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Water temperature as an index of cod distribution in Subarea 1 (West Greenland)

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The present paper is a continuation of the author's work on determination of the relationships between water temperature and cod distribution on the West Greenland banks (Svetlov, I.I., 1969). Asynchronous relationships according to which it is possible to forecast in advance the areas of the most probable cod concentrations are considered in the paper. A method for such forecasting was suggested by K.G.Konstantinov and used for forecasting the fishery importance of separate areas in the Barents Sea (Konstantinov, K.G., 1964; Konstantinov, K.G. and A.I.Mukhin, 1964; Konstantinov, K.G., 1967a).

Some relationships between water temperature and fishery importance of Div.1B are considered in the paper; Store Hellefiske Bank is in this division where an intensive cod feeding is observed usually in summer and early autumn (Rasmussen, 1956; Sidorenko, I.N., 1964).

Water temperature anomaly of the 0-50, 50-100, 100-200 m layers on the station at 66°37'N, 57°05'W in July (Herman, 1967) and in the area off Godthaab (64°11'N, 51°43'W) was taken as an index of the heat state of the sea (Bulletin Hydrographique, 1959-1962). The fishery importance of Div.1B as a percentage, calculated as a ratio of cod yield in Div.1B in the given month to the total yield in all divisions of Subarea 1 in the same month was taken as an index of cod distribution. While calculating the fishery importance of Div.1B the data on cod catches, taken by all fishing gears, were used. Data on catches were obtained from Statistical Bulletins of ICNAF for the period 1954 to 1966 (ICNAF Statistical Bulletin, 1956-1968).

Because no data on water temperature were available from the Godthaab station since 1962 and from the station at 66°37'N, 57°05'W since 1966, the data on catches for the last years were not included in the statistical analysis. Some relationships that are considered below were obtained from the data available by means of correlation analysis.

A. Water temperature anomalies in the 50-100 m layer in July (Fig.1a) and the fishery importance of Div.1B in November

Diagram of the relationship between the temperature anomaly in the 50-100 m layer on the station at 66°37'N, 57°05'W in July and the fishery importance of Div.1B in November is represented in Fig. 1b. The correlation coefficient (r) is 0.851, whereas the range length N = 13, the error of correlation coefficient (E) is 0.051; $\frac{r}{E} = 16.6$, i.e. the relationship is real. The dependence is characterized by the following equation:

$$F_{\underline{XI}} = 40.2\ \Delta t_{\underline{VII}50-100} + 27.5 \qquad (1)$$

where: $\Delta t_{\underline{VII}50-100}$ - temperature anomaly in the 50-100 m layer on the station at 66°37'N, 57°05'W in July.

$F_{\underline{XI}}$ - fishery importance of Div.1B in November.

The relationship shows that if the temperature increases, then the fishery importance of Div.1B will also generally increase. Table 1 illustrates the fitness of the equation (1).

Equation (1) shows that in 84% of cases the error was not greater than 20% of the amplitude of the forecasting index.

B. Water temperature anomalies in the 100-200 m layer in July and cod distribution in Div.1B in November

Water temperature anomalies in the 100-200 m layer on the abovementioned station (66°37'N, 57°05'W) in July and fishery importance of Div.1B in November (Fig. 2) were compared. The relationship between the comparative values (the length of the range N = 13) is expressed in terms of the correlation coefficient r = 0.800; error E = 0.067; $\frac{r}{E}$ = 11.9, the equation is represented as:

$$F_{\underline{XI}} = 26.8\ \Delta t_{\underline{VII}100-200} + 23.7 \quad (2)$$

where: $\Delta t_{\underline{VII}100-200}$ - water temperature anomaly in the 100-200 m layer on the station at 66°37'N, 57°05'W in July

$F_{\underline{XI}}$ - fishery importance of Div.1B in November.

Table 2 illustrates the fitness of equation (2).

Equation (2) shows that in 69% of cases the error was not greater than 20% of the amplitude of the forecasting index.

From Figs. 1 and 2 it might be seen that in separate years some anomalies in general regularity were registered. Especially, a considerable anomaly was observed in 1964,when water temperature in July decreased, the fishery importance of Div.1B in November decreased.

In accordance with the hydrological observations (Svetlov, 1966) water temperature in 1964 on almost the whole of the western coast of Greenland was above the norm. But in July on the station at 66°37'N, 57°05'W it was 0.1-0.3° beneath the average temperature of the 50-100 m, 100-200 m layers. It is supposed that the water temperature reduction could be the result of the cold Canadian Current waters expansion, that in July 1964 came near this station, whereas the heat level of 1964 for the whole Subarea 1 was fairly high (Bratberg, E., 1965; Hansen, P.M. and F. Hermann, 1965; Meyer, A., 1965). Perhaps, therefore, the cod concentrations observed in Div.1B till November caused a sharp increase of the fishery importance of this division.

C. Water temperature anomalies in the 50-100 m layer in July and fishery importance of Div.1B in December

Comparison of the water temperature anomaly in the 50-100 m layer in July on the station at 66°37'N, 57°05'W and fishery importance of Div.1B in December showed a direct relationship. The correlation coefficient r = 0.828; n = 13; E = 0.063 (Fig.3); $\frac{r}{E}$ = 13. The relationship is expressed by the following formula:

$$F_{\underline{XII}} = 32\ \Delta t_{\underline{VII}50-100} + 23 \quad (3)$$

where: $\Delta t_{\underline{VII}50-100}$ - water temperature anomaly in the 50-100 m layer on the station at 66°37'N, 57°05'W in July

$F_{\underline{XII}}$ - fishery importance of Div.1B in December

The values of the fishery importance (Table 3) were calculated for the assessment of the fitness of equation (3).

D. Water temperature of the 0-50 m layer on the Godthaab station in October and fishery importance of Div.1B in June next calendar year

One more type of dependence between water temperature of the 0-50 m layer in October on the Godthaab station and fishery importance of Div.1B in June of the following calendar year is represented in Fig. 4. The correlation coefficient (r) of this relationship is 0.70, (N = 10), E = 0.11, $\frac{r}{E}$ = 6.4, the regression is:

$$F_{\underline{VI}n+1} = 23.3\ t_{\underline{X}0-50} - 43.5 \quad (4)$$

where: $t_{\overline{X}0-50}$ - water temperature of the 0-50 m layer on the Godthaab station in October.

$F_{\overline{VI}n+1}$ - fishery importance of Div.1B in June of the following calendar year (n - year of temperature observations).

The values of fishery importance calculated due to equation (4) are represented in Table 4.

In the calculations of the fishery importance due to equations (3) and (4) in 80% of cases the error was not greater than 20% of the amplitude of forecasting index. The estimate of the fishery importance value due to equations (1-4) was made for those years which are indicated in Tables 1-4.

Asynchronous character of the above considered relationships is a peculiar feature. This fact is of great importance for fishery forecasting. As is known, the fish do not react immediately; besides, their migration from one area to another takes time (Konstantinov, 1967b). The equations of relationships obtained above provide a means of forecasting the fishery importance of Div.1B from 4 to 8 months in advance.

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Table 1. Actual and calculated values of fishery importance of Div.1B, anomalies and errors in percentage from the long-term amplitude ($A = F_{max.} - F_{min.} = 60.7$)

Year	$F_{act.}$	$F_{calc.}$	$E = F_{act.} - F_{calc.}$	$\frac{E}{A}$	$\frac{E}{A}$ %
I954	II,9	I9,5	-7,6	0,I2	I2
I955	I8,0	32,5	-I4,5	0,24	24
I956	I5,2	II,4	+3,8	0,06	6
I957	4,6	8,7	-4,I	0,07	7
I958	2,5	II,4	-8,9	0,I4	I4
I959	3,7	7,4	-3,7	0,06	6
I960	4,6	II,4	-6,8	0,II	II
I96I	28,2	3I,5	-3,3	0,05	5
I962	3I,6	3I,5	+0,I	0,00	0
I963	50,5	47,6	+2,9	0,05	5
I964	63,2	35,5	+27,7	0,46	46
I965	4I,7	43,6	-I,9	0,03	3
I966	53,7	5I,6	+2,9	0,03	3

Table 2. Actual and calculated values of fishery importance of Div.1B, anomalies and errors in percentage from the long-term amplitude ($A = F_{max.} - F_{min.} = 60.7$)

Year	$F_{act.}$	$F_{calc.}$	$E = F_{act.} - F_{calc.}$	$\frac{E}{A}$	$\frac{E}{A}$ %
I954	II,9	I0,3	+I,6	0,03	3
I955	I8,0	I8,3	-0,3	0,00	0
I956	I5,2	I8,3	-3,I	0,05	5
I957	4,6	I5,7	-II,I	0,I8	I8
I958	2,5	I5,7	-I3,2	0,22	22
I959	3,7	I3,0	-9,3	0,I5	I5
I960	4,6	I3,0	-8,4	0,I4	I4
I96I	28,2	I8,0	+9,9	0,I6	I6
I962	3I,6	2I,0	+I0,6	0,I7	I7
I963	50,5	37,I	+I3,4	0,22	22
I964	63,2	34,4	+28,8	0,49	4[illegible]
I965	4I,7	45,I	-3,4	0,06	6
I966	53,7	69,3	-I5,6	0,26	26

Table 3. Actual and calculated values of fishery importance of Div.1B, anomalies and errors in percentage from the long-term amplitude ($A = F_{max.} - F_{min.} = 44.4$)

Year	$F_{act.}$	$F_{calc.}$	$E = F_{act.} - F_{calc.}$	$\frac{E}{A}$	$\frac{E}{A}$ %
I956	2,9	I0,2	-7,3	0,I6	I6
I957	0,6	5,8	-5,2	0,I2	I2
I958	0,4	I0,2	- 9,8	0,22	22
I959	0,I	7,0	-6,9	0,I6	I6
I960	I6,0	I0,2	+5,8	0,I3	I3
I96I	28,7	26,2	+2,5	0,06	6
I962	42,0	26,2	+25,8	0,58	58
I963	4I,I	39,0	+2,I	0,05	5
I964	39,4	35,4	+4,0	0,09	9
I965	I4,5	35,8	-2I,3	0,48	48
I966	44,5	42,2	+2,3	0,05	5

Table 4. Actual and calculated values of fishery importance of Div.1B, anomalies and errors in percentage from the long-term amplitude ($A = F_{max.} - F_{min.} = 46.9$)

Year	$F_{act.}$	$F_{calc.}$	$E = F_{act} - F_{calc}$	$\frac{E}{A}$	$\frac{E}{A}$ %
I954	0,4	2,7	-2,3	0,05	5
I955	I,8	3,I	-I,3	0,03	3
I956	0,5	0,9	-0,4	0,00	0
I957	4,8	8,0	-3,2	0,07	7
I958	I,8	20,I	-I8,3	0,39	39
I959	47,3	23,4	+23,9	0,5I	5I
I960	I2,I	I6,I	-4,0	0,08	8
I96I	I8,8	I7,3	+I,5	0,03	3
I962	I9,8	24,8	-5,0	0,II	II
I963	7,I	5,2	+I,9	0,04	4

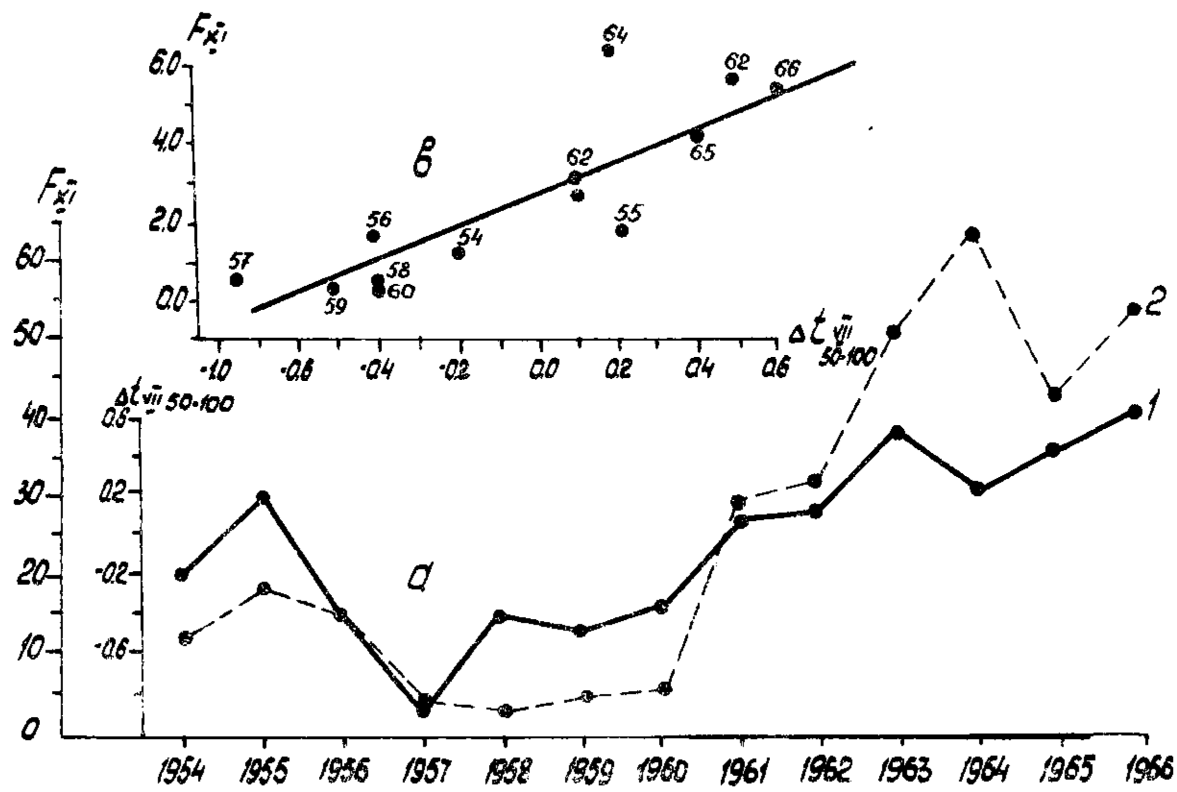

Fig. 1. Comparison between the fishery importance (F) of Div.1B in November and temperature anomaly in the 50-100 m layer on the station at 66°37'N, 57°05'W in July:
a) water temperature anomaly (1) and fishery importance (2),
b) the relationship between them.

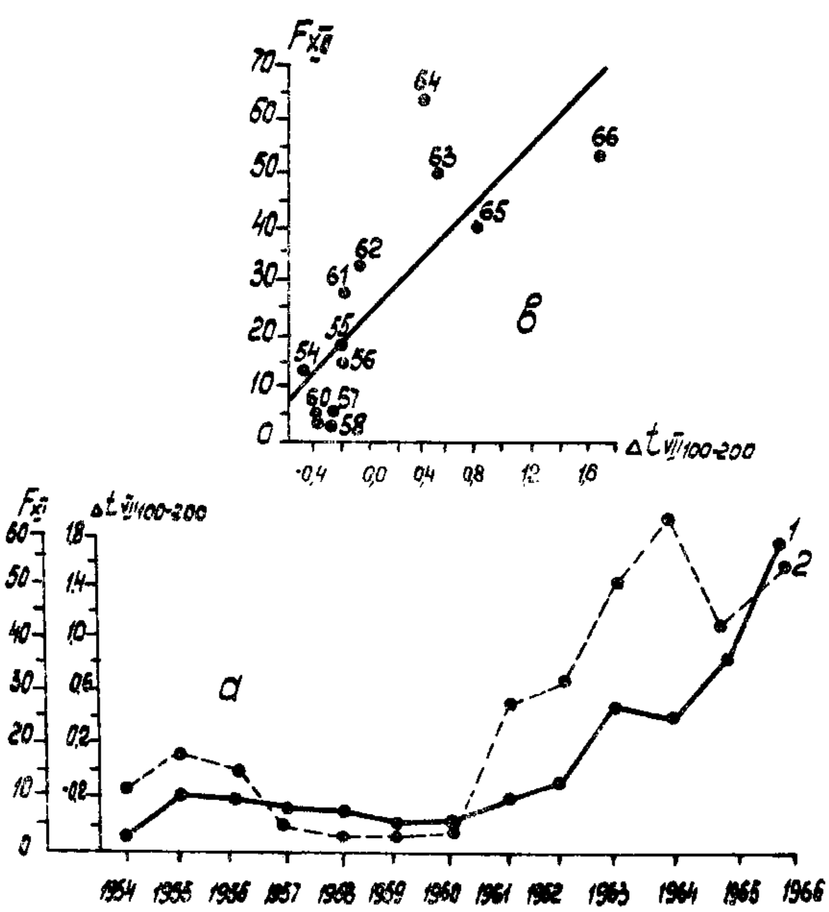

Fig. 2. Comparison between the fishery importance (F) of Div.1B in November and water temperature anomaly in the 100-200 m layer on the station at 66°37'N, 57°05'W in July:
a) water temperature anomaly (1) and fishery importance (2),
b) the relationship between them

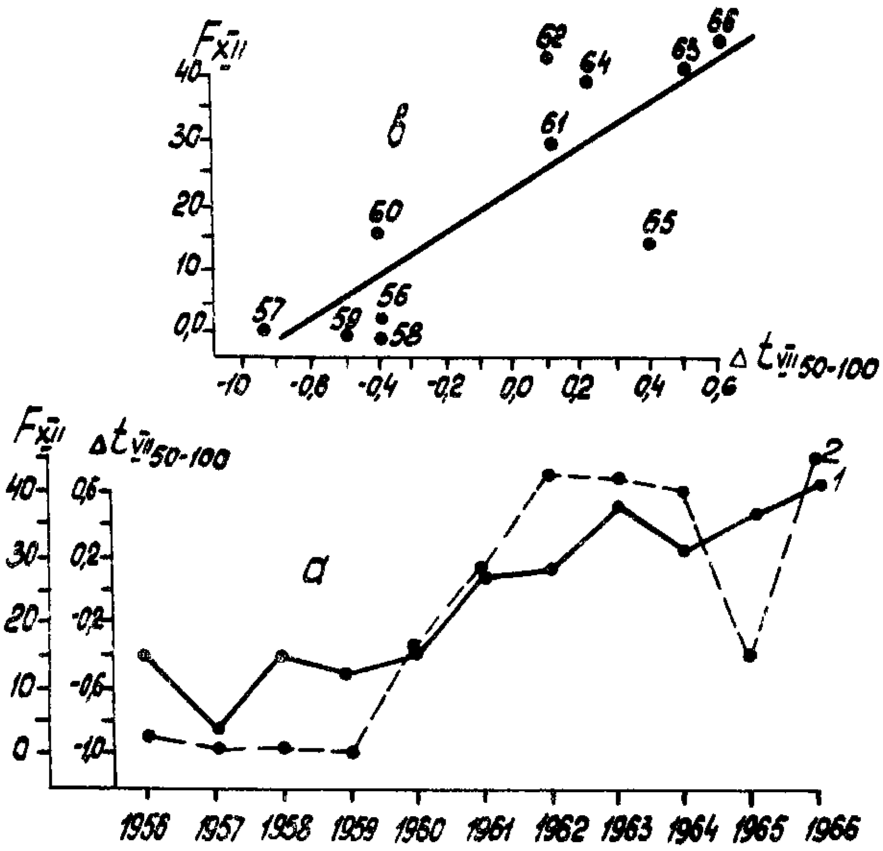

Fig. 3. Comparison between the fishery importance (F) of Div.1B in December and water temperature anomaly in the 50-100 m layer on the station at 66°37'N, 57°05'W in July:

a) water temperature anomaly (1) and fishery importance (2),

b) the relationship between them

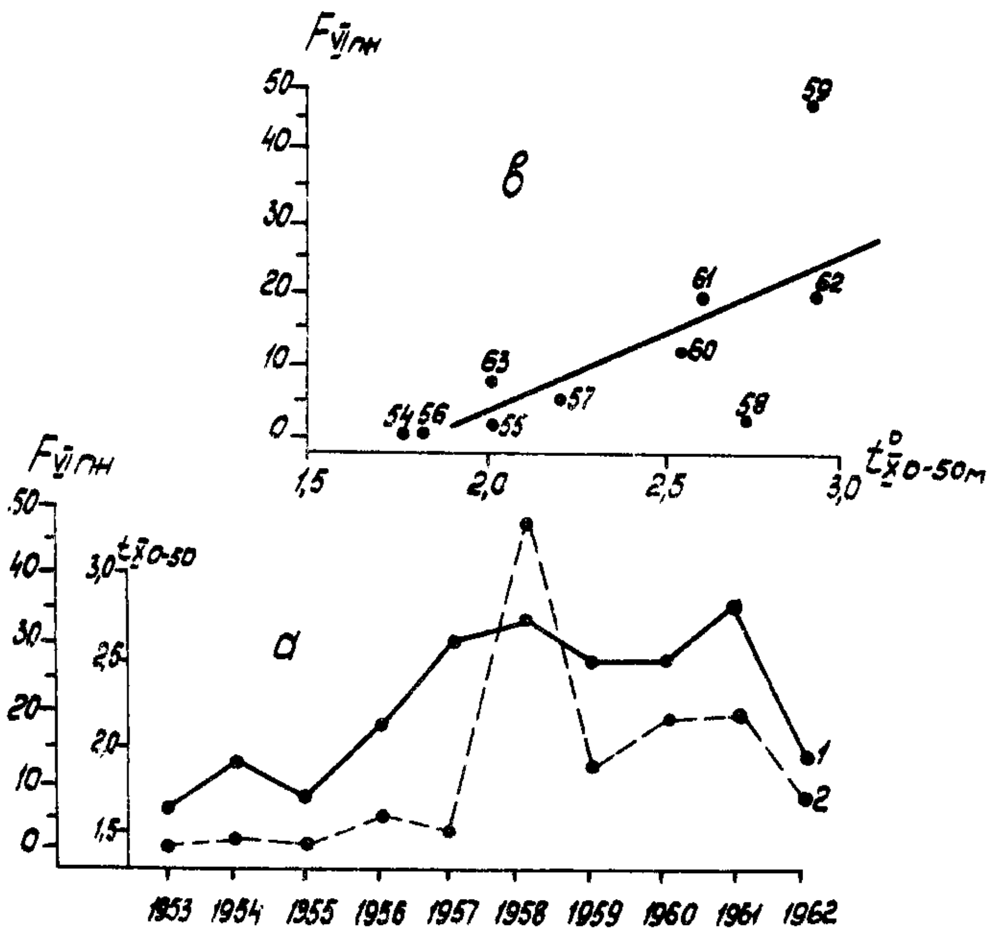

Fig. 4. Comparison between the water temperature of the 0-50 m layer in October and the fishery importance (FVIn+1) of Div.1B in June of the following calendar year (n - year of temperature observations):

a) water temperature (1) and fishery importance (2),

b) the relationship between them