vessel. As a result, only a slight number of birds followed the trawling vessel (Manikowski, 1966), since at that time they were feeding at other fishing trawlers. The removal of fish scraps overboard by flushing the deck with water was done after the processing of fish. Then the birds gathered in the vicinity of the trawler until all the food had been collected. This

Table XXIX

Numbers of days of observations in fisheries in the North Sea

Fishery No.	Dates of observations	Numbers of days
1	13—15 February	3
	21—22 February	2
	29 February—6 March	7
	Total days	12
2	16 February	1
	19—20 February	2
	28 February	1
	Total days	4
3	25—27 August	3
	10 September	1
	16 September	1
	17 October	1
	Total days	6
4	14—16 October	3
	Total days	3
5	28 August—8 September	12
	11—15 September	5
	6—11 October	6
	Total days	23
	Total for all fisheries	48

type of behaviour of the birds did not allow the adequate determination of the proportions of migrating specimens and those sitting on the sea surface, because all the birds stayed near the trawler feeding or waiting for food during this phase of fishing. At the time of trawling the birds flew to another vessel that was busying herself with hauling in the nets and processing the fish.

Only observations with the maximum numbers of birds at the time of hauling in the nets with fish have been taken into consideration in the further elaboration of material.

The weather fluctuations in the fisheries showed a great amplitude, embracing the wind-speed from 0 to 8 degrees on the Beaufort scale, the state of sea from 0 to 9, and the barometric pressure from 995 to 1035 millibars.

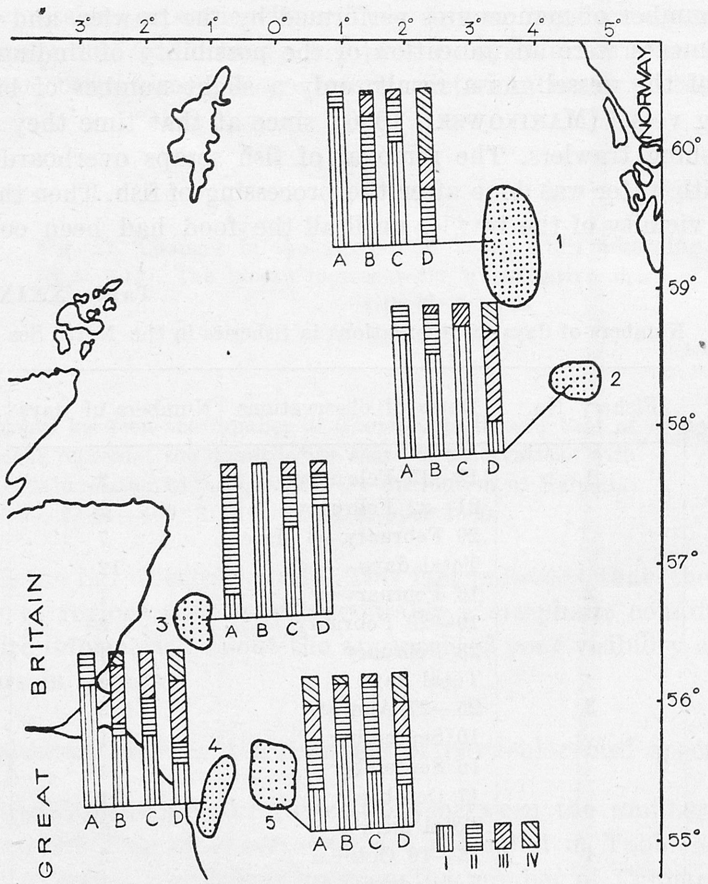

Fig. 23. Distribution of fisheries in the North Sea. The graphs show the quantitative share of observations with different numbers of birds of the four species examined: A. *Fulmarus glacialis*: I. 0—10, II. 11—40, III. 41—100, IV. over 100. B. *Rissa tridactyla*: I. 0—50, II. 51—100, III. 101—400, IV. over 400. C. *Sula bassana*: I. 0—10, II. 11—40, III. over 40. D. *Larus marinus*: I. 0—10, II. 11—40, III. 41—100, IV. over 100

Fulmars, Kittiwakes, Great Black-backed Gulls and Gannets occurred most numerously in the fisheries and only these species are included in the present study.

2. Fulmar *Fulmarus glacialis* (Linnaeus, 1761)

Fulmars appeared nearly everyday in the period of investigation. Their maximum numbers in an observation were 600 specimens on 28 August, 430 on 29 August and 400 on 30 August 1968. The numbers of Fulmars in particular observations are presented in Fig. 24. The changes in the number of these birds are significantly correlated (Table XXX) with the situation of the trawler and the month in which the observation was carried out (Figs. 23 and 25A). The figures show that the largest numbers of birds were observed in fishery No. 5 and, as regards the time, in August and September.

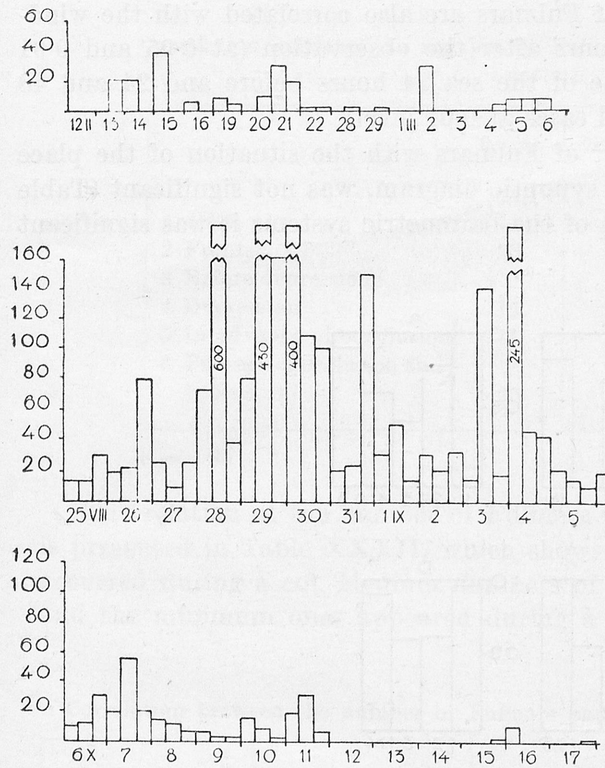

Fig. 24. Numbers of Fulmars in particular observations made in the fisheries in the North Sea in the morning, at noon and in the afternoon in the periods: 12 February — 6 March 1964, 25 August—16 September 1968, and 6—17 October 1968

Table XXX

Analysis of significance levels of correlations between the number of Fulmars and the factors examined

	—48	—24	—12	0	+12	+24	+48
Fishery				**0·01**			
Month of observation				**0·01**			
Number of trawlers				0·10			
Size of catches				0·99			
Time of day				0·70			
Time of day+				0·99			
Wind-speed	0·10	**0·05**	0·95	0·20	0·50	0·90	**0·01**
Wind direction				0·70			
State of sea	0·30	**0·01**	0·70	0·10	0·20	**0·01**	**0·01**
Cloudiness	0·99	0·20	0·99	0·99	0·99	0·90	0·50
Visibility	0·99	0·50	0·20	0·50	0·30	0·70	0·30
Barometric pressure	0·99	0·99	0·99	0·30	0·50	0·30	0·99
Air temperature				0·30			

The changes in the number of Fulmars are also correlated with the wind-speed 24 hours before and 48 hours after the observation (at 0·05 and 0·01 levels, respectively) and the state of the sea 24 hours before and 24 and 48 hours after the observation (in all cases at 0·01 level).

The correlation of the number of Fulmars with the situation of the place of observation, as plotted on the synoptic diagram, was not significant (Table XXXI), but with the movements of the barometric systems it was significant at the 0·05 level.

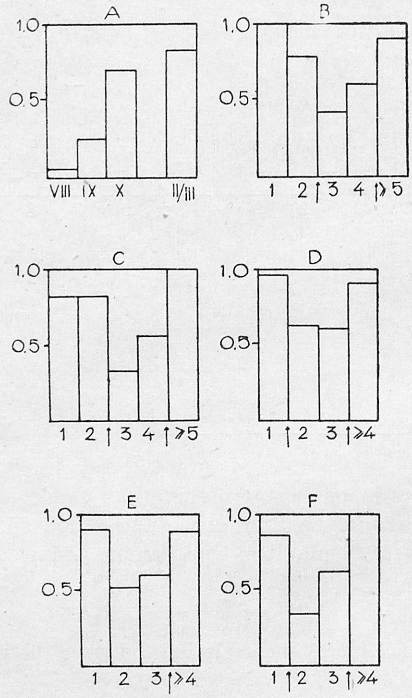

Fig. 25. Changes in the number of Fulmars according to A — month of observations, B, C — wind-speed (N = —24, +48), D—F — state of sea (N = —24, +24, +48). The blocks of Graph A represent the quantitative share of observations with 0—100 birds, and those of the remaining graphs with 0—400 birds

Fig. 25B and C, which presents the correlation between the number of Fulmars and the wind-speed 24 hours before and 48 hours after the observation, shows that there was a rise in the number of these birds before and after winds of speeds ranging from 2 to 4 degrees on the Beaufort scale. Lighter winds brought about falls in the number of birds and, on the other hand, a fall in this number was followed by stronger winds. A similar situation occurs in so far as the states of the sea associated with the wind-speed are concerned (Fig. 25D, E and F). Waves of a strength of 2—3 degrees were preceded and followed by a rise in the number of Fulmars.

Table XXXI

Correlation between the number of Fulmars and the synoptic situation pattern

	0—25	26—50	51—100	above 100
1 High	12	1		
2 Fronts	23	4	3	4
3 Before depression	9	1	2	2
4 Depression	15	3		1
5 In advance of occulusion	17	3		2
6 Passage of occlusion and behind it	25	5		2

$F = 1{\cdot}85$

The relation of the number of Fulmars to the general barometric situation is presented in Table XXXII, which shows that a rise in the number of birds occurred during a col. Medium numbers of birds were observed during a high and the minimum ones appeared during a low.

Table XXXII

Correlation between the number of Fulmars and the movement of barometric systems

	0—25	26—50	51—100	above 100	Mean
1 High	24	6	3	2	35
2 Low	36	11	2	2	21
3 Col	14	3	4	4	77

$F = 3{\cdot}99$
$p < 0{\cdot}05$

The largest numbers of Fulmars were recorded in August and September and in the fishery which, out of all the fisheries in the region of Great Britain, was situated farthest from the coast. A rise in the number of these birds took place within an area of a relatively low gradient of fluctuations of wind-speed and state of sea, that is, in a barometric col. The presence of these birds in advance of moderate winds indicates the possibility of their active choice of such a region of the sea as can provide them with the optimum conditions to carry on flights in search of food. On the other hand, they are able to anticipate the approach of too strong or too light winds and leave a given area 24 and 48 hours earlier.

The lack of correlation between the number of Fulmars and the number of fishing trawlers, the output of fishing and the time of day shows that these birds are not associated with the presence of ships in an absolute manner.

3. Kittiwake *Rissa tridactyla* (Linnaeus, 1758)

Kittiwakes occurred everyday throughout the study period. Their numbers were subject to great fluctuations, ranging from several to 2000 specimens. Fig. 26 gives the numbers of Kittiwakes in particular observations. The largest numbers were observed in October, February and March in fisheries Nos. 1, 4 and 5, and the smallest ones in August and September in fisheries Nos. 2 and 3 (Figs. 23 and 27 A). These differences are significant at the 0·01 level (Table XXXIII).

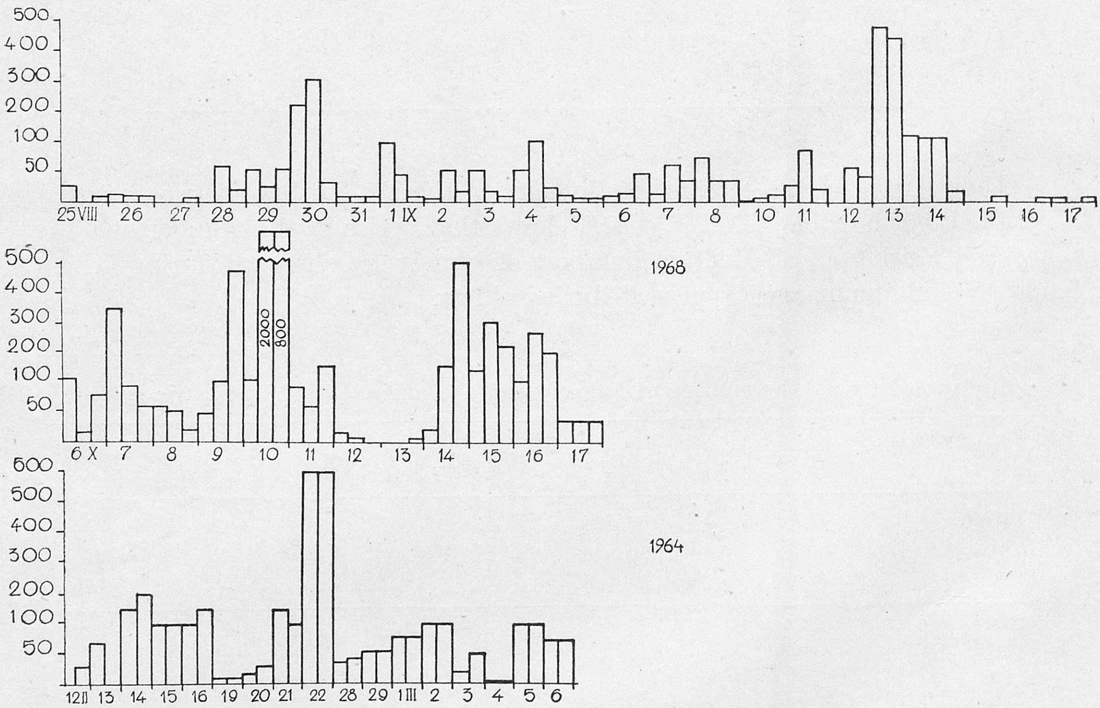

Fig. 26. Numbers of Kittiwakes in particular observations made in the fisheries of the North Sea in the morning, at noon and in the afternoon in the periods: 12 February — 6 March 1964, 25 August—17 September 1968 and 6—17 October 1968

Out of the weather factors, the wind-speed 24 hours before and after observation (at 0·05 and 0·01 levels), the wind direction at the time of observation (0·01), the state of sea 24 hours before and 12 and 24 hours after the observation (0·01, 0·05 and 0·02), and the cloud-cover and barometric pressure 12 hours before the observation (0·05 and 0·05) had an effect on the number of Fulmars. The correlation between the number of birds and the place of observation plotted on the synoptic diagram is not significant (Table XXXIV) but that of the number of birds with the movement of a high was significant at the 0·01 level and with the passage of an occlusion at the 0·05 level (Tables XXV and XXXVI).

Fig. 27E and F shows the quantitative share of observations with given numbers of Kittiwakes at various wind-speeds 24 hours before and after the observation. It will be seen from both these graphs that an increase in wind-

Table XXXIII

Analysis of significance levels of correlation between the number of Kittiwakes and the factors examined

	−48	−24	−12	0	+12	+24	+48
Fishery				**0·01**			
Month of observation				**0·01**			
Number of trawlers				0·50			
Size of catches				0·80			
Time of day				0·30.			
Time of day+				0·30			
Wind-speed	0·20	**0·05**	0·50	0·99	0·20	**0·01**	0·30
Wind direction				**0·01**			
State of sea	0·70	**0·01**	0·10	0·80	**0·05**	**0·02**	0·30
Cloudiness	0·70	0·30	**0·05**	0·70	0·10	0·90	0·50
Visibility	0·99	0·80	0·90	0·50	0·80	0·30	0·30
Barometric pressure	0·99	0·99	**0·05**	0·70	0·50	0·10	0·70
Air temperature				0·20			

Table XXXIV

Correlation between the number of Kittiwakes and the synoptic situation pattern

	0—50	51—100	above 100
1 High	6	8	
2 Fronts	20	7	6
3 Before depression	5	6	3
4 Depression	8	5	6
5 In advance of occlusion	8	7	8
6 Passage of occlusion and behind it	26	2	4

F = 0·79

speed was followed or preceded by a rise in the number of birds. In both cases a slight rise in the number of birds occurred also when the wind-speed decreased to 1 degree on the Beaufort scale or lower. Similarly, a rise occurred when the west winds were blowing, whereas a fall coincided with the east winds (Fig. 28).

Fig. 27 B, C and D shows a relationship between the number of Kittiwakes and the state of the sea 24 hours before and 12 and 24 hours after the observation. In all the cases the rise in the number of birds was correlated with an increase in waving. It also occurred 12 hours after an increase in cloudiness (Fig. 27 G) and 12 hours after a drop in barometric pressure (Fig. 27 H).

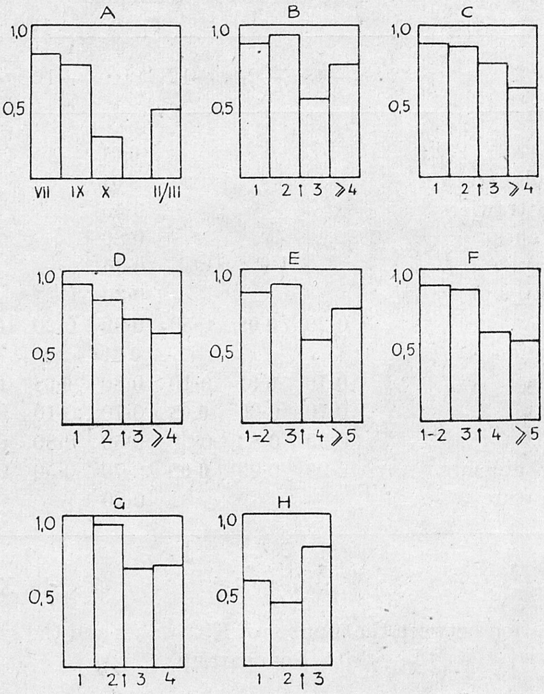

Fig. 27. Changes in the number of Kittiwakes according to A — month of observations, B, C, D — state of sea (N = —24, +12, +24), E, F — wind-speed (—24, +24), G — cloudiness (N = —12), H — barometric pressure (N = —12). The blocks represent the quantitative share of observations with 0—50 birds in Graph A, 0—100 in Graphs B—G and 0—60 in Graph H. Designations of barometric pressure in Graph H: 1. Below 1010 millibars, 2. 1011—1020 millibars, 3. above 1020 millibars

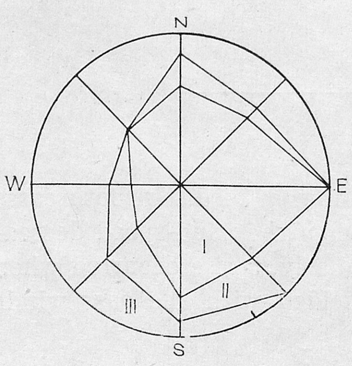

Fig. 28. Changes in the number of Kittiwakes according to the wind-direction (N = 0). I. 0—50, II. 51—100, III. over 100 birds in an observation

Tables XXXV and XXXVI illustrate the number of birds as related to the situation of a high and the passage of an occlusion and show that an increase in it took place at the edge of the high and behind the occlusion.

The presence of Kittiwakes was not correlated with the number of trawlers and the size of catches in the fishery. Apart from the changes in the number of birds dependent on season on the and situation of the fishery, the Kittiwakes

Table XXXV

Correlation between the number of Kittiwakes and the movement of the high in relation to the place of observation

	0—50	51—100	above 100	Mean
1 High	14	7		41·0
2 High-pressure ridge	10	4	1	49·2
3 Edge of high	2	5	2	215

$F = 9{\cdot}1$
$p < 0{\cdot}05$

Table XXXVI

Correlation between the number of Kittiwakes and the movement of the occlusion in relation to the place of observation

	0—50	51—100	bove 100	Mean
1 Passage of occlusion and ahead it	29	12	7	77·3
2 Behind occlusion	8	2	3	253·4

$F = 4{\cdot}41$
$p < 0{\cdot}05$

grew in number 24 and 12 hours after a deterioration of weather consisting in an increase in wind-speed, sea waves and cloudiness and a fall in barometric pressure. A complex weather analysis shows that this situation occurred at the edge of a high and after the passage of an occlusion. The number of birds rose both 12 and 24 hours before an increase in wind-speed and sea waving. It was increased at the time of west winds.

4. Great Black-backed Gull *Larus marinus* Linnaeus, 1758

Great Black-backed Gulls were observed everyday. The maximum numbers of birds reached 2000 specimens on 16 October 1968, 1500 on 17 October 1968, 900 on 22 February 1964 and 400 on 5 March 1964. Fig. 29 presents the numbers of these birds in particular observations. Table XXXVII is an analysis of

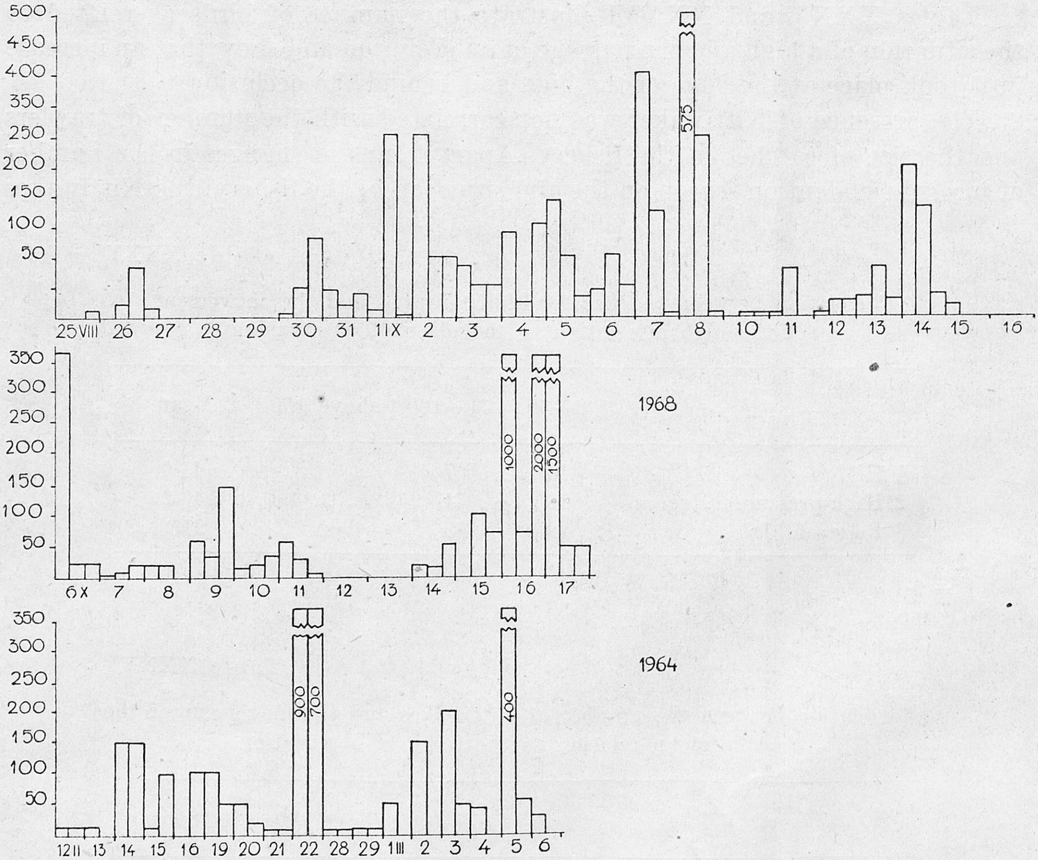

Fig. 29. Numbers of Greater Black-backed Gulls *Larus marinus* in particular observations made in the fisheries in the North Sea in the morning, at noon and in the afternoon in the periods 12 February — 6 March 1964, 25 August—16 September 1968 and 6—17 October 1968

relationships between the number of gulls and the environmental factors examined. It shows that the number of gulls is significantly correlated only with such weather factors as cloudiness 12 hours after the observation and barometric pressure 12 hours before the observation. The relationship of the number of birds with the synoptic pattern and the movement of weather systems except for the movement of a high-pressure system is insignificant (Tables XXXVIII and XXXIX).

The share of observations with given numbers of gulls as related to cloudiness is given in Fig. 30 A, which shows that a rise in the number of birds preceded an increase in cloudiness. This share in relation to the barometric pressure 12 hours before the observation is presented in Fig. 30 B. The number of birds rose 12 hours after a drop in barometric pressure. When a high was active, the number of gulls increased at the edge of the system and decreased in its middle and in a high-pressure ridge.

Table XXXVII

Analysis of significance levels of correlation between the number of Great Black-backed Gulls and the factors examined

	—48	—24	—12	0	+12	+24	+48
Fishery				0·98			
Month of observation				0·70			
Number of trawlers				0·30			
Size of catches				0·20			
Time of day				0·70			
Time of day+				0·10			
Wind-speed	0·90	0·50	0·90	0·30	0·30	0·99	0·20
State of sea	0·70	0·70	0·70	0·70	0·50	0·99	0·20
Wind direction				0·20			
Cloudiness	0·70	0·90	0·30	0·70	**0·05**	0·10	0·70
Visibility	0·20	0·70	0·50	0·80	0·90	0·99	0·99
Barometric pressure	0·30	0·50	**0·02**	0·99	0·99	0·99	0·99
Air temperature				0·30			

Table XXXVIII

Correlation between the number of Great Black-backed Gulls and the synoptic situation pattern

	0—50	51—100	above 100
1 High	10	1	3
2 Fronts	23	6	3
3 Before depression	9	3	2
4 Depression	11	1	6
5 In advance of occlusion	12	3	7
6 Passage of occlusion and behind it	22	5	6

$F = 1.72$

Table XXXIX

Correlation between the number of Great Black-backed Gulls and the movements of the high in relation to the place of observation

	0—50	51—100	above 100	Mean
1 Centre of high	9	3	3	117
2 High-pressure ridge	8	2	4	124
3 Edge of high	1	2	2	362

$F = 4.02$

$p < 0.05$

The foregoing data indicate lack of correlation between the number of Great Black-backed Gulls and the fishery, season, number of trawlers and size of catches. The changes in the abundance of this species are associated only with the changes in weather

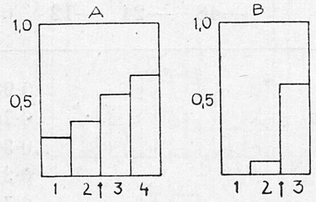

Fig. 30. Changes in the number of Greater Black-backed Gulls according to A — cloudiness (N = +12), B — barometric pressure (N = —12). The blocks represent the quantitative share of observations with 0—40 birds in Graph A and 0—10 in Graph B. Barometric pressure in Graph B: 1. below 1010 millibars, 2. 1011—1020 millibars, 3. over 1021 millibars

5. *Larus* sp. juv.

Young gulls of different species were recorded as a separate group, because it was difficult to identify them under field conditions, and their number was analysed against some environmental factors. Table XL shows that the largest numbers of birds belonging to this group were observed in October (Fig. 31 A).

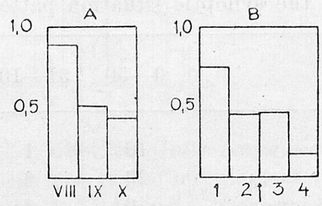

Fig. 31. Changes in the number of young gulls *Larus* sp. according to A — month of observations, B — number of Great Black-backed Gulls. The blocks represent the quantitative share of observations with 0—40 birds. Numbers of Great Black-backed Gulls in Graph B: 1. 1—10, 2. 11—40, 3. 41—100, 4. over 100

Table XL

Levels of significance of correlations between the number of young gulls *Larus* sp. and the factors examined

	0
Total of Greater Black-backed Gulls	**0·01**
Fishery	0·70
Month of observation	**0·05**
Number of trawlers	0·70
Size of catches	0·99
Time of day	0·99
Time of day+	0·99

The other factors exerted no influence on the number of these birds. The correlation between the rise in the number of Great Black-backed Gulls and that of juveniles is significant at the 0·01 level (Table XL, Fig. 31B) and indicates that the latter birds belonged chiefly to this species. For this reason I gave up calculating the relations between the changes in the number of birds of this group and the changes in weather.

6. Gannet *Sula bassana* (LINNAEUS, 1758)

Gannets appeared in the study area everyday. Their number reached 1000 specimens on 16 October, 500 on 17 October and 130 on 6 October 1968. The numbers of Gannets in particular observations are given in Fig. 32. Levels

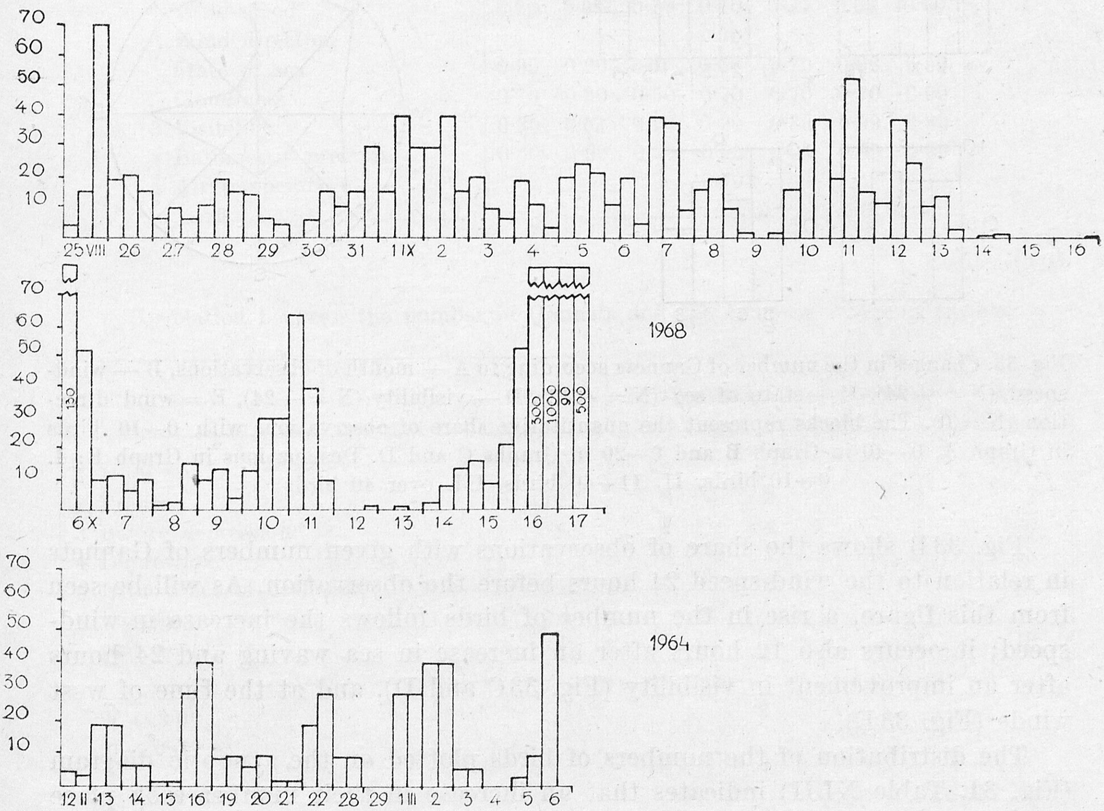

Fig. 32. Numbers of Gannets *Sula bassana* in particular observations made in the fisheries in the North Sea in the morning, at noon, and in the evening in the periods 12: February—6 March 1964, 25 August—16 September 1968 and 6—17 October 1968

of significance of the relationships between the number of these birds and the environmental factors examined are presented in Table XLI. The correlation between the number of Gannets and the month of observation, shown in Fig. 33A, is significant at the 0·05 level. The birds were most numerous in October and least numerous in February and March.

Out of the weather factors, the wind-speed 24 hours before the observation, wind direction at the time of observation, state of the sea 12 hours and visibility 24 hours before the observation had an effect on the number of birds, significant at the 0·05, 0·01, 0·01 and 0·02 levels, respectively.

The relationships of the number of Gannets with the place of observation against the synoptic pattern (Table XLII) and with the general type of weather prevailing in the fishery (Table XLIII) are also significant.

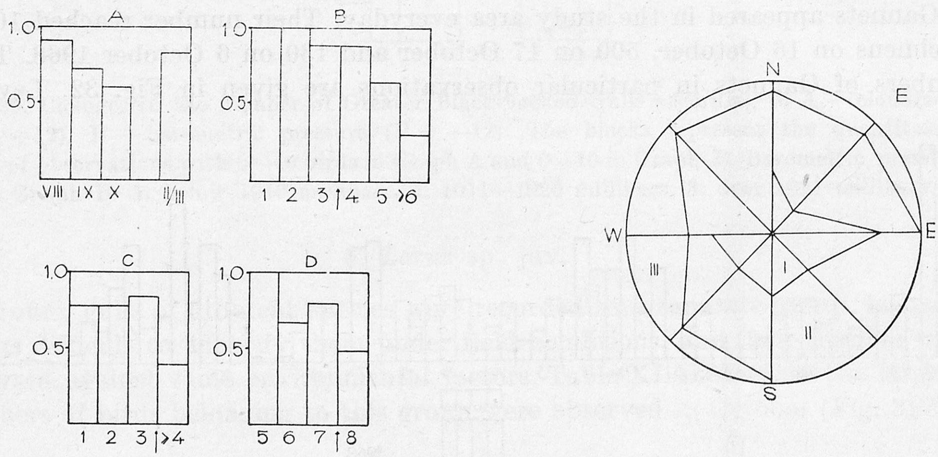

Fig. 33. Changes in the number of Gannets according to A — month of observations, B — wind-speed (N = —24), C — state of sea (N = —12), D — visibility (N = —24), E = wind direction (N = 0). The blocks represent the quantitative share of observations with 0—10 birds in Graph A, 0—40 in Graph B and 0—20 in Graphs C and D. Designations in Graph E: I. 0—10 birds, II. 11—40 birds, III. over 40 birds

Fig. 33B shows the share of observations with given numbers of Gannets in relation to the wind-speed 24 hours before the observation. As will be seen from this figure, a rise in the number of birds follows the increase in wind-speed; it occurs also 12 hours after an increase in sea waving and 24 hours after an improvement in visibility (Fig. 33C and D), and at the time of west winds (Fig. 33E).

The distribution of the numbers of birds plotted on the synoptic diagram (Fig. 34, Table XLII) indicates that an increase in their number took place at the time of the passage of an occlusion and behind it, in the vicinity of other fronts and in advance of a low. A fall in the number of birds occurred ahead of an occlusion. Generally speaking, the Gannets grew in number when the low-pressure systems were active and decreased during a high and col (Table XLIII).

The results presented above show that the number of Gannets on the sea rose after a deterioration of weather inclusive of an increase in wind-speed and higher sea waves or during the phenomena that accompany the passage of a depression.

Table XLI

Analysis of significance levels of correlations between the number of Gannets and the factors examined

	—48	—24	—12	0	+12	+24	+48
Fishery				0·10			
Month of observation				**0·05**			
Number of trawlers				0·20			
Size of catches				0·50			
Time of day				0·80			
Time of day+				0·10			
Wind-speed	0·90	**0·05**	0·30	0·10	0·70	0·99	0·50
Wind direction				**0·01**			
State of sea	0·99	0·20	**0·01**	0·50	0·70	0·99	0·50
Cloudiness	0·70	0·30	0·50	0·70	0·70	0·70	0·99
Visibility	0·30	**0·02**	0·20	0·90	0·30	0·99	0·80
Barometric pressure	0·50	0·90	0·20	0·95	0·99	0·99	0·99
Air temperature				0·70			

Table XLII

Correlation between the number of Gannets and the synoptic situation pattern

	0—10	11—20	21—40	above 40	Mean
1 High	9	3		2	11
2 Fronts	17	8	2	6	32
3 Before depression	8	2	4	2	120
4 Depression	11	3	3	2	13
5 In advance of occlusion	14	6	3		12
6 Passage of occlusion and behind it	12	10	8	2	19

$F = 3{\cdot}05$
$p < 0{\cdot}05$

Table XLIII

Correlation between the number of Gannets and the movement of barometric systems

	0—10	11—20	21—40	above 40	Mean
1 Depression	19	10	13	9	57
2 High and high-pressure ridge	27	21	7	1	15

$F = 4{\cdot}18$
$p < 0{\cdot}05$

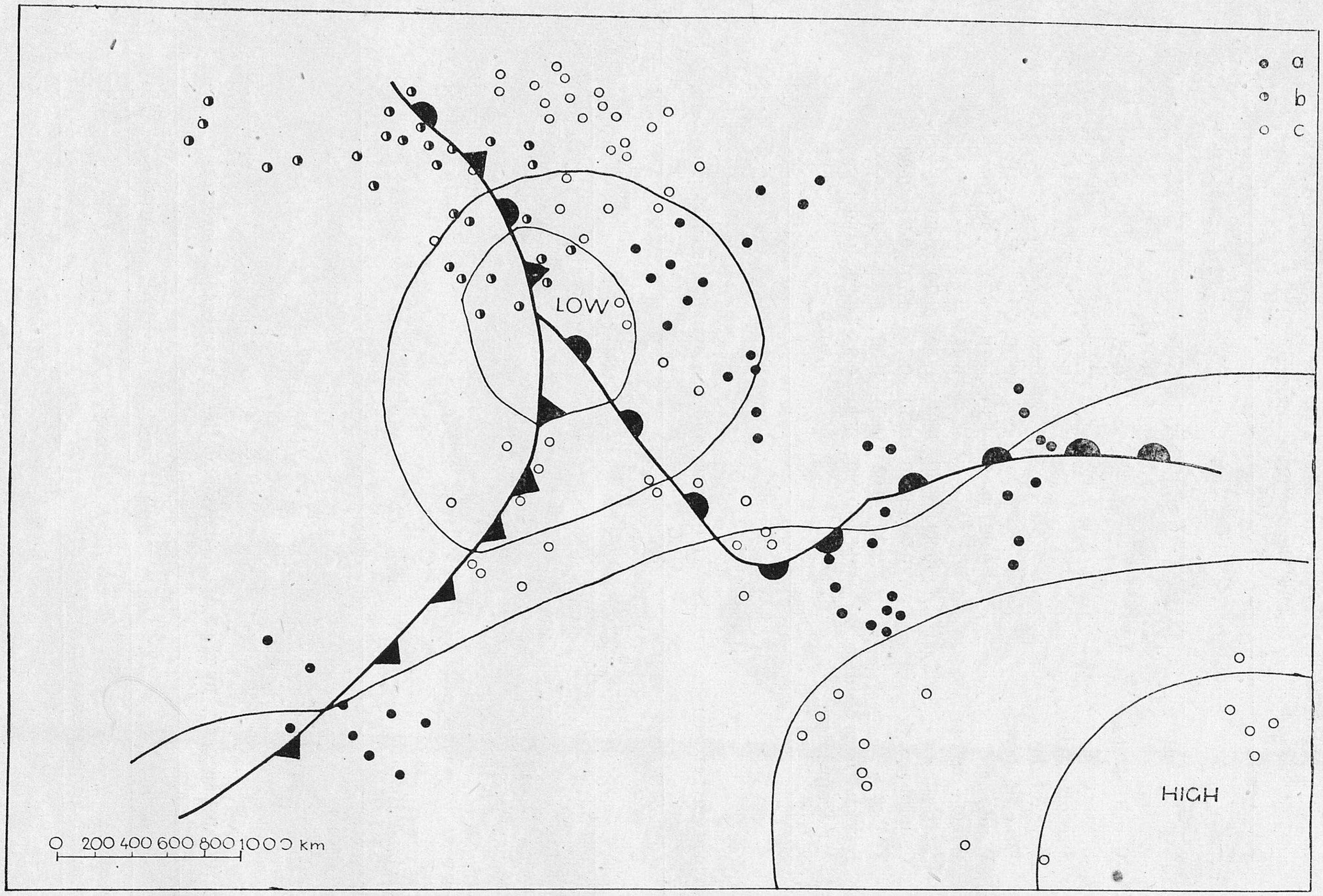

Fig. 34. Correlation between the mean number of Gannets in an observation and the situation of the place of observation plotted on the synoptic diagram. a — mean above 23 birds, b — 19 birds, c — 14 birds

7. Relations between the numbers of birds of particular species

Levels of significance for the quantitative correlations between different bird species in the North Sea are offered in Table XLIV, which shows that there were no such correlations.

Table XLIV

Levels of significance of correlations between the numbers of particular species examined in the fisheries in the North Sea

Fulmarus glacialis	— *Larus marinus*	: 0·50
Fulmarus glacialis	— *Rissa tridactyla*	: 0·80
Fulmarus glacialis	— *Sula bassana*	: 0·50
Rissa tridactyla	— *Larus marinus*	: 0·70
Rissa tridactyla	— *Sula bassana*	: 0·70
Larus marinus	— *Sula bassana*	: 0·70

V. FISHERIES OFF THE COASTS OF NORTH-WESTERN AFRICA

1. Introductory

The cruise to the fisheries situated in the shelf region off the north-western coast of Africa was made in the trawler m. s. „Tasergal" from 2 December 1964 to 12 April 1965. The stay in the fisheries lasted 67 days. The numbers of days and dates of the stay in particular fisheries are given in Table XLV. Figs. 1 and 35 show the itinerary of the cruise and the situation of the fisheries.

Fishing was started before the sunrise and ended late in the evening. All the fish unfit for consumption and scraps were removed to the sea. As there are no data concerning the size of catches in these fisheries, the quantities of fish caught and scraps removed were not taken into account in the further analysis of the material. Neither was the sort of manoeuvres performed by the trawler included in it.

The amplitude of the fluctuations of weather was small and marked out by the wind-speed from 1 to 7 degrees on the Beaufort scale, the state of sea from 0 to 5—6 degrees, the air temperature from +14 to +30°C and the barometric pressure from 1008 to 1030 millibars. The analysis of observations covered the species which occurred in the largest numbers in the vicinity of the trawler: Lesser Black-backed Gulls *Larus fuscus* L. and Brown Boobies *Sula leucogaster* (Bodd.). Mean numbers of birds from the observations on a given day and mean values of the weather elements examined were used in comparisons.

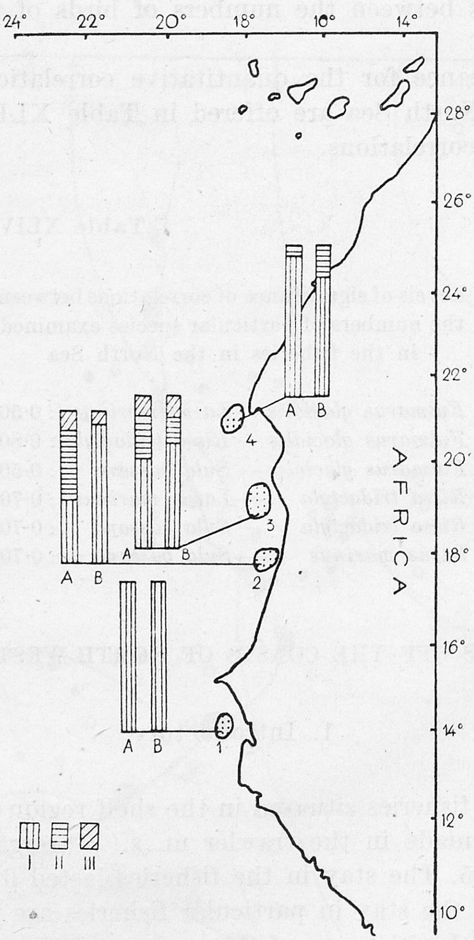

Fig. 35. Distribution of fisheries in the north-western African waters. The graphs represen the quantitative share of observations with different numbers of birds of the two species observed: A. *Larus fuscus*: I. 0—100, II. 101—300, III. over 300, B. *Sula leucogaster*: I. 0—10, II. 11—20, III. over 20

2. Lesser Black-backed Gull *Larus fuscus* Linnaeus, 1758

The numbers of Lesser Black-backed Gulls ranged from hardly a few to about 1000 specimens on 22 December, 26 December and 23 January. In Fig. 36 they are presented for particular days of investigation. They were dependent on the place of fishing (Table XLVI). Fig. 35 shows the distribution of observations with three quantitative groups of birds in different fisheries (significant correlation at 0·01 level). It will be seen from this figure that the observations including larger numbers of birds were most frequently made in fisheries Nos. 2 and 3, situated between the parallels of latitude 17 and 20 °N. The numbers of birds observed in December were significantly larger (at 0·01 level) than those recorded in the other months (Fig. 37 A). The numbers of gulls were significantly

Table XLV

Numbers of days of observation in fisheries in the North-West Africa region

Fishery No.	Dates of observations	Numbers of days
1	2—6 March	5
	Total days	5
2	17—18 December	2
	21—22 January	2
	27 February—1 March	3
	8—12 March	5
	23 March	1
	Total days	13
3	15—16 December	2
	19—20 December	2
	22—28 December	7
	19—20 January	2
	23 January — 3 February	12
	24—26 February	3
	13—16 March	4
	19—22 March	4
	24—27 March	4
	Total days	40
4	18 January	1
	17, 18, 28, and 29 March	4
	Total days	5
Others	4 February, 7, 30, and 31 March	4
	Total days	4
	Total for all fisheries	67

correlated with the following environmental elements: the wind-speed 24 hours after the observation (0·05), the daily maximum wind-speed in all the cases examined, and the state of sea 24 hours before and at the time of the observation (0·02 and 0·05, respectively).

The relationship between the number of birds and the wind-speed 24 hours after the observation is illustrated in Fig. 37B, which shows that a rise in the number of Lesser Black-backed Gulls in a fishery precedes an increase in wind-speed. Fig. 37D — H presents a relationship between the number of gulls and the daily maximum wind-speed. An increase in wind-speed appears to have been accompanied by a rise in the number of birds observed. The degree of sea waving is associated with the wind-speed. Its effect on the number of birds is given in Figs 37C and I. This figure shows that the number of birds rose 24 hours after and simultaneously with an increase in sea waving.

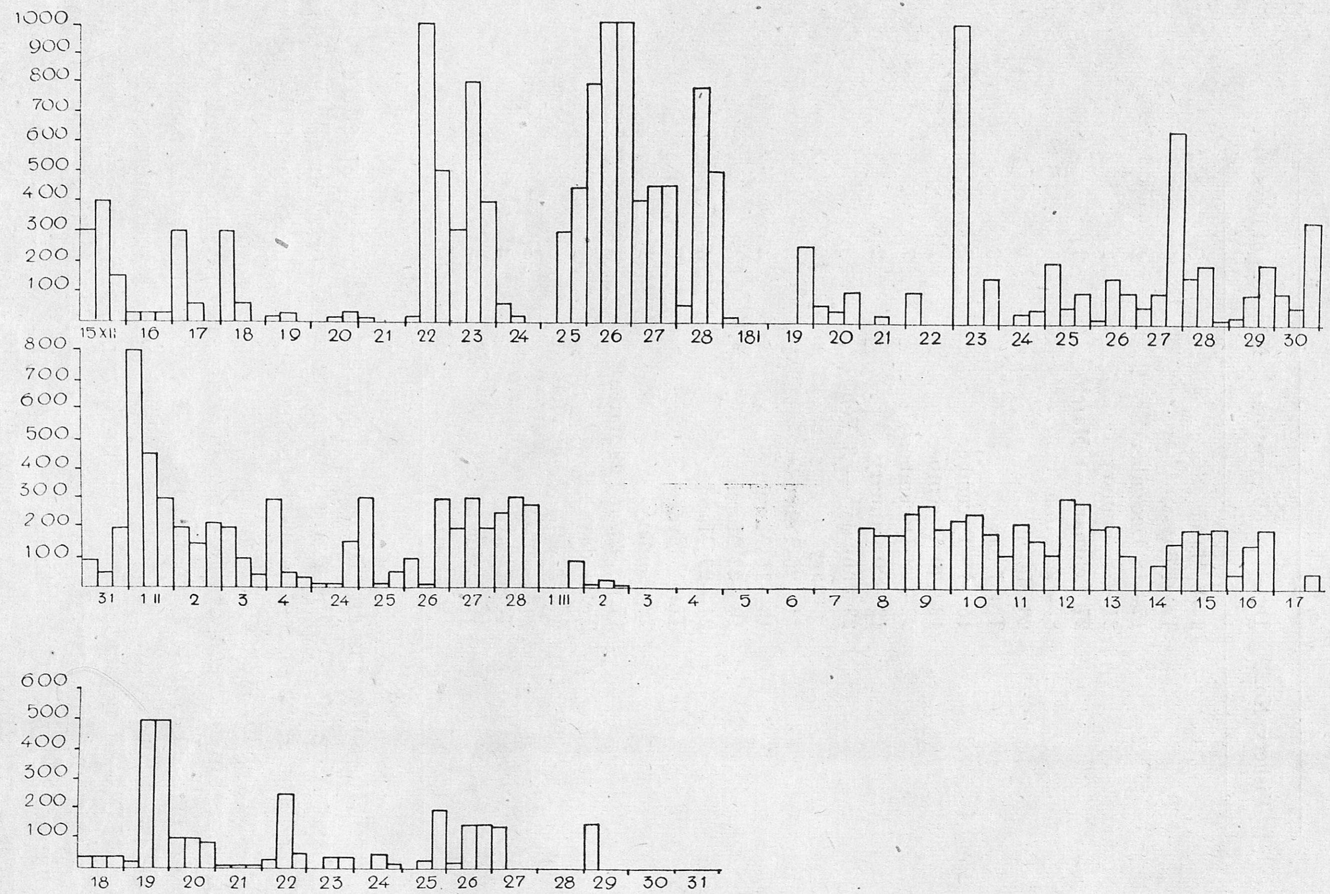

Fig. 36. Numbers of Lesser Black-backed Gulls *Larus fuscus* in particular observations made in the fisheries off the coast of north-western Africa in the morning, at noon and in the afternoon from 15 December 1964 to 31 March 1965

Table XLVI

Analysis of significance levels of correlations between the number of Lesser Black-backed Gulls and the factors examined

	—48	—24	0	+24	+48
Fishery			**0·01**		
Month of observation			**0 01**		
Wind-speed	0·50	0·10	0·20	**0·05**	0·50
Maximum wind-speed	**0·05**	**0 01**	**0·02**	**0·01**	**0 05**
State of sea	0·20	0·10	**0·05**	**0·02**	0·50
Cloudiness	0·30	0·50	0·99	0·70	0·30
Visibility	0·99	0·99	0·99	0·99	0·99
Minimum visibility	0·95	0·20	0·99	0·70	0·80
Barometric pressure	0·20	0·99	0·20	0·50	0·20
Air temperature	0·70	0·80	0·99	0·99	0·99
Water temperature			0·99		

Table XLVII

Correlation between the number of Lesser Black-backed Gulls and the movement of barometric systems

	0—30	31—100	101—200	above 200	Mean
1 High	2	5	7	4	173
2 Low	4	6	10	5	125

$F = 6{\cdot}36$
$p < 0{\cdot}05$

Table XLVIII

Correlation between the number of Lesser Black-backed Gulls and the movements of the cold front

	0—30	31—100	101—210	above 200	Mean
1 Approach of front		1	1	9	118
2 Passage of front				5	223
3 Behind front	1	3	1	5	70

$F = 7{\cdot}25$
$p < 0{\cdot}01$

An analysis of the influence of the movement of barometric systems on the number of gulls, offered in Table XLVII, reveals that a rise in this number coincides with the occurrence of a high in the study area and a fall with a low. In addition, the number of gulls rises during the passage of a cold front and decreases ahead of and behind it (Table XLVIII).

The foregoing data indicate that Lesser Black-backed Gulls give preference to sea areas with fairly strong winds and, in consequence, increased sea waving. This may be caused by the fact that winds facilitate their flight in search of food. In the region investigated the wind-speed seldom exceeded 5 degrees on the Beaufort scale.

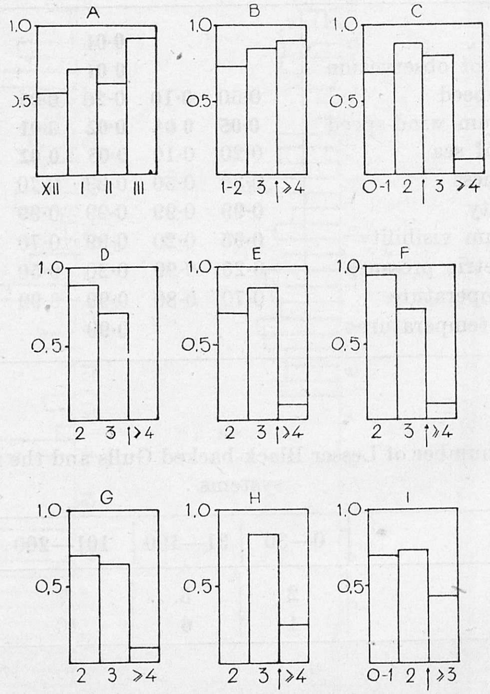

Fig. 37. Changes in the number of Lesser Black-backed Gulls according to A — month of observations, B — wind speed (N = +24), C and I — state of sea (N = +24), D—H — daily maximum wind-speed (N = +48, +24, 0, —24, —48). The blocks represent the quantitative share of observations with 0—200 birds in Graph A and 0—150 in the remaining graphs

Table XLIX

Analysis of significance levels of correlations between the number of Brown Boobies and the factors examined

	—48	—24	0	+24	+48
Fishery			0·80		
Month of observation			**0·01**		
Wind-speed	0·80	0·95	0·99	0·20	0·99
Maximum wind-speed	0·80	0·80	0·99	0·95	0·50
State of sea	0·50	0·20	0·20	0·30	0·50
Cloudiness	0·99	0·98	0·99	0·99	0·90
Visibility	0·99	0·70	0·99	0·99	0·99
Barometric pressure	0·70	0·99	0·30	0·80	0·90
Air temperature	0·70	0·50	0·70	0·90	0·50
Water temperature			0·99		

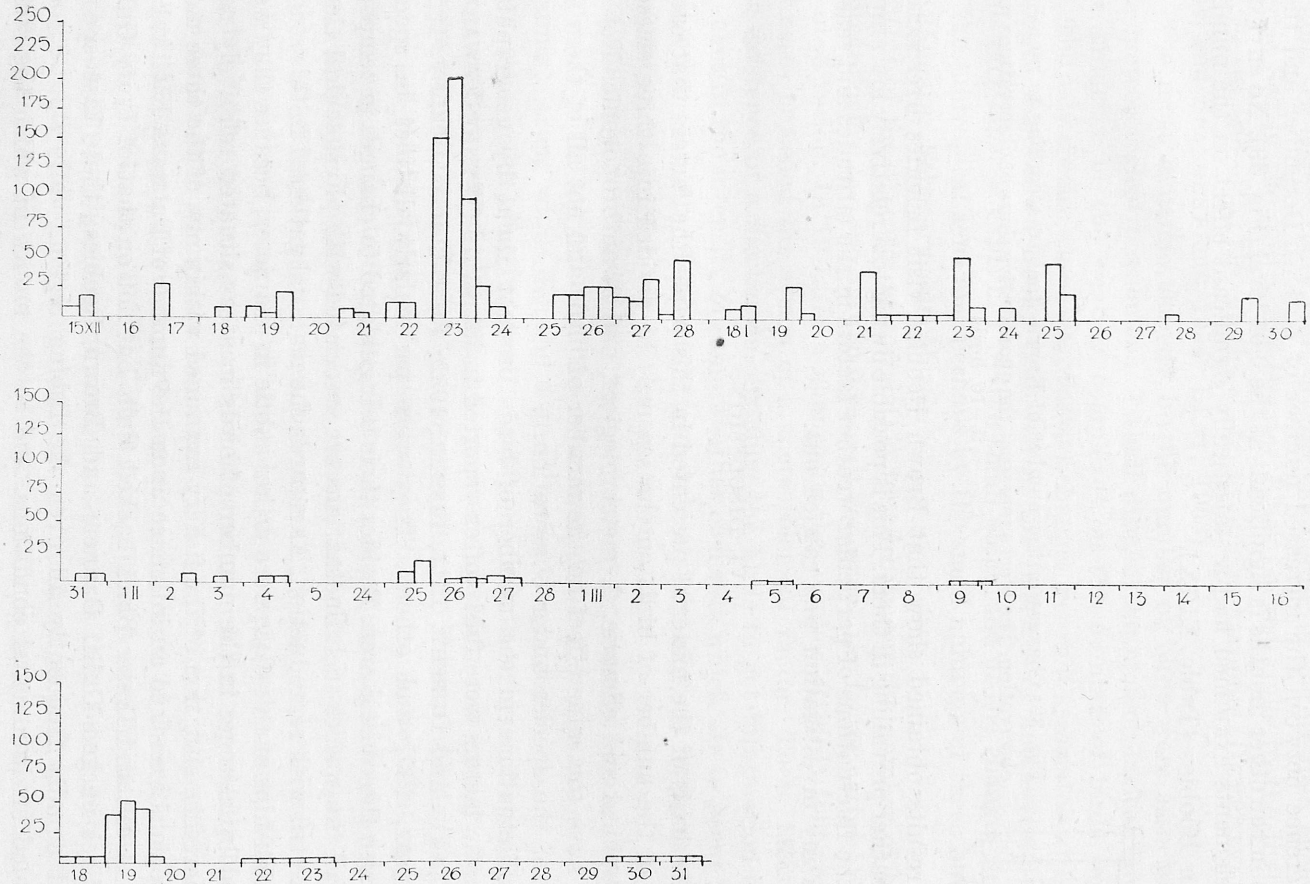

Fig. 38. Numbers of Brown Boobies *Sula leucogaster* in particular observations made in the fisheries off the coast of north-western Africa in the morning, at noon and in the afternoon from 15 December 1964 to 31 March 1965

3. Brown Booby *Sula leucogaster* (BODDAERT, 1783)

Brown Boobies appeared in the study area irregularly, being most numerous in December. Their numbers in particular observations are presented in Fig. 38. The difference between the increased number of birds in December and their numbers in the other months is significant at the 0·01 level (Fig. 39). No environmental elements examined had a statistically significant effect on the number of Brown Boobies (Table XLIX).

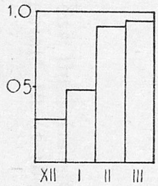

Fig. 39. Changes in the number of Brown Boobies according to month of observation. The blocks represent the quantitative share of observations with 0—10 birds

The results obtained show that Brown Boobies visit fisheries irrespective of the weather prevailing in them. This is possible owing to a relatively low amplitude of the fluctuations of particular weather factors in the latitudes and season in which my investigation was carried out.

VI. DISCUSSION

On the basis of the material presented in this paper the factors that cause changes in the number of birds on the sea may be divided into three classes: 1. geographical and climatic, 2. meteorological, and 3. anthropogenic. Not all of them have the same effect on the number of birds and not all of them act on each of the species under observation.

The fluctuations in the number of birds brought about by geographical and climatic factors were fairly often reported in literature (WYNNE-EDWARDS, 1935; RANKIN and DUFFEY, 1948, FISHER, 1952; FISHER and LOCKLEY, 1954; BIELOPOLSKI, 1957 and others). They were particularly distinct in species visiting also the coastal area. Besides their being related to changes in temperature, in all the species such fluctuations are associated with physiological changes connected with reproduction. As regards the material gathered in this study, the relationships of this class were rather subtle in character, because they were expressed by changes in the number of birds in areas situated relatively near each other. The situation of the fishery examined within one of the three main fishing regions exercised an influence upon the number of Fulmars, Kittiwakes, Glaucous Gulls and Lesser Black-backed Gulls but not on that of Ivory Gulls, Great Black-backed Gulls, Gannets and Brown Boobies; these last species appeared equally frequently all over the fishing region.

Seasonal environmental conditions, and so the month in which the study was carried out, influenced the occurrence of Fulmars, Kittiwakes, Lesser Black-backed Gulls, Gannets and Brown Boobies, but not the number of Ivory Gulls, Great Black-backed Gulls and Glaucous Gulls.

Out of the species examined, only two, Great Black-backed Gulls and Ivory Gulls, occurred in the sea regions irrespective of the time (month) of observation and the place of fishing. This may be due to the fact that these species inhabit sea edges: Ivory Gulls live at the border of the ice-field enclosing the Arctic Sea in the north and Greater Black-backed Gulls in the littoral zone of the sea and often also on the shore, feeding in harbours (DEMENTYEV, GLADKOV and SPANGENBERG, 1954; BENT, 1963).

The most dynamic changes in the number of birds were associated with the meteorological phenomena. I shall discuss the meteorological factors and the influence of the weather complexes on the number of birds separately.

The only species whose quantitative changes were not associated with weather changes was Brown Booby observed in the fisheries of north-western Africa. This fact may be explained by the small amplitude of the changes in weather in the subtropical zone and perhaps by the small numbers of these birds found in January, February and March.

Out of the 42 cases of correlation found between the number of birds and meteorological factors, only in 5 cases it concerned the factor active at the time of observation. In 19 cases a change in the number of birds followed and in 18 cases preceded the action of a meteorological factor. These facts suggest the existence of a mechanism enabling the birds to get information as to the changes in the intensity of some weather elements which are to occur in 12, 24 and even 48 hours. This mechanism is certainly of great importance to the adaptation of these birds to the sea environment.

Changes in wind-speed and sea waving may be counted among the meteorological factors that influence the occurrence of birds on the sea in an essential manner. Strong winds demand a great use of energy for motion in the air and they may make effective food acquisition difficult or even imposible. Flight in a windless period also demands greater expenditure of energy. Poor winds in the tropical zone of the globe are according to FISHER and LOCKLEY (1954) and WING (1956) one of the reasons why Albatrosses do not visit the northern hemisphere. Owing to their specific manner of acquisition of food by continuous examination of the sea surface from the air, the brids of all the species described in this paper make use of wind also or air currents resulting from the action of wind on the waving sea or the sides of a ship (GROEBBELS, 1956). Strong winds hinder and protract the flight of birds, which has repeatedly been found in so far as land species are concerned. While migrating, passerines also make use of the systems of winds prevailing along the route of their flight (WILLIAMSON, 1958, 1961 a, b, c, 1962 a; CORNWALLIS, 1959). A sudden change in the wind direction during their migration over a sea causes their being drifted from the chosen route often to regions remote from the shore (WILLIAMSON, 1955; LACK, 1959; BRADLE, MOWBRAY and EATON, 1931; SCHOLANDER, 1955; JORDANS and NIETHAMMER, 1957). The sea birds respond to the disadvantageous action of too strong winds by staying in areas where the wind-speed is on the decrease or is going to decrease, as in the case of Fulmars and Kittiwake in the region of Labrador and Newfoundland. The necessity of finding suitable areas is also connected with the lack of shelter in the open sea. Birds which inhabit land environments or the shore are able to avoid the effects of strong winds, e. g. by taking shelter in ground depressions (TINBERGEN, 1953; ZALETAYEV, 1952). It should be mentioned that in some cases the systems of regularly blowing winds may be used by birds during their migrations and when they wander about the oceans (DORST, 1956).

The wind direction may be of local importance, since it makes birds move from one place to another, e. g. from the northern to the southern shore of Hel Peninsula (BIEŃ and DOBROWOLSKI, 1961), or gather together, e. g., an increase in the number of Kittiwakes, Fulmars and Gannets at the coasts of Great Britain during westerly winds (WILLIAMSON, 1962b). The gathering of Kittiwakes and Gannets in the fisheries off the coast of Great Britain at the time of westerly winds, observed in the present study, supports this statement.

Changes in the state of sea are, as a rule, caused by the action of wind on the superficial layers of water. It is difficult to interpret the relationships between the number of birds and the degree of sea waving, because the consequences of the action of heavy winds on the sea birds are not known exactly. The results obtained indicate that this influence is advantageous, for an increase in sea waving often resulted in a rise in the number of birds, e. g., Fulmars, Kittiwakes, Gannets and Lesser Black-backed Gulls.

Changes in visibility and cloudiness will be discussed jointly, as they both condition the navigation of birds on the sea. Poor visibility, caused by fog, rainfall or interception of light, makes the observation of the field of vision and, consequently, the so-called topographical orientation difficult (GRIFFIN, 1944; WOJTUSIAK and FERENS, 1947a, b; SARGENT, 1962, and others). A deterioration of visibility probably brought about the migrations of Ivory Gulls to the sea (in the fisheries in the Labrador region). An improvement in visibility was also followed by a rise in the numbers of Fulmars and Gannets.

Good visibility may facilitate the birds, among other things, to get information as to the occurrence of food at the surface of the sea in fisheries. As has been demonstrated (MANIKOWSKI, 1966), the sight of birds feeding near a ship is a signal that informs the gulls about the presence of fish scraps at the surface of the sea.

Heavy cloudiness makes the spatial orientation of birds difficult or impossible (KRAMER, 1951; MATHEWS, 1951, 1955). The ceasing of migration on cloudy days was also observed in land species SCHÜTZ, 1952; JENKINS, 1953; WILLIAMSON, 1958, 1962a, b; LACK, 1962; LACK and LACK, 1966; DAVIS, 1966; PARSLOW, 1969). It is noteworthy, that some bird species, e. g., waders, are able to choose the right direction of migration even when the sky is heavily overcast (EVANS, 1968). Studies carried out by NISBET and DRURY (1967) also show that the cloud-cover does not interfere with the migration of birds.

The investigation presented in this paper shows that the decrease in cloudiness followed a rise in the numbers of Fulmars and Glaucous Gulls in the fisheries off the coast of Labrador. Out of the other species, Kittiwakes and Great Black-backed Gulls appeared in larger numbers before an increase in cloudiness in the North Sea, and the remaining species occurred on the sea independently of the degree of cloudiness.

Barometric pressure is the meteorological factor that may be treated as the prognostic of other weather elements. A drop in pressure indicates the approach of a depression, which usually brings stronger winds, cloudiness and rainfall, whereas a rise in air pressure presages an improvement in weather. However, changes in pressure are not used by birds as indications of meteorological changes. This is evidenced by the lack of correlation between the number of birds and the changes in barometric pressure. Other authors, especially those conducting field studies, also hold the opinion that barometric pressure, treated independently of other weather factors, has no effect on the intensity of bird migrations (Schütz, 1952; Jenkins, 1953; Raynor, 1956; Hassler et al., 1963). Nevertheless, some workers observed a correlation between the behaviour of animals and the changes in barometric pressure (Alle et al., 1958; Ahlqvist and Palmgren, 1935). Bagg et al (1950) also suggest the existence of a relationship between the migration of birds and the changes in pressure.

Air temperature and that of the superficial layer of sea are important factors responsible for the distribution of birds on the sea. In his study carried out in the north-western Pacific Kuroda (1960) found that within an area examined some species may show a peculiar thermal preference. A dependence of the distribution of birds on the temperature of the superficial layer of sea was also ascertained by Bailey (1966). The Gulf Stream is of great importance to the distribution of birds in the North Atlantic (Rankin and Duffey, 1948). The influence of the temperature of the supperficial layer of sea on the distribution of birds in the Labrador region was also stated by Rees (1965). In the present study I succeeded in observing a relationship between the rise in the number of Fulmars and a drop in the temperature of the superficial layer of sea in the Labrador region of the Atlantic. According to Fisher (1952) and Bryan (1968), there is a slight correlation between the distribution of Fulmars and the temperature of sea.

The results of my investigation indicate also an influence of air temperature on the occurrence of Kittiwakes in this region of the Atlantic. It is an interesting fact that, according to the classification proposed by Wynne-Edwards (1935), Fulmars and Kittiwakes belong to the species of pelagic distribution.

Analyses of the effect of weather as a complex of factors made it possible to establish correlations in some cases such as allow the arrangement of the responses of birds to single weather factors. In general, a rise in the number of birds occurred during a high or col (in 5 cases examined). Exceptions were Gannets, which gathered together at the time of the passage of a depression over the fishery and Ivory Gulls, Great Black-backed Gulls and Kittiwakes in the North Sea, whose appearance did not show any correlation with the barometric system.

The passage of a depression was accompanied by a rise in the number of Gannets and a fall in the number of Fulmars, Glaucous Gulls and Lesser Black-backed Gulls. The changes in the number of the remaining four species were not correlated with the occurrence of a depression.

A rise in the number of Glaucous Gulls and Lesser Black-backed Gulls was associated with the passage of a cold front, that in the number of Gannets with the passage of an occlusion, and a fall in the number of Glaucous Gulls with the passage of a warm front. The passage of fronts, irrespective of their character, caused a rise in the number of Gannets, a fall in the number of Fulmars and Kittiwakes in the Atlantic and that in the number of Ivory Gulls. The changes in the number of Brown Boobies were not correlated with the changes in weather.

Generally speaking, in most cases a rise in the number of birds was observed during anticyclonic weather, a fall during lows. The action of fronts may induce both a rise and a fall in the number of birds. The results of investigations conducted by Vernon (1969) and Nisbet and Drury (1969) on migrating land birds indicate that the changes in weather accompanying the passage of fronts may reduce the rate of migration.

A logical consequence of the changes in the number of birds in one place is their migration, whose rate and amplitude of the number should agree with the rate and amplitude of the intensity of the factors with which the changes in the number of birds are correlated. In the case under study I am concerned with two, zoogeographical and meteorological, types of the causes of changes in the number of birds. The zoogeographical factors, in the form of phenological changes the duration of which is of the order of months, do not raise any objections and are known from some earlier studies on this subject. The weather factors were responsible for the migrations of birds to the areas with the optimum meteorological conditions, the rate of weather changes being fast and the changes themselves occurring in the course of successive days or hours. So far weather-induced migrations have been found in the Swift *Apus apus* (L.). The approach of a depression promotes these birds to migrate in the opposite direction to that of the wind. Thus the birds shorten their stay in the zone of rainfall accompanying the approaching depression (Koskinies, 1950). The distances covered by Swifts in their weather migrations reach above 500 miles as the crow flies, though the actual route is far longer. On migration the Swifts may orient themselves by avoiding places with small numbers of insects on which they feed, zones of rainfall, and other weather conditions such as heavy cloud-cover, low cloud ceiling etc. (Lack, 1955, 1956). Similar migrations were observed in Black Swifts *Nephoecetes niger* (Gm.) in British Columbia (Udvardy, 1954).

On the basis of the studies on sea birds carried out so far it is generally supposed that birds avoid the type of weather designated as „stormy“. In areas overrun with tropical cyclones, the birds that have not managed to escape from the place in which a cyclone is formed or over which it is passing are driven to the centre or „eye“ of the storm and carried away for long distances, often far inland (Murphy, 1936; Iouain, 1953; Tuck, 1968). Strong gales also cause drifts of sea birds to the land, often resulting in the death of the birds (Pashby and Cudworth, 1969). A gale was preceded by a rise in the number of birds, accompanied by a fall, and followed by a rise again. This is the case with different species of birds (Routh, 1949; Elgmork, 1961). During rather strong winds all species of birds show a tendency to fly against the wind, which would prevent them from being drifted away from the occupied area and, in the case of an approaching depression, to the regions with still stronger winds (Murphy, 1936; Thom, 1956; Browne, 1958).

The present study shows that the migrations of sea birds are a mass phenomenon characteristic of all the species observed in all the areas examined, where the amplitude of fluctuations of particular weather factors reaches its extreme values. In the fisheries situated in the subtropical zone no weather migrations were observed in Brown Boobies, whereas Lesser Black-backed Gulls flew to the areas with stronger winds and sea waving, which confirms the supposition quoted above after Fisher and Lockley (1954) and Wing (1956) that there exists a barrier, formed by the equatorial belt of calms, for birds characterized by soaring flight.

In so far as the type of reactions to weather changes is concerned, Gannets hold a separate position because of their atypical migrations towards the areas occupied by depressions with strong winds. It may be supposed that this behaviour is connected with their ways of acquisition of food. Feeding in the vicinity of a fishing trawler enables these birds to collect sufficient amounts of food in a relatively short time. Having ceased feeding, the Gannets flew off towards the land in the evening. Hence, it may be supposed that in a spell of fairly favourable weather conditions the birds of this species feed in places less remote from the colonies in which they spend the night and that this type of weather is propitious to their finding food. These birds have the possibility of choice of a suitable area, because they are able to cover as many as 400 miles in their flights to feeding grounds (Nelson, 1966).

Some common characters may be distinguished in Great Black-backed Gulls and Ivory Gulls in respect of their responses to weather. They consist in the fact that there is no correlation between the number of these birds and the changes in wind-speed and sea waving as well as the zoogeographical factors. The appearance of Ivory Gulls, which live on the shores of Arctic islands (Birkenmajer, 1969), is invasive in character and it is probably their escape from approaching poor visibility and rainfall. No similar relationship could be demonstrated clearly enough for Greater Black-backed Gulls, but it may be similar in character in connection with the occurrence of correlation between the number of birds and the cloudiness 12 hours after counting them. Hence, it may well be that their stay on the sea is an escape from the unfavourable weather conditions prevailing in the area occupied by them previously.

The appearance of Glaucous Gulls on the sea preceded mild winds accompanied by anticyclonic weather. As the fisheries visited by these birds were situated close to the shore, it should be supposed in accordance with the opinions of Dementyev et al. (1954) and Bent (1963) that they most readily spend the winter time along the sea-shore. Their migrations to the sea preceded a day with high-pressure weather by one or two days.

Fulmars and Kittiwakes are species characterized by their pelagic distribution in the Atlantic Ocean, which means that during their stay on the sea they keep far from the shores, visiting the land only in the breeding season. Hence the clear relationship of the number of these birds with the situation of the fishery and the month in which the observation was carried out. The relationship between the occurrence of these species and the weather changes was also evident. Both these species give their preference to areas with moderate winds and avoid depressions and disturbances of weather connected with the passage of fronts. During unfavourable weather the specimens that had failed to fly away from the area occupied gather in the vicinity of ships and more than usual avail themselves of the scraps removed from the deck. In these birds, as in the remaining species, a change in weather induces not only responses consisting in commencement of migration, but also a change in their ways of living. Observations made in the North Sea showed that in this region the responses of Fulmars to weather changes resembled those in the Atlantic Ocean. Kittiwakes occurred in larger numbers in areas with increasing wind-speed. The migrations of birds in connection with the shifting of barometric systems are of great importance to them, because in the course of a few successive days the numbers of birds reach an amplitude ranging from several dozen to several thousand specimens. This phenomenon may be called weather migrations, since the birds move to areas which are more favourable in respect of weather.

A factor that makes it possible for birds to choose the optimum conditions on the sea actively is their orientation concerning the distribution and heading of barometric systems. The existence of such orientation in some birds is suggested by Meischner (1963). The responses of birds in advance of weather changes have often been reported in literature (Szulejkin, 1954; Tarasow, 1956; Sokołowski, 1958; Brudin, 1961 and others). The oncoming of rains and — in a sea region — storm weather may be signalled by changes in air humidity, temperature, cloudiness etc. There may also be other factors inducing meteorotropic responses in man and animals. The approach of depressions and storm centres is accompanied by ultralong waves emitted by them (Reiter, 1951; König, 1958). Wever (1967, 1968) pointed out an effect of this type of radiation on the daily rhythm pattern of man. Szulejkin (1954) suggests that the organisms associated with sea environment are able to perceive acoustic waves of subaudible frequencies emitted by the strongly waving sea surface. Palmgren (1937) and Warden et al. (1935—40) claim that there is correlation between the intensity of flights of passerines and the changes in the atmospheric electric fields and the degree of air ionization. These factors have been taken into consideration, because the dependence of the intensity on the changes in the meteorological conditions were not always unequivocal, which has also been emphasized by some more recent authors, e. g., SCHOLANDER (1955) and OWEN (1958). The effect of an electric field generated by the movement of air masses on animals has not, as yet, been examined adequately (SCHÜTZ, 1955; SCHWERDTFEGER, 1963), though some experimental studies (SCHUÀ, 1952; 1954; HEINE, 1961; HEINE and KÖNIG, 1961; KHOLODOV, 1966) indicate the sensitivity of various species of animals to changes in electrical charge. Particularly violent changes in the physical and chemical conditions of environment (among other things changes in the degree of air ionization) are associated with the passage of fronts. The amplitude of these changes is termed the front activity (TROMP, 1963). TROMP distinguished also five important elements of a front responsible for biological changes:

1. the speed at which it travels,
2. the size of barometric pressure fall,
3. the size of temperature fall or rise,
4. the size of disturbance in the atmospheric electric field, and
5. the amount and duration of rainfall.

The activity of fronts, which particularly strongly affect the human organism, induces behavioural and physiological changes concerning nearly all organs. The influence of these disturbances on the organism of birds has not, as yet, been explained thoroughly. The ascertainment of the possibility of perception by birds of disturbances in the electric or electromagnetic field induced by the movements of fronts and low-pressure systems might explain the phenomenon of weather orientation and anticipation of a definite type of weather in birds.

Analogically to the terms used in ecology, in the case of sea birds one can speak of a weather habitat or environment as one of the main factors determining the distribution of birds within a geographical zone inhabited by a given species.

The presence of vessels, chiefly trawlers, fishing in an area and the manner in which this is done should be treated as a complex of anthropogenic factors. These factors include such elements analysed in the present study as the number of fishing vessels, the size of catches, the manoeuvres performed by vessels while handling the nets, and the method of fishing. The presence of a vessel had also a selective effect on the number of bird species open to observation. In the Atlantic and North Sea the vessels are avoided by the species of the genus *Puffinus* and probably the *Alcidae*, whereas they attract the *Laridae*, *Stercorariidae*, Fulmars and Gannets (RANKIN and DUFFEY, 1948; FISHER, 1952; FISHER and LOCKLEY, 1954; BOSWALL, 1960; REES, 1963; ELGMORK, 1966). However, it should be emphasized that in none of the cases examined it was possible to demonstrate a simple correlation between the number of birds and that of vessels and the size of catches or the amount of scraps used by birds as food. A rise in the number of Kittiwakes in the daytime until they reach a maximum in the evening hours, observed in the region of Labrador and Nowfoundland, is probably associated with the presence of vessels. The cause of this is the fact that having come across a vessel, when wandering about the sea, the birds remain in her vicinity so long that, as a result, an increase in their number is observed as the time goes on. No Kittiwakes were found in the neighbourhood of the trawler (within the reach of searchlights) in the night. No such accumulation of birds was found in Fulmars, because these remained near the vessel also at night.

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STRESZCZENIE

W pracy przedstawiono wyniki badań nad zmianami zachowania się oraz zmianami ilości ptaków w zależności od zmian środowiska, głównie w postaci zmian pogody. Obserwacje nad ptakami przeprowadzane były z pokładów polskich trawlerów rybackich poławiających na Morzu Północnym, u wybrzeży Nowej Fundlandii i Labradoru oraz u wybrzeży północno-zachodniej Afryki (ryc. 1). Obserwacji ornitologicznych dokonywano za pomocą lornetki 11×40, co 1,5 godziny. Czas trwania jednej obserwacji wynosił 20 minut. Wyjątek stanowiły badania w czasie jednego rejsu na Morze Północne i rejsu na łowiska położone w pobliżu Afryki, kiedy obserwacji dokonywano trzy razy dziennie. W czasie obserwacji notowano liczbę ptaków, wiek oraz rodzaj wykonywanych czynności. Na ogólną liczbę ptaków przebywających w pobliżu statku składały się: maksymalna ilość ptaków latających w pobliżu statku, suma ptaków siedzących na powierzchni morza, suma ptaków latających w powietrzu, nie związanych ze statkiem. Stada ptaków, liczące kilkaset lub kilka tysięcy osobników, oceniano szacunkowo. Wyniki całodziennych obserwacji pogrupowano w trzy grupy: ranne do godz. 11, południowe od 11—15, wieczorne od 15 do zmierzchu (czasu miejscowego). Brano pod uwagę w dalszych opracowaniach obserwację, w której notowano maksymalną liczbę ptaków w poszczególnych trzech przedziałach czasowych. Ilości ptaków porównywano z następującymi czynnikami meteorologicznymi: szybkością i kierunkiem wiatru, stanem morza, zachmurzeniem nieba, widzialnością, ciśnieniem barycznym, temperaturą powietrza, temperaturą powierzchni morza. Związek pomiędzy tymi czynnikami a liczbą ptaków oceniano za pomocą testu chi-kwadrat. Ponadto badano wpływ wymienionych czynników pogodowych zaistniałych 12, 24 i 48 godzin przed obserwacją oraz 12, 24, 48 godzin po dokonaniu obserwacji. W ten sposób (zalecany

przez SOLLBERGER (1965), TROMP (1963)) ustalono, w jakich przypadkach pojaw lub zmiana zachowania się ptaków poprzedza zmianę pogody, oraz w jakich przypadkach jest jej następstwem.

Dodatkowo dokonywano analizy map synoptycznych z badanych akwenów, dokonując kompleksowej analizy pogody. W skład tej oceny wchodziło opisanie, która część układu barycznego zalegała nad łowiskiem (wyż, niż, siodło), opisanie zależności pomiędzy ruchem frontów a położeniem miejsca obserwacji (uwzględniano rodzaj frontu i odległość od łowiska). Sporządzano schematy mapy synoptycznej, na które nanoszono położenie miejsca obserwacji z zachowaniem takich proporcji odległości w stosunku do wyżów, niżów i frontów, jakie znajdowały się na oryginalnych mapach synoptycznych. Istotność związku zmian liczby ptaków w zależności od panującej sytuacji barycznej oceniano za pomocą analizy wariancyjnej.

Badania w okolicy Labradoru i Nowej Fundlandii dokonywane były w dniach od 19 II do 9 V 1968 (tab. IV, ryc. 2). Na łowisku najliczniej przebywały *Fulmarus glacialis*, *Rissa tridactyla*, *Larus hyperboreous*, *Pagophila eburnea*. Te gatunki wzięto pod uwagę w czasie dalszego opracowywania.

Zmiany ogólnej ilości *Fulmarus glacialis* przedstawiono na ryc. 3. Wyniki badań związku liczby ptaków z czynnikami środowiska przedstawiono w tab. V. Z tabeli tej oraz ryc. 2 wynika, że największe ilości ptaków obserwowane były na łowiskach położonych w północnych rejonach akwenu. Najwięcej ptaków obserwowano w marcu, mniej w kwietniu i w maju (ryc. 4A). Wzrost liczby ptaków następował również w czasie wzrostu wydajności połowów ryb (ryc. 4B). Stwierdzono również związek pomiędzy liczbą *Fulmarus glacialis*, a zmianami szybkości wiatru przed 24 godzinami. Wzrost liczby *Fulmarus glacialis* następował po wzroście szybkości wiatru w dniu poprzednim, 48 godzin po pogorszeniu się widzialności oraz 12 godzin po wzroście ciśnienia barycznego (rys. 4C, F, G). Jednocześnie wzrost liczby ptaków następował 48 godzin przed spadkiem zachmurzenia nieba i 48 godzin przed polepszeniem się widzialności (ryc. 4D, E). Wzrost liczby ptaków następował również w związku z niską temperaturą powierzchni morza. Z kompleksowej analizy pogody wynika, że wzrost liczby ptaków następował wówczas, gdy nad łowiskiem zalegał skraj wyżu, niżu, siodło baryczne (ryc. 5, tab. VII—X). Ogólnie można stwierdzić, że ptaki te unikają sztormowej pogody w niżach oraz słabych wiatrów w obrębie układów wyżowych.

W tab. XI przedstawiono poziomy istotności związku pomiędzy procentem *Fulmarus glacialis* latających za statkiem a badanymi czynnikami. Wzrost procentu ptaków notowano w czasie wzrostu szybkości wiatru, 24 godziny po wzroście zachmurzenia nieba, 24, 12 godzin i po 12 godzin przed spadkiem ciśnienia barycznego (ryc. 6A, B, C, D, E, F). Najwięcej ptaków notowano również w czasie przechodzenia niżu i frontów (tab. XII).

Procent ptaków latających w powietrzu niezależnie od statku wzrastał 48 godzin po wzroście ogólnej ilości *Fulmarus glacialis*, 24 godziny po spadku szybkości wiatru i zachmurzenia nieba (tab. XIII, ryc. 7A, B, C, D).

Procent ptaków siedzących na powierzchni morza wzrastał 48 godzin po wzroście szybkości wiatru, oraz 12 godzin po słabych wiatrach, w czasie słabych wiatrów i w czasie słabego falowania morza. Więcej *Fulmarus glacialis* siedziało na powierzchni morza w czasie wiatrów południowo-zachodnich (tab. XIV, ryc. 8A, B, C, D, E).

Reasumując można stwierdzić, że żerowanie ptaków za statkiem odbywa się w czasie działania pogody powodującej spadek ogólnej liczby ptaków (działanie czynników niekorzystnych), loty w powietrzu (migracje) i siedzenie ptaków na powierzchni morza występują w czasie pogody zbliżonej do powodującej gromadzenie się dużych ilości *Fulmarus glacialis* na łowisku.

Ilości *Rissa tridactyla* w czasie obserwacji na łowiskach w pobliżu Labradoru i Nowej Fundlandii przedstawiono na ryc. 9. Najliczniej gatunek ten obserwowano w lutym i marcu, występował zwłaszcza na łowiskach położonych w północnych regionach badanego akwenu. Najwięcej ptaków przebywało w pobliżu statku w czasie trałowania, wybierania i wydawania sieci oraz w położeniu statku w dryfie. Więcej ptaków notowano wieczorem, najmniej rano (tab. XVI, ryc. 10A, B, C, 11). Ponadto wzrost liczby ptaków następował 12 i 24 godziny przed spadkiem szybkości wiatru oraz w czasie spadku temperatury powietrza. Najwięcej ptaków notowano w wyżu i siodle barycznym oraz po przejściu frontów (tab. XVII, XVIII, ryc. 12A—F, 13).

Procent *Rissa tridactyla* latających za statkiem wzrastał w godzinach wieczornych, 12 i 24 godziny po wzroście zachmurzenia nieba (tab. XIX, ryc. 14A—C).

Procent *Rissa tridactyla* latających w powietrzu wzrastał w czasie szybkości wiatru 2—3° w skali Beauforta oraz 12 godzin po niskim zachmurzeniu nieba (tab. XX, ryc. 15A, B).

Procent *Rissa tridactyla* siedzących na powierzchni morza wzrastał w czasie ogólnego wzrostu liczby ptaków tego gatunku oraz w czasie słabego falowania (tab. XXI, ryc. 15C, D).

Ogólnie można stwierdzić, że większy procent *Rissa tridactyla* migruje (lata w powietrzu) w czasie pogody zbliżonej do takiej, która powoduje zwiększanie się liczby ptaków — jest to głównie spadek szybkości wiatru. Z wystąpieniem migracji wiąże się również niskie zachmurzenie nieba. Po silnym zachmurzeniu większy procent ptaków żeruje za statkiem.

Ilości *Larus hyperboreus* w czasie obserwacji na łowiskach w okolicy Labradoru i Nowej Fundlandii przedstawiono na ryc. 16. Najwięcej ptaków notowano na łowiskach położonych najbliżej lądu, 24 i 48 godzin przed spadkiem szybkości wiatru i 24 godziny przed spadkiem zachmurzenia nieba. Wzrost ponadto następował w wyżu i siodle barycznym oraz za niżem (tab. XXIII, XXIV, ryc. 17A—C, 18).

Ilości *Pagophila eburnea* w czasie obserwacji przedstawiono na rycinie 19. Wzrost liczby tych ptaków następował 12 godzin przed spadkiem widzialności i wystąpieniem opadu deszczu lub śniegu (tab. XXV, XXVII, ryc. 21).

Badania na Morzu Północnym wykonywano w czasie trzech rejsów w dniach od 3 II do 9 III 1964, 22 VIII do 19 IX 1968, 4 X do 25 X 1968. Trasy rejsów i położenie łowisk przedstawiono na ryc. 1 i 23, ilości dni i daty pobytów na poszczególnych łowiskach przedstawiono w tab. XXIX. Do obliczeń wzięto pod uwagę wyniki obserwacji prowadzonych w czasie wybierania sieci na pokład statku i obróbki ryb, kiedy w pobliżu przebywało najwięcej ptaków. Z gatunków najliczniej gromadzących się w pobliżu statku opracowano cztery: *Fulmarus glacialis*, *Rissa tridactyla*, *Larus marinus* i *Sula bassana*.

Liczbę *Fulmarus glacialis* w czasie obserwacji przedstawiono na ryc. 24. Najwięcej ptaków obserwowano na łowisku oznaczonym numerem 5, zwłaszcza w miesiącach sierpniu i wrześniu. Wzrost liczby tego gatunku następował 24 godziny przed i 48 godzin po wiatrach o szybkości 2—4° w skali Beauforta. Podobna zależność występuje w stosunku do stanów morza (tab. XXX, ryc. 25A—F). Ponadto wzrost liczby ptaków następował w siodle barycznym, mniej w wyżu i niżu (tab. XXXII).

Ilości *Rissa tridactyla* w czasie obserwacji na Morzu Północnym przedstawiono na ryc. 26. Najwięcej ptaków notowano w lutym, marcu i październiku na łowiskach 2 i 3 (ryc. 23, 27A). Wzrost liczby mew następował w czasie wiatrów zachodnich, oraz 24 godziny przed i 24 godziny po wzroście szybkości wiatru. Wzrost liczby ptaków wiązał się również ze wzrostem falowania powierzchni morza 24 godziny przed, 12 i 24 godziny po obserwacji. Wzrost liczby ptaków następował też 12 godzin po spadku ciśnienia barycznego i wzroście zachmurzenia nieba (tab. XXXIII, ryc. 27B—H).

Ilości *Larus marinus* obserwowanych na Morzu Północnym przedstawiono na ryc. 29. Wzrost liczby ptaków następował 12 godzin przed wzrostem zachmurzenia nieba, 12 godzin po spadku ciśnienia barycznego oraz na skraju wyżu (tab. XXXVII, XXXIX, ryc. 30A, B).

Ilości *Sula bassana* w czasie obserwacji na Morzu Północnym przedstawiono na ryc. 32. Liczniej gatunek ten obserwowano w październiku, najmniej licznie w lutym i marcu. Wzrost liczby ptaków następuje ponadto 24 godziny po wzroście szybkości wiatru, 12 godzin po wzroście falowania morza i 24 godziny po polepszeniu widzialności oraz w czasie wiatrów zachodnich. Wzrost ptaków następował w czasie przechodzenia niżów (tab. XLI, XLII, XLIII, ryc. 33A—E, 34).

Badań na łowiskach położonych na szelfie w pobliżu północno-zachodniej Afryki dokonywano w czasie rejsu w dniach od 2 XII 1964 do 12 IV 1965 (tab. XLV, ryc. 1, 35). Do obliczeń wzięto pod uwagę wyniki obserwacji *Larus fuscus* i *Sula leucogaster*.

Ilości *Larus fuscus* w czasie obserwacji przedstawiono na ryc. 36. Najwięcej ptaków tego gatunku obserwowano na łowiskach nr 2 i 3. Więcej ptaków obserwowano w grudniu niż w miesiącach pozostałych. Wzrost liczby ptaków na morzu następował w związku z wystąpieniem silniejszych wiatrów (maksymalną szybkość osiągały one w granicach 5—7° w skali Beauforta) oraz silniejszym falowaniem powierzchni morza. Wzrost następuje ponadto w czasie zalegania wyżu nad badanym akwenem (tab. XLVI, XLVII, ryc. 37A—J).

Ilości *Sula leucogaster* w czasie poszczególnych obserwacji przedstawiono na ryc. 38. Więcej ptaków obserwowano w grudniu niż w miesiącach następnych. Z innych badanych czynników żadne nie były związane w sposób statystycznie istotny ze zmianami liczby *Sula leucogaster* (tab. XLIX, ryc. 39).

Z przedstawionego materiału wynika, że czynniki powodujące zmiany liczby ptaków na morzu można zaklasyfikować do trzech grup: 1. geograficzne i klimatyczne, 2. meteorologiczne, 3. antropogeniczne. Miejsce połowu w obrębie każdego z łowisk miało wpływ na liczebność ptaków należących do 4 gatunków, miesiąc, w którym dokonywano badań powodował różnice w ilości ptaków u 5 badanych gatunków. Tylko dwa gatunki: *Larus marinus* i *Pagophila eburnea* pojawiały się na morzu niezależnie od położenia statku na łowisku oraz od pory roku.

Najbardziej dynamiczne zmiany liczby ptaków wiązały się ze zmianami czynników meteorologicznych. Wyjątek stanowiły tu *Sula leucogaster*. Istnienie tego faktu tłumaczyć można niewielką amplitudą zmian pogody w rejonach międzyzwrotnikowych. Spośród 42 przypadków związku istotnego statystycznie pomiędzy liczbą ptaków badanych gatunków a wartością czynnika pogodowego tylko w 5 przypadkach istniał związek pomiędzy aktualnie działającym czynnikiem pogodowym a liczbą ptaków. W pozostałych przypadkach zmiana wartości elementu pogodowego poprzedzała zmianę liczby ptaków lub następowała po zmianie liczby ptaków.

Czynniki pogodowe można poklasyfikować na działające mechanicznie — wiatr i falowanie powierzchni morza, warunkujące orientację przestrzenną — zachmurzenie nieba i widzialność, działające termicznie — temperatura powietrza i temperatura powierzchni morza, oraz jako oddzielną grupę — ciśnienie powietrza, mające, jak wynika z badań, marginesowe znaczenie zarówno jako czynnik determinujący pobyt ptaków, jak też jako czynnik mogący orientować zwierzę co do ewentualnej zmiany pogody.

Wzrost liczby ptaków notowano zazwyczaj w związku z przechodzeniem wyżów, spadek w niżach. W niżach natomiast następował wzrost liczby ptaków przebywających w pobliżu statku i korzystających z wyrzucanych odpadów.

W związku ze zmianami liczby ptaków, zależnymi od zmian pogody, można mówić o migracjach pogodowych mających na celu przemieszczenie się ptaków w akwen o dogodniejszych warunkach fizycznych. W przypadku ptaków żyjących na Oceanie ma to wielkie znaczenie ze względu na brak możliwości schronienia się przed niekorzystnymi warunkami pogodowymi np. w postaci sztormów lub okresów ciszy. W związku z tym typem migracji stwierdzono u ptaków morskich specyficzną orientację co do nadchodzących zmian pogodowych. Reakcja ptaków wyprzedzała zmianę niektórych czynników pogodowych nawet o 48 godzin. Istnienia mechanizmu, powodującego wcześniejsze zdobycie informacji co do kierunku przebiegu zmian pogody w przyszłości, za pomocą metodyki przyjętej przy wykonywaniu tych badań nie udało się ustalić. W rozdziale VI rozważano możliwość związku orientacji pogodowej u ptaków ze zmianami pola elektromagnetycznego, wzbudzanego między innymi w czasie przemieszczania się frontów.

W związku z wykazanym związkiem występowania poszczególnych gatunków ptaków z określonymi wartościami czynników pogodowych można analogicznie do pojęć używanych w ekologii mówić o siedlisku lub środowisku pogodowym jako jednym z głównych czynników determinujących rozmieszczenie ptaków w obrębie strefy geograficznej, zajmowanej przez gatunek.

Jako zespół czynników antropogenicznych należy rozumieć obecność statków przebywających na łowiskach rybackich. Wszystkie wzięte w pracy pod uwagę gatunki ptaków korzystały ze statku jako miejsca, w pobliżu którego znajdować się może pożywienie. Nie stwierdzono jednak powszechnej zależności pomiędzy liczbą statków i wydajnością połowów ryb a liczbą ptaków w poszczególnych dniach.

РЕЗЮМЕ

В настоящей работе представлено итоги исследований над изменениями поведения, а также изменениями количества птиц в зависимости от смены среды, главным образом смены погоды. Наблюдения над птицами велись из палуб польских тральщиков, производящих отлов рыб в Северном море, у побережий Ньюфаундленда и Лабрадора, у побережий северо-западной Африки (фиг. 1). Наблюдения производились с помощью бинокля 11×40 через 1,5 часа. Продолжение одного наблюдения 20 минут. Как исключение составляли исследования во время одного рейса в Северном море и рейса около Африки, когда наблюдения велись три раза в день. Во время наблюдений отмечалось количество птиц, возраст, а также характер выполняемых действий. На общее количество птиц, находящихся вблизи судна складывались: максимальное количество птиц, летающих вблизи судна, сумма птиц, летающих в воздухе не связанных с судном. Стаи птиц состоящие из несколько сот или несколько тысяч особей принимались оценочно. Итоги наблюдений распределено в три группы: утренние до 11 часов, обеденные с 11—15 часов, вечерние с 15 до сумерек (местного времени). Принималось во внимание наблюдение, в котором помечалось максимальное количество птиц в отдельных трёх интервалах времени. Количества птиц сравнивались со следующими метеорологическими факторами: скоростью и направлением ветра, состоянием моря, облачностью неба, видимостью, атмосферным давлением, температурой воздуха, температурой поверхности моря. Связь между этими факторами и количеством птиц определялись при помощи χ^2. Кроме того отмечалось влияние выше упомянутых факторов погоды, возникших в 12, 24 и 48 часов перед наблюдением, а также 12, 24 и 48 часов после наблюдения. Таким образом предлагаемым Сольбергером (1965), Тромпом (1963), установлено в таких случаях появление или изменение поведения птиц опережает изменение погоды, а также в каких случаях является её следствием.

Добавочно, анализировано синоптические карты исследованных аквенов, производя комплексный анализ погоды. В состав этой оценки входило описание,

которая часть барической системы находилась над местом ловли (область повышенного давления, пониженного давления, седловина), описание зависимости между движением фронтов и расположением места наблюдения (учитывалось род фронта и расстояние от места ловли). Приготавливались схемы синоптических карт, на которые наносились положения мест наблюдений с сохранением таких пропорций расстояний в отношении к областям повышенного давления, пониженного давления и фронтов, которые находились на оригинальных синоптических картах. Действительность связи изменений количества птиц в зависимости от существующей барической ситуации определялась при помощи дисперсионного анализа.

Исследования в окрестности Лабрадора и Ньюфаундленда произведено с 19 II по 9 V 1968 г. (табл. IV, фиг. 2). В месте ловли наиболее обильны были: *Fulmarus glacialis, Rissa tridactyla, Laurus hyperboreus, Pagophila eburnea*. Эти виды были приняты во внимание при дальнейшей работе.

Изменения в общем количестве *Fulmarus glacialis* представлено на фиг. 3. Итоги исследований над связью количества птиц с факторами среды представлено в табл. V. С этой таблицы, а также фиг. 2 следует, что наибольшее количество птиц наблюдалось в местах ловли, расположенных в северных районах аквена. Наибольше птиц наблюдалось в марте, меньше в апреле и мае (фиг. 4 A). Рост количества птиц происходил также во время роста ловли рыб (фиг. 4 B). Констатировано также связь между количеством *Fulmarus glacialis* и изменением скорости ветра перед 24 часами. Рост количества *Fulmarus glacialis* происходил после усиления скорости ветра на предыдущий день, 48 часов после ухудшения видимости и 12 часов после увеличения атмосферного давления (фиг. 4 C, F, G). Одновременно рост количества птиц происходил 48 часов перед понижением облачности неба и 48 часов перед улучшением видимости (фиг. 4 D, E). Возрастание количества птиц происходило также в связи с низкой температурой поверхности моря. Из комплексного анализа погоды следует, что возрастание количества птиц имело место тогда, когда над местом ловли находился край области повышенного давления, пониженного давления или седловина (фиг. 5, табл. VII—X). То есть эти птицы избегают шторма при пониженном давлении и слабых ветров в области повышенного давления.

В табл. XI представлено уровни истинности связи между процентом *Fulmarus glacialis*, летающих за судном и исследуемыми факторами. Рост процента птиц отмечался во время роста скорости ветра, 24 часа после роста облачности, 24, 12 часов после и 12 часов перед понижением атмосферного давления (фиг. 6 A, B, C, D, E, F). Наибольше птиц также отмечалось во время прохождения области пониженного атмосферного давления и фронтов (табл. XII).

Процент летающих птиц в воздухе независимо от судна возрастал 48 часов после роста общего количества *Fulmarus glacialis*, 24 часа после уменьшения скорости ветра и облачности (табл. XIII, фиг. 7 A, B, C, D).

Процент сидящих птиц на поверхности моря возрастал 48 часов после возрастания скорости ветра и 12 часов после слабых ветров, во время слабых ветров и слабого волнения моря. Больше *Fulmarus glacialis* сидело на поверхности моря во время юго-западных ветров (табл. XIV, фиг. 8 A, B, C, D, E).

Резюмируя можна констатировать, что добыча корма птицами за судном имеет место во время действия погоды причиняющей понижение общего количества птиц (действие отрицательных факторов), лёт в воздухе (миграции) и сидение птиц на поверхности моря имеет место во время погоды похожей на ту, при которой собирается большое количество *Fulmarus glacialis* в месте улова.

Количества *Rissa tridactyla* во время наблюдений в местах лова возле Лабрадора и Ньюфаундленда представлено на фиг. 9.

Наиболее многочисленным он был в феврале и марте, а также в местах ловли, расположенных в северных районах исследованного аквена. Наибольше птиц находилось вблизи судна во время траления, выбирания и отдачи сетей, а также когда судно находилось в дрейфе. Больше птиц отмечалось вечером, меньше утром (табл. XVI, фиг. 10 A, B, C, 11). Кроме того рост количества птиц происходил 12 и 24 часа перед понижением скорости ветра, а также во время понижения температуры воздуха. Наибольше птиц отмечено в области повышенного давления и в седловине, а также после прохождения фронтов (табл. XVIII, фиг. 12 A-F, 13).

Процент *Rissa tridactyla*, летающих за судном возрастал в вечерние часы, 12 и 24 часа после роста облачности на небесном своде (табл. XIX, фиг. 14 A—C).

Процент *Rissa tridcatyla* летающих в воздухе возрастал во время скорости ветра 2—3° по шкале Бофорта, а также 12 часов после слабой облачности небесного свода (табл. XX, фиг. 15 A, B).

Процент *Rissa tridactyla*, сидящих на поверхности моря возрастал во время общего роста количества птиц этого вида, а также во время слабого волнения (табл. XXI, фиг. 15 C, D).

В общем можно констатировать, что больший процент *Rissa tridactyla* мигрирует (летает в воздухе) во время погоды сближённой к той, которая является причиной увеличения количества птиц — это главным образом является уменьшение скорости ветра. С миграцией также связана слабая облачность небесного свода. После сильной облачности, больший процент птиц добывает пищу за судном.

Количество *Larus hyperboreus* во время наблюдений в местах ловли в районе Лабрадора и Ньюфаундленда представлено на фиг. 16. Наибольше птиц отмечено в местах ловли, расположенных вблизи суши, 24 и 48 часов перед уменьшением скорости ветра и 24 часа перед уменьшением облачности небесного свода. Рост также происходил в области повышенного давления и в барической седловине (табл. XXIII, XXIV, фиг. 17 A—C, 18).

Количества *Pagophila eburnea* во время наблюдения представлено на фиг. 19. Рост количества этих птиц имел место 12 часов перед понижением видимости и выпадением атмосферных осадков или снега (табл. XXV, фиг. 21).

Исследования на Северном море производились во время трёх рейсов с 3 II по 9 III 1964 г., 22 VIII по 19 IX 1968 г., 4 X по 25 X 1968 г. Трассы рейсов и расположения мест ловли представлено на фиг. I и 23, количество дней и даты пребывания на отдельных местах ловли представлены на фиг. XXIX. К подсчётам принято во внимание итоги наблюдений, проводимых во время выбирания сетей на палубу судна и обработки рыб, когда вблизи находилось наибольшее количество птиц. Из наиболее сосредотачивающихся видов вблизи судна исследовано четыре: *Fulmarus glacialis, Rissa tridactyla, Larus marinus, Sula bassana*.

Количество *Fulmarus glacialis* во время наблюдений представлено на фиг. 24. Наибольшее количество птиц наблюдалось в месте ловли обозначенном номером 5, а также в августе и сентябре. Рост количества этого вида имел место 24 часа перед и 48 после ветров со скоростью 2—4° шкалы Бофорта. Подобная зависимосить наблюдается в отношении к состояниям моря (табл. XXX, фиг. 25 A—E). Кроме того рост количества птиц происходил в барической седловине, менее в области с повышенным и пониженным атмосферным давлением (табл. XXXII).

Количества *Rissa tridactyla* во время наблюдений в Северном море представлено на фиг. 26. Наибольшее количество птиц отмечено в феврале, марте и октябре, в местах ловли 2 и 3 (фиг. 23, 27 A). Рост количества чаек происходил во время западных ветров, а также 24 часа перед и 24 часа после роста скорости ветра. Также рост количества птиц был связан с возрастанием волнения моря 24 часа перед, 12, 24 часа после наблюдения. Рост количества птиц происходил также 12 часов после падения атмосферного давления и усиления облачности небесного свода (табл. XXXIII, фиг. 27 B—H).

Количества *Larus marinus*, наблюдаемые на Северном море представлено на фиг. 29. Рост количества птиц происходил 12 часов перед ростом облачности небесного свода, 12 часов после падения атмосферного давления, а также на периферии области повышенного атмосферного давления (табл. XXXVII, XXXIX, фиг. 30 A, B).

Количества *Sula bassana* во время наблюдений на Северном море представлено на фиг. 32. Более многочисленным этот вид был в октябре, а наименее в феврале и марте. Кроме того рост количества птиц происходил 24 часа после роста скорости ветра, 12 часов после усиления волнения моря и 24 часа после улучшения видимости, а также во время западных ветров. Рост количества птиц происходил во время прохождения областей с пониженным атмосферным давлением (табл. XLI, XLII; XLIII, фиг. 33 A—E, 34).

Исследования в местах ловли, расположенных на шельфе вблизи северо-западной Африки производились во время рейса со 2 XII 1964 по 12 IV 1965 гг. (табл. XLV, фиг. 1, 35). К подсчётам принято во внимание итоги наблюдений *Larus fuscus* и *Sula leucogaster*.

Количества *Larus fuscus* во время наблюдения представлено на фиг. 36. Наибольшее количество этого вида наблюдалось в местах ловли 2 и 3. Больше птиц наблюдалось в декабре, чем в остальных месяцах. Рост количества птиц на море происходил в связи с усилением ветров (максимальная их скорость доходила до 5—7° шкалы Бофорта), а также усилением волнения поверхности моря. Рост имел место также при области повышенного атмосферного давления над исследованным аквеном (табл. XLVI, XLVII, фиг. 37 A—J).

Количество *Sula leucogaster* во время отдельных наблюдений представлено на фиг. 38. Больше птиц наблюдалось в декабре, чем в остальные месяцы. С других исследованных факторов, никакой не был связан статистически существенным способом с изменениями количества *Sula leucogaster* (табл. XLIX, фиг. 39).

Из представленных выше данных следует, что факторы причиняющие изменения количества птиц на море можна отнести к трём группам: I. географические и климатические, 2. метеорологические, 3. антропогенные. Место ловли имело влияние на численность птиц, принадлежащих к 4 видам; месяц, в котором производились исследования влиял на количество птиц у 5 исследованных видов. Только 2 вида: *Larus marinus* и *Pagophila eburnea* появлялись на море независимо от положения судна в месте ловли, а также времени года.

Наиболее динамичные изменения численности птиц были связаны с изменениями метеорологических факторов. Исключением здесь был *Sula leucogaster*. Этот факт можно объяснить небольшой амплитудой изменения погоды в тропикальных районах. Среди 42 случаев существенно статистической связи между количеством исследованных видов птиц и значением погодного фактора, только в 5 случаях существовала связь между актуально действующим фактором погоды и количеством птиц. В остальных случаях изменение значения погодного элемента предшествовало изменению количества птиц или происходило после изменения количества птиц.

Погодные факторы можно разделить на действующие механически — ветер и волнение поверхности моря, обуславливающие пространственную орьентацию — облачность небесного свода и видимость, действующие термически — температура воздуха и температура поверхности моря и, как отдельную группу — давление атмосферного воздуха, имеющее, как следует из опытов, второстепенное значение равно, как фактор предопределяющий пребывание птиц, а также как фактор могущий ориентировать животное относительно возможного изменения погоды.

Рост количества птиц отмечался обычно в связи с прохождением областей повышенного давления, падение — пониженного давления. В областях пониженного давления происходил рост количества птиц, находящихся вблизи судна и пользующихся выбрасываемыми отпадками.

В связи с изменениями количества птиц, зависящими от изменений погоды можно говорить об погодных миграциях, целью которых является перемещение птиц в аквен с благоприятными физическими условиями.

В случае птиц живущих на океане это имеет большое значение в связи с отсутствием возможности укрытия перед неблагоприятными погодными условиями, например: штормами или периодами тишины. В связи с этим типом миграции констатировано у морских птиц специфическую ориентацию относительно приближающихся погодных изменений. Реакция птиц опережала изменение некоторых погодных факторов даже на 48 часов. Существование механизма вызывающего более раннюю добычу информации направления изменения погоды в будущем, с помощью методики принятой при выполнении этих исследований не удалось установить. В VI разделе продумано возможность погодной ориентации у птиц в связи с изменением электромагнитного поля возбуждаемого, между прочим, во время перемещения фронтов.

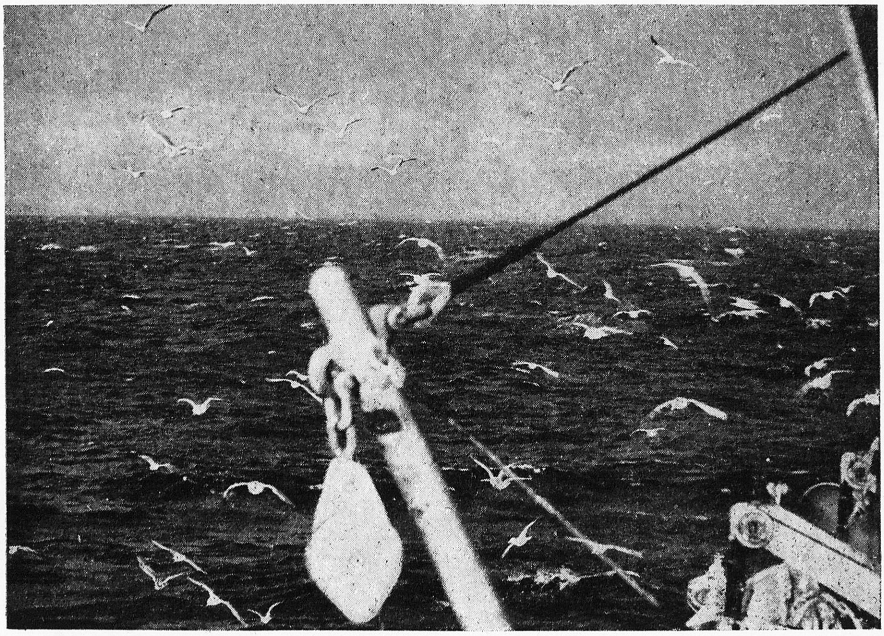
В связи с обнаруженной связью встречаемости отдельных видов птиц с определёнными значениями погодных факторов можно аналогично принятым в экологии понятиям, говорить также о погодном биотопе или среде, как одном из главных факторов предопределяющих размещение птиц в пределах географической зоны, занимаемой видом.

Под комплексом антропогенных факторов следует понимать наличие судна пребывающего в местах ловли рыб. Все виды птиц взятых в этой работе во внимание пользовались судном, как местом в близи которого может находиться корм. Однако не найдено общей зависимости между количеством суден и производительностю ловли рыб, а также количеством птиц в отдельные дни.

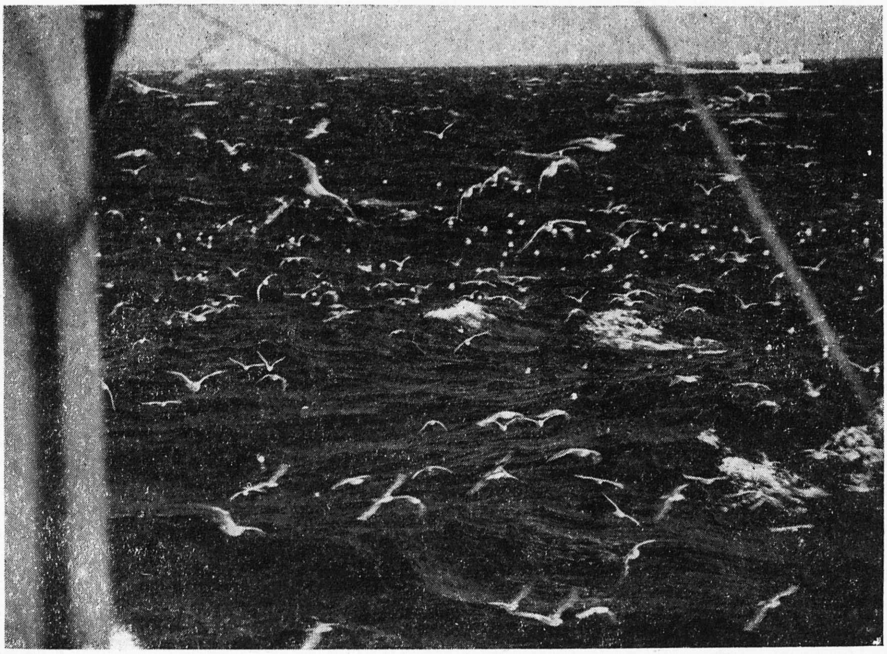
Plate IX

Phot 1. Birds accompanying a trawling vessel. North Sea, August 1968

Phot. 2. Birds approaching a trawler while the net with fish is being drawn in. North Sea, August 1968



Phot. 1



Phot. 2

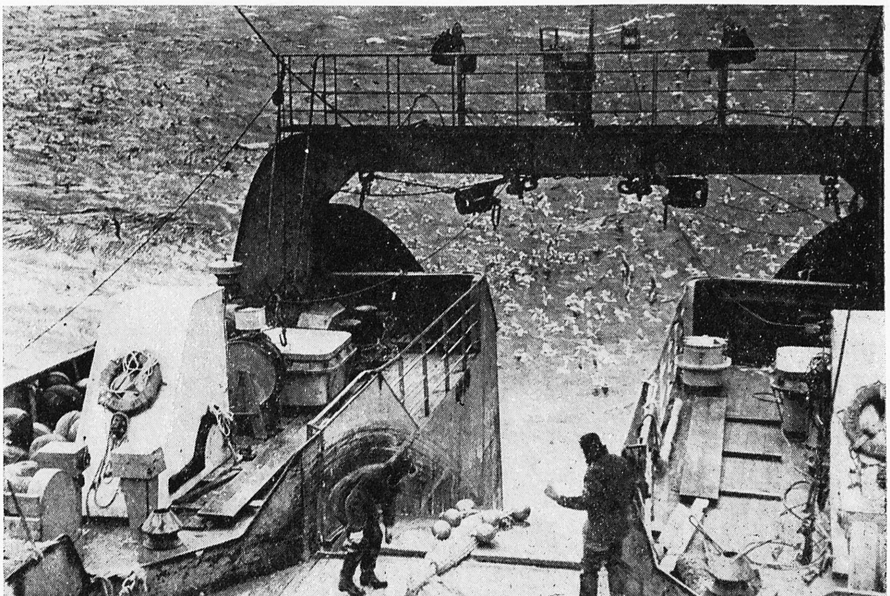
S. Manikowski
Phot. author

Plate X

Phot. 3. Great Black-backed Gulls picking up food from the sea surface. North Sea, August 1968

Phot. 4. Birds feeding at the back of trawler. Atlantic, in the region of Newfoundland and Labrador; March 1968

Phot. 3



Phot. 4

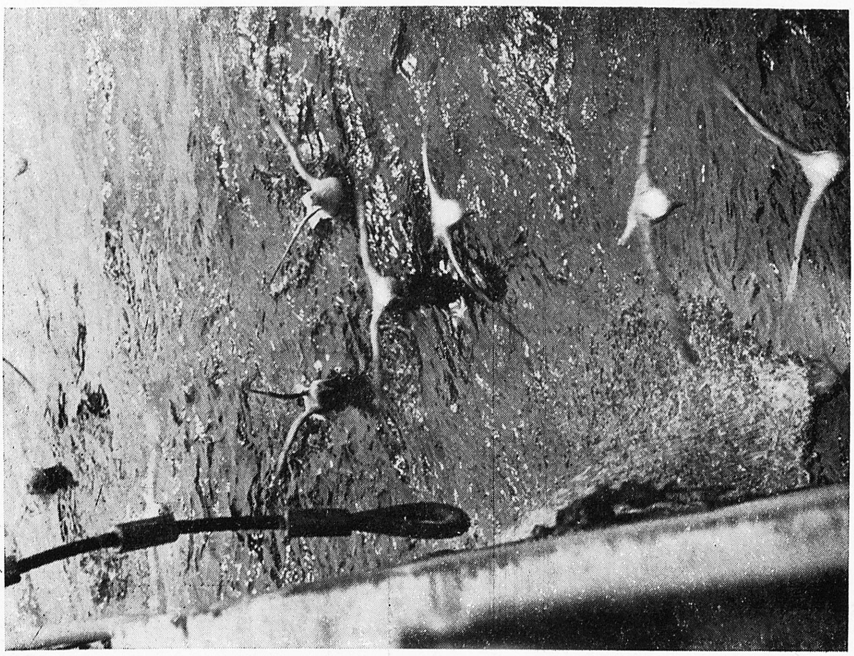
S. Manikowski
Phot. author

Plate XI

Phot. 5. Fulmars in search of food at the outlet of the drain of the fish processing plant. Atlantic, in the region of Newfoundland and Labrador; April 1968

Phot. 6. Kittiwakes cathing fish which have got out through the meshes. North Sea, September 1968

Phot. 6



Phot. 5

S. Manikowski
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