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C.M.1974/H.21

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THE STUDY OF THE ABIOTIC REASONS OF FLUCTUATIONS IN THE STRENGTH OF NORTH SEA HERRING

INTRODUCTION

In special literature there are no clear data concerning the correlation between the strength of the North Sea herring stocks and biotic factors (such as the size of the parent stock, the number of hatched larvae), provided that the herring stock size, particularly older age groups, is not depleted. Not allowing for the latter limitation, the strength of the North Sea herring is dependent on the environmental conditions during the earlier stages of herring development (eggs-larvae-fry) which are hypothetically favourable or unfavourable to its survival. In some well-known papers the influence of water temperature in the spawning and postspawning periods (Shirokov, 1964, a; Antonov, 1965; Postuma, 1971) and of supposed larvae drift towards the future habitats (Carruther, 1938, 1951, Shirokov, 1964 b) upon the strength of Dogger and Downs herring stocks has been studied.

In the study on possible abiotic conditions causing the fluctuations in the strength of the North Sea herring we used the conventional methods. The only difference was that the prespawning period was also studied, and besides temperature measurements such factors as prevailing wind strength and the groups of the baric fields over the North Sea earlier isolated (Alemasov, 1971, fig.1) were analysed.

MATERIAL AND METHODS

As temperature chracteristics, the mean monthly surface water temperatures in the statistical squares of the North Sea

(ICES, 1962, 1970 a,b) averaged for the north-west (Buchan stock), south-west (Dogger stock), southern (Downs stock) and south-east (Bløden area) areas of the Sea were taken. The bottom temperatures must have been more representative, however, they are not so complete as the surface one.

The data on the prevailing wind strength were given as monthly sums of wind force (by Beaufort scale), and the data on the groups of baric fields - as monthly sums of days with every group. The prevailing wind strength and the groups of baric fields were determined by the daily synoptical charts.

As the stock strength indices, the catches of three year old recruits (2 winter rings) per fishing effort unit were taken. These indices are given in the paper by Burd (1966) and in ICES material (1972) for three major stocks of North Sea herring.

The data of the pre-war and post-war periods on the recruit catches are not comparable (maybe with the exception of the Downs stock), therefore, we decided to divide these data into two series; the 1921-1935 broods, according to Burd (1966), that is the pre-war period, and the 1951-1967 broods, according to ICES material (1972).

The both series were correlated with the monthly values of the above abiotic factors from January of herring birth year to December of the next year. The calculations were made by means of computer.

Since the total number of correlation factors appeared to be extremely great, a careful analysis was needed, firstly, not to take the random correlation factors, no matter how high, for the indices of real correlations, and secondly, not to ignore the correlation factors though low, however, promoting the indications of really existing correlations.

Therefore we decided to consider only those correlation factors which could have been satisfactorily explained from the physical point of view on one hand, and relatively close factors in both series of observations for 1921-1935 and 1951-1967 on the other hand. The availability of the correlation factors in both series within the mean-root-square error (σ_r) was considered to be the criterion of the identity.
This mean-root-error is known to be determined (Brooks, Carruthers, 1953) by the formula: $\sigma_r = \frac{1-r^2}{N-1}$, and its maximum value for a series of 1951-1967 (number of observations N=17) is 0.25.

RESULTS

All the attempts to reveal the real correlation factors (proceeded from the above criteria) for the indices of wind strength and for other specified abiotic factors in prespawning period were not a success. For spawning and post-spawning periods the real* correlation factors were found (together with some correlation factors given in square brackets which are not acceptable proceeded from our criterion) (table 1).

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* Below it is evident that the reality of the correlation factors for the post-spawning period is characteristic only of the first stage of our analysis (table 1).

Table 1

The correlation factors between the strength of North Sea herring and abiotic factors

Herring stock	Series of observations	Groups of baric fields S-E during spawning periods			Water temperature during spawning (VIII-XII) and post-spawning (I-III) periods			
		VIII	(IX+X)/2	(XI+XII)/2	VIII	(IX+X)/2	(XI+XII)/2	(I+II+III)/3
Buchan	1951-67	-0.63			0.29			0.28
	1922-35	-0.57			-0.64			-0.31
Dogger	1951-67		-0.52			-0.33		0.30
	1921-34		-0.47			-0.04		0.17
Downs	1951-67			0.58			0,40	0.39
	1921-34			0.56			0.38	0.53

Notes: 1. S-E - differences of monthly dates with southern (S) and eastern (E) groups of baric fields.

2. Water temperature during spawning periods is given for herring habitats, while during post-spawning period - for the south-west (Buchan and Dogger stocks) and south-east (Downs stock) North Sea.

From Table 1 it is evident that the highest and most steady correlation factors are characteristic of the groups of baric fields during spawning periods of all the stocks, as well as spawning and post-spawning water temperature relative to Downs stock. Lower correlation factors seen in both series of observations concern the post-spawning water temperature relative to Dogger stock. Since the indices of correlation factors for the spawning and post-spawning water temperature relative to Buchan stock differ in the two series of observations, these correlations were considered to be ineffective. The conclusion of Postuma (1971) about the presence of a negative correlation between water temperature during spawning and the strength of Dogger herring stock in the post-war period is confirmed by our data for 1951-1967. However, in 1921-1934 such a correlation was practically absent, and according to our criterion (σ_r = 0.25) there is no reason to consider it as an effective.

For Dogger and Downs herring stocks we have tried a multiple correlation (according to Brooks, Carruthers, 1953) where the strength of herring stocks was expressed by a dependent X_1 and the groups of baric fields and water temperature during the spawning and post-spawning periods by independent variables (X_2, X_3, X_4 , accordingly). The results are given in table 2.

Table 2

The particular (r) and multiple (R) correlation factors between the strength of the North Sea herring and abiotic factors

Herring stock	Series of observations	$r_{12.4}$	$r_{14.2}$	$r_{12.34}$	$r_{13.24}$	$r_{14.23}$	R
Dogger	1951-67	-0.53	0.37				0.61
	1921-34	-0.45	0.06				0.47
	1951-67			0.35	0.07	0.06	0. 58
	1921-34			0.50	0.42	0.49	0.73

Notes: 1. The indices 1,2,3,4 following the r denote the variables x_1,x_2,x_3,x_4; the indices following the point denote the excluded variables.

2. The values given in the square brackets do not satisfy the criterion $\sigma_r = 0.25$.

While the particular correlation factors which express the correlation between the herring strength and groups of baric fields without regard for the influence of water temperature remain constant in both series of observations according to our criterion, this cannot be said about the correlation between the stock strength and water temperature without regard for the influence of the groups of baric fields. These latter correlation factors observed in 1921-34 for the Dogger stock and in 1951-1967 for the Downs stock are too negligible to make any contribution to the multiple correlation factors compared with the paired correlation between the strength and the groups of baric fields. Basing on the second stage of the analysis (see table 2) we have concluded that the influence of water temperature upon the strength of the North Sea herring is ineffective, its external expression being only a result of duplication of information contained in the characteristics of groups of baric fields, The duplication may have a following explanation from the physical point of view: in the North Sea the relatively high water temperature measurements correspond to the southern group of baric fields during the warmer half year (all the year round in the southern North Sea), while relatively low measurements correspond to the eastern group of baric fields during cold season (Alemasov, AtlantNIRO Trans., in press).

Thus, the two-stage correlation analysis has shown that among the abiotic factors studied only the groups of baric fields revealed an effective correlation with fluctuations in the strength of the North Sea herring.

The pattern of this correlation is rather specific: higher recurrence of the southern or lower recurrence of the eastern groups of baric fields during the spawning periods of the Buchan (VIII) and Dogger (IX-X) stocks are not favourable to formation of strong broods, which can be conditioned by the opposite combinations of recurrence of the mentioned groups of baric fields. A correlation between the two groups of baric fields and the strength for Downs (XI-XII) stock is of the opposite character.

The reliability of the correlation factors obtained from a series of observations for 1951-1967 (see table 1) is confirmed not only by their significance levels (0.01 for Buchan stock,   0.05 for Dogger and Downs stocks), but by a series of observations for 1921-1935 as well. The correlation graphs are shown in fig.2.

DISCUSSION

What can be said about the physical mechanism of a correlation revealed? Since the question is that the atmospheric circulation during the spawning periods of herring affects the strength of the stock, it is likely that we have to do with the peculiarities of the drift of hatched larvae in the wind-driven sea currents.

First, the question on the influence of winds upon the strength of the North Sea herring and other fishes stocks in view of possible larvae drift was raised by Carruthers and his followers. He suggested that the strong broods of Downs stock herring are formed when during the spawning a higher pressure in the south-eastern area and a lower pressure in the south-western area are observed (Carruthers, 1938), or in other words when during spawning in the southern area the southern and western components of wind prevail (Carruthers, Lawford and Veley, 1951). Simultaneously, Carruthers considered the high strength of Downs herring to be stipulated by the drift of the larvae in the north-eastern direction.

It is evident that our results well agree with the data by Carruthers, because the pressure diatribution given by this author is characteristic of the southern group of baric fields. Further it is seen that our data conform as well to the interpretation of the larvae drift given by Carruthers.

It should be noted that Gulland (1953) cast doubt on the results by Carruther because of a certain arbitrariness of his choice of years of spawning periods; in our work the constant periods have been studied.

One of the followers of Carruthers, Veley (1952), suggested that the predominance of the western wind component during the sprat spawning periods in the south-west North Sea is unfavourable to its strength (according to Veley the reason lies in the larvae drift offshore). This result is also indirectly (since other than herring species was studied) concurrent with our (see below).

A hypothesis on the influence of the fry drift upon the strength of the Dogger herring is given in detail by Shirokov (1964, b). The studies of the direction and velocity of possible fry drift affected by summarized wind-driven currents from September to March allowed him to suggest (fig.3) that the strong broods are formed while the drift to the south-eastern and southern areas and the poor broods - to the central North Sea. The conclussions by Shirokov, however, are of quantitative character and do not well agree with the data on the strength of the stocks.

It seems that in the paper cited the question on the larvae (fry) drift is solved too straightforward. Firstly, the passive drift is characteristic only of the earliest development stages of the larvae. Secondly, the way of the larvae towards their future habitats (Bløden area) where they will stay as the young herring is likely to be more complex.

Now, basing on the information drawn from the special literature, we'll try to summarize the pattern of distribution and drifts of the North Sea herring at their early developmental stages so that to make a physical interpretation of the correlations obtained.

It is known (Hodson, 1957) that before reaching the length of 7-10 cm the fry generally inhibit the inshore water leaving it later for the open sea. During this time the habitat of the fry covers both the south-east North Sea and the whole English east coast (Wood, 1959, 1971).

It is clearly seen from O-group herring distribution in May-August of the next year after the birth (Postuma, Zijlstra and Das, 1965, fig.4).

As to larvae migrations (according to Parrish and Saville, 1965), they occur along the western and south-eastern coasts of the North Sea. Some data indicate that the larvae from the northern area were observed along the English coast in October. The larvae hatched at the western extremity of the Dogger Bank in September rounded the Bank and were observed at its southern extremity in October; in November and December they occurred around the Oyster Bank and by March they began to break into the German Bight. Downs larvae from the hatching area (at the eastern entrance to the English Channel) migrated in the north-eastern direction and at the beginning of January were seen along the Zeeland and in February - in the German Bight.

Such a pattern of the larvae migrations must be stipulated by a general cyclonic cycle of the constant currents in the North Sea marked by many authors, in particular, recently by

Dubrovin and Amarov (1972) (fig.5).

The described pattern of distribution and migrations of herring larvae threw light upon the physical mechanism of the revealed correlations between the strength of herring stocks and the groups of baric fields.

Fig.1 shows that when the eastern group of baric fields is available, the eastern flows of the air providing the corresponding water movements result in a drift of the hatched larvae from the Buchan and Dogger Banks to the inshore areas, where favourable conditions for their development are likely to be established, as well as for their migration in the southern and south-eastern directions within the system of the constant currents. However, when the southern group of baric fieldds occurs, the south-western flows of the air may result in a drift of the larvae offshore where they may not survive. The northern group of the baric fields leads to the formation of the north-western flows of the air; if the northern flows are considered to be favourable for the following successful development of the larvae, the western ones are the contrary, thhrefore this latter group of baric fields is specified as a "neutral" relative to the strength of the stock.

For Downs herring the southern group of baric fields is favourable to the distribution of the larvae along the coast in the north-eastern direction which cannot be said about the eastern group. The northern group of baric fields is likely to be favourable to the larvae of its western component, though unfavourable to the larvae of its northern component thus being a "neutral" as a whole.

The correlations revealed make it possible to forecast the future abundance of the recruits after the birth by the regression equations (fig.2). However any success in forecasting the abundance in the nearest future is somewhat doubtful, because due to a considerable depletion of the North Sea herring stocks certain biotic correlations such as "spawning potential-strength" may arise, the first signs of which have already been stated (ICES, 1973).

SUMMARY

The material for 1921-1935 and 1951-1967 revealed significant correlations between the abundance of the North Sea herring recruits and recurrence of the groups of baric fields over the North Sea (the types given by the author) during the spawning periods (VIII - Buchan stock, IX-X - Dogger stock, XI-XII - Downs stock).

The heightened recurrence of the southern group of baric fields or lowered of the eastern one are not favourable to the formation of the strong year-classes of Buchan and Dogger herring and favour the strength of Downs stock. The contrary combination of the recurrence of the above groups of baric fields is retrospective.

A drift of the hatched larvae to favourable or unfavourable areas for their development surves as a physical basis of the correlation. Most favourable are the coastal areas of the

western and south-eastern North Sea due to their shallow character and the presence of constant currents providing a drift of the larvae towards the Bløden area.

The correlations revealed make it possible to forecast the future abundance of the recruits immediately after their birth. These correlations, however, are likely to be effective only when the state of the herring stocks is satisfactory.

LIST OF FIGURES

REFERENCES:

Alemasov, B.E., 1971. The types of baric fields over the North Sea. Trudy AtlantNIRO, vyp.34. Kaliningrad.

Antonov, A.E., 1965. The forecasting of the relative strength of the Baltic cod and Bank herring of the North Sea. Rybnoe khoziaistwo no.5, Moscow.

Dubrovin, B.I., Amarov, G.L., 1972. Non-periodic currents in the North Sea. Trudy AtlantNIRO, vyp.48. Kaliningrad.

Shirokov, L.V., 1964 a. On forecasting of Downs herring strength. Trudy AtlantNIRO, vyp.13. Kaliningrad.

Shirokov, L.V., 1964. b. On the reasons of fluctuations in the Bank herring brood abundance in the North Sea. Trudy AtlantNIRO, vyp.13. Kaliningrad.

ICES service hydrographique, 1962, Mean monthly temperature and salinity of the surface layer of the North Sea and adjacent waters from 1905 to 1954.

ICES service hydrographique, 1970 a. Monthly means of surface temperature and salinity for areas of the North Sea and the North-Eastern Atlantic in 1957-1961

ICES service hydrographique, 1970 b. Monthly means of surface temperature and salinity for areas of the North sea and the North Eastern Atlantic in 1962-1966.

ICES, 1972. Report of the North Sea herring assessment working group meetings C.M. H:5.

ICES, 1973. Report of the North sea herring assessment working group meetings. C.M. H: 27.

Hodson, W.C., 1957. Herring and its fishery. London.

Parrish B.B. and Saville A., 1965. The biology of the North-East Atlantic herring populations. Oceanogr. mar. Biol. Ann. Rev., 3.

Postuma K.H., 1971. The effect of temperature in the spawning and nursery areas on recruitment of autumn-spawning herring in the North sea. Rapp. P.-v. Reun. Cons. perm. int. Explor. Mer., 160.

Postuma K.H., Zijlstra J.J. and Das N., 1965. On the immature herring of the North sea. J. Cons. perm. int. Explor. Mer, 29.

Veley V.F.C., 1952. Brood strength fluctuations in the sprat. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer, 131.

Wood, R.J., 1959. Investigations on O-group herring. J. Cons. perm int. Explor. Mer, 24.

Wood P.J., 1971. Whitebait herring on the English east coast. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer, 160.

Burd A.C., 1966. On stock and recruitment of Buchan Bank and Downs herring. C.M. H:29.

Brooks C., Carruthers N., 1953. Handbook of statistical methods in meteorology. London.

Carruthers J.N., 1938. Fluctuations in the herring of the East Anglian autumn fishery, the yield of the Ostend spent herring and the haddock of the North sea - in the light of relevant wind conditions. Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer, 107.

Carruthers J.N., Lawford A.Z. and Veley, V.F.C., 1951. Fishery hydrography: brood strength fluctuations in various North sea fish, with suggested methods of prediction. Kieler Meeresforsch., 8.

Gulland J.A., 1953. Correlations on fisheries hydrography. J. Cons. perm. int. Explor. Mer., 18, N 3.

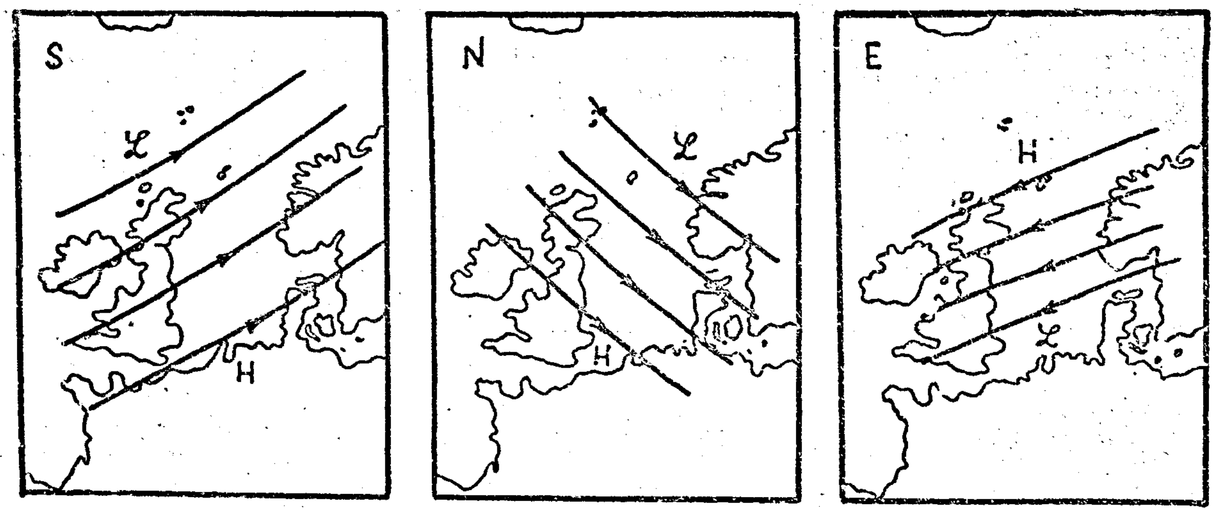

Fig. 1

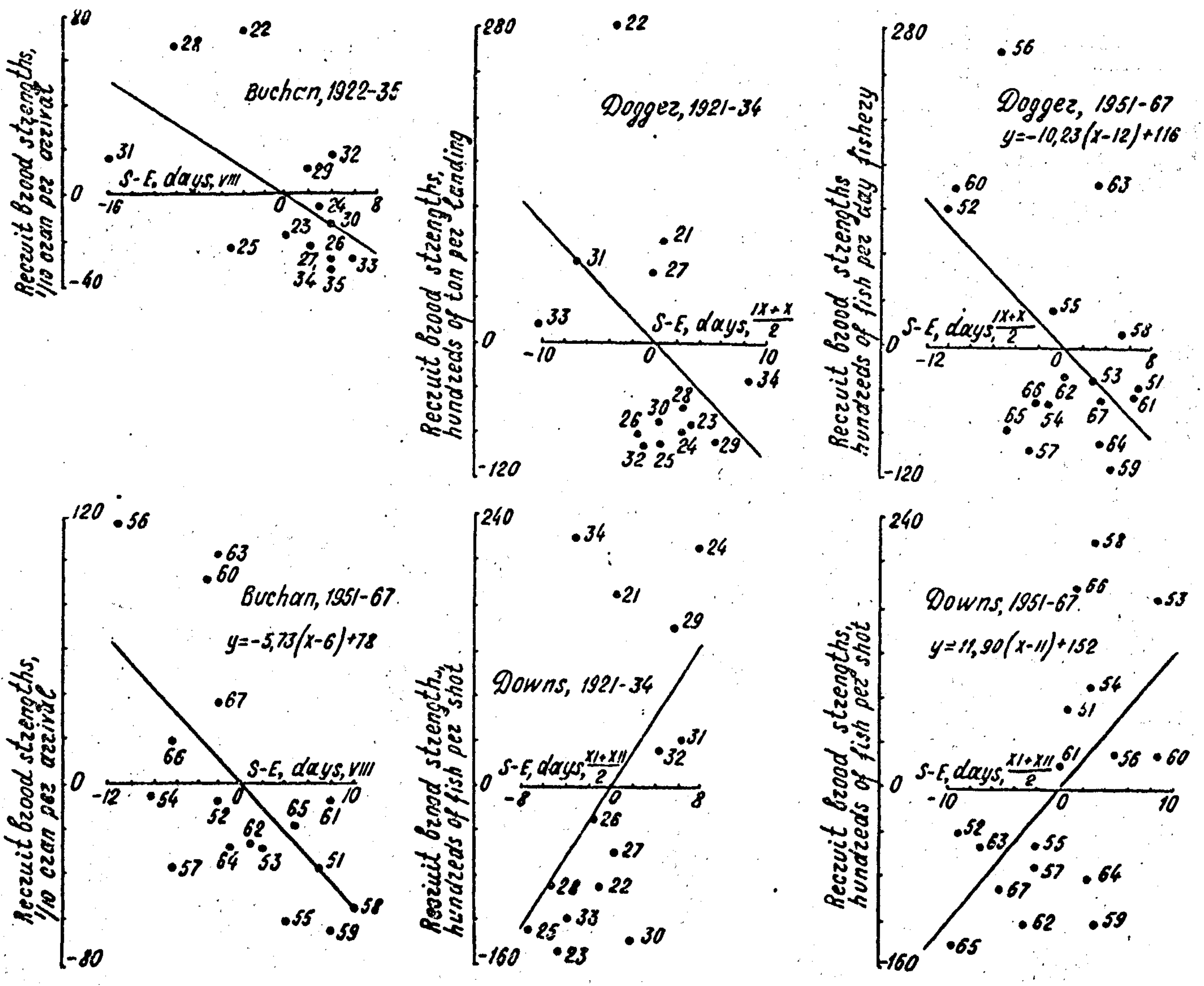
Buchan, 1922-35
Recruit brood strengths, 1/10 oran per arrival
S-E, days, VIII
Dogger, 1921-34
Recruit brood strengths, hundreds of ton per landing
S-E, days, (IX+X)/2
Dogger, 1951-67
y=-10,23(x-12)+116
Recruit brood strengths hundreds of fish per day fishery
S-E, days, (IX+X)/2
Buchan, 1951-67
y=-5,73(x-6)+78
Recruit brood strengths, 1/10 cran per arrival
S-E, days, VIII
Downs, 1921-34
Recruit brood strength, hundreds of fish per shot
S-E, days, (XI+XII)/2
Downs, 1951-67
y=11,90(x-11)+152
Recruit brood strengths, hundreds of fish per shot
S-E, days, (XI+XII)/2

Fig.2

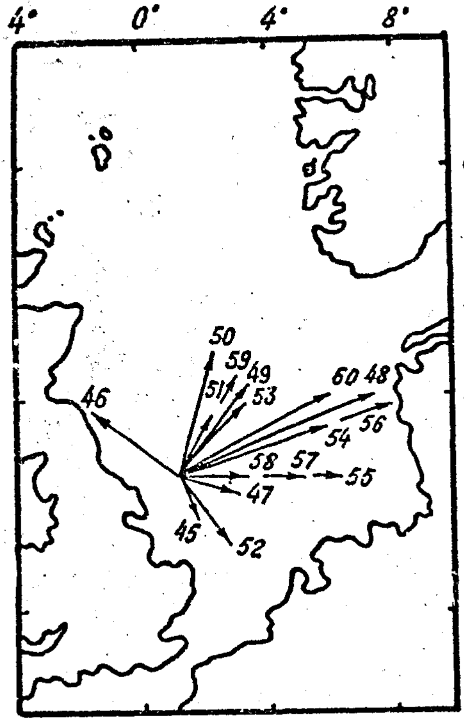

Fig. 3

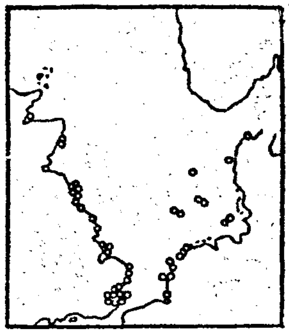
Fig 4

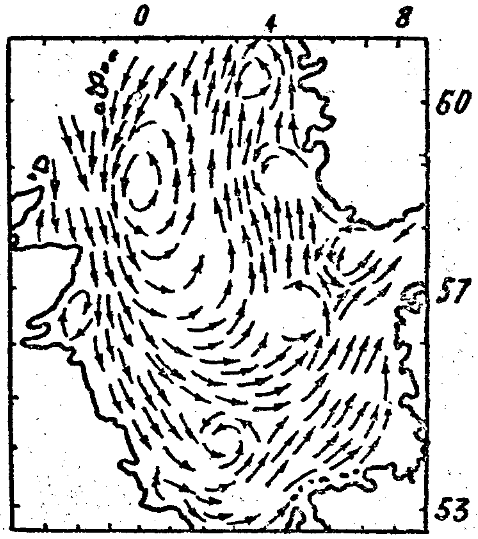

Fig 5

Подп. в печ. IO/УII 1974 г. Зак. 857. Тир. 205