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The Effect of Atmospheric Circulation on the Strength of Cod Year-classes off Labrador

by

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Abstract

Based on analysis of existing notions as to the impact of atmospheric circulation on thermal and dynamic state of the Labrador Current waters the hypothesis is assumed which explains the reasons of changes of the Labrador cod year classes strength. A primitive regression model is drawn up within the framework of the hypothesis, which gives an opportunity to forecast tentatively the recruitment of cod stock 4 - 5 years in advance.

Introduction

At present the problem of dynamics of commercial stock recruitment of fish in the ocean is being studied, but it has been already estimated that the results of replacement of most fish species are determined primarily by environmental conditions within the period of embryos development and larvae going on to active feeding (Dementyeva, 1976; Laevastu and Hela, 1974). Following this statement we made an attempt to find regularity in the change of strength of Labrador cod year classes and to apply this regularity to forecasting the recruitment of the mentioned population.

Materials and methods

While carrying out the investigation the following hydrometeorological and biological data were used:

- data of water temperature, salinity and density at Station 27 (47°33'N, 52°35'W) in the period of 1950-1959 (Huyer and Verney, 1975);

- mean temperature values in the 0 - bottom layer of water at Station 27 in winter months (February, March) 1950 - 1963 (Templeman, 1965);

- monthly values of meridional atmospheric circulation indices, calculated for the part of the parallel of 60°N between the meridians of 50° and 70°W for the period since 1950 (Kondratovich, 1977). These indices which are the version of Kats' indices (1960), characterize the dominating meridional transfer at the sea level and are determined by the formula:

$$I_m = \frac{bmk}{\lambda_2 - \lambda_1},$$

where b is an interval between the isobars (in millibars) in the charts of air pressure at the sea level; m is the number of intersections of the parallel between the meridians λ_2 and λ_1 by the isobars; $k = (\cos\varphi)^{-1}$ is a scale factor to reduce the arc length of the parallel at the latitude φ to the arc length of the equator.

According to the methods of calculations (Kondratovich, 1977), isobar intersections from south to north are considered positive, and those in the reverse direction - negative. So, positive values of the index correspond to the case of predominance of the south transfer constituent, negative values - to the case of prevalence of the north constituent. The intensity of transfer is characterized by the index module.

To estimate the strength of Labrador cod year classes we used the data of Postolaky (1978 b) on cod age composition in the catches taken by Murmansk large refrigerator trawlers in the South Labrador area (Division 2J) during the first six months of a number of years (1961-1975).

This problem was solved by means of constructing and testing the working hypothesis; methods of correlation analysis were applied at the stage of testing.

Analysis, the working hypothesis and results

The changes of abiotic and biotic factors which influence the survival of oceanic fish in the period of early stages of their ontogenesis are formed as a result of various processes among which the interaction between the ocean and the atmosphere is probably the most important one. This process is revealed in the interchange of energy and masses between both media, atmospheric circulation being, as a rule, the regulator in all kinds of interchange(Kraus, 1976; Malkus, 1965; Sukhovey, 1977). In this connection it would be interesting to analyse the effects of variability of air transfer in the Labrador Current area.

The impact of atmospheric processes on thermal and dynamic state of the Northwest Atlantic waters was investigated by Sukhovey (1977). In her opinion, the formation of water temperature anomalies in the Labrador and Newfoundland areas is conditioned by the variability of air transfer along the Labrador Current. The intensification of the north winds accompanied by the increase in advection of the cold dry air from the arctic area is considered to result in growing losses of heat on the sea surface and intensification of cold waters transportation by the Labrador Current, which produced negative anomalies of water temperature in this region. In case of weakening north air flows heat irradiation and discharge of the Current waters will reduce, which will lead to formation of temperature positive anomalies. Sukhovey emphasized that this mechanism is the most typical presumably in winter when processes of interaction are the most intensive.

The mentioned effects are worth being paid attention to from the point of view of the Labrador cod ecology, that is why it is reasonable to prove their existence.

For this purpose we used the data of hydrological obser - vations at Station 27, which are as yet the only reliable regular information of winter hydrological conditions in the

Labrador Current area. Estimation of influence of meridional air transfer on water temperature in winter was conducted with the help of temperature values in the 0 - bottom layer at this station and the indices of meridional air circulation over the region located up-stream. As a result of the analysis it was determined that the connection between water temperature and the intensity of north air transfer really exists, and its character corresponds to the above-mentioned notions. The dependence of water temperature on air flow from the north in the period of seasonal minimum of temperature, i.e. in February-March, proved to be the closest (linear correlation coefficient r = 0.78) on averaging the indices for January - March. The availability of asynchronous connection together with synchronous one is conditioned in this case not only by possible delay in time along with spreading of temperature disturbances of advective origin, but also by the thermal inertia of water masses.

If, according to Sukhovey, changes of air transfer intensity over the Labrador area are accompanied by the variations of heat and moisture flows having the same direction off the sea surface, the increase of salinity may be expected to correspond to the fall of temperature in the upper layer in winter and vice versa. The analysis of data on temperature and salinity of waters in the surface layer at Station 27 for the period of 1950-1959 proves the availability of this connection. For instance, the correlation between the mentioned parameters relating to the middle of February, is characterized by the value of r = -0.72, and for the middle of March - -0.94, respectively. The pronounced difference of closeness of connections probably is not of principal charcter, however, the analysis of more prolonged observations is needed to make final conclusions.

The formation of temperature and salinity anomalies with opposite marks assures the appearance of considerable anomalies of density of the surface layers waters at the end of

winter. Year-to-year distinctions of the intensity of winter convective mixing which are manifested in the changes of maximal depth of the homogeneous layer in the distribution of water density vertically at Station 27 are connected with appearance of these anomalies.

In connection with the fact that winter convective mixing is very important for enrichment of the photic layer with biogeneous substance (Dietrich and Kalle, 1961), year-to-year changes of this process may influence considerably on plankton development, i.e. on formation of nutritive base of fish larvae. From the above-considered scheme of processes follows that prerequisites for the increase of biological productivity in the Labrador Current area are formed in the years the beginning of which is marked with the intensification of the north air transfer.

The temperature negative anomalies in water masses in winter are connected with such a feature in Labrador cod distribution as removal of wintering and, probably, spawning concentrations to the south (Konstantinov, 1968). As a drift of Labrador cod eggs, according to Bulatova's data (1968) and Postolaky's information (1972), occurs southward in the Labrador Current waters, spawning in the areas of the continental slope located further to the south than usually promotes the reduction of larvae drift distance to the areas with favourable temperature conditions. In this case it may be expected that with the part of generation an incubation period which is one of the most crucial stages in formation of fish year classes abundance, will become shorter. Apparently, this effect of winter intensification of air flows from the north will be manifested more prominently, if the dynamic conditions anomaly will be preserved during cod mass spawning. Such a period includes March and April (Postolaky, 1978 a).

With the aim of testing the above listed notions the statistic estimation of connection between the meridional atmospheric circulation and the strength of Labrador cod year classes was performed.

The following indices were assumed:

$\overline{I_M}$ - the mean index of meridional atmospheric circulation relating to the parallel of 60°N between the meridians of 50° and 70°W for January - April;

$\sum_{i=5}^{7} n_i$ - the total of cod specimens at the age of 5, 6 and 7 years, which belong to a certain year class, in mean catches per an hour of trawling of a large refrigerator trawler in the South Labrador area for the first half-year.

The indices of year classes strength were determined for the year classes appeared in 1956 - 1968. For the same period the indices of a winter-spring meridional atmospheric circulation were calculated. The correlation analysis of these data for the mentioned period confirmed the availability of linear connection between the parameters which is estimated by the coefficient $r = -0.68$. This connection being significant under the significance level $p = 0.02$ indicates that intensification of the north air transfer in a winter-spring period favoured the formation of strong year classes. As it was mentioned above, in such a situation negative anomalies of air and water temperature are formed in the Labrador Current area in late winter, and positive anomalies of water salinity and density - in the layer of convective mixing. The increase of the amount of ice and icebergs may be attributed to the additional easily observed features.

The revealed connection is presented by the regression equation of the kind:

$$\sum_{i=5}^{7} n_i = -1180.2\,\overline{I_M} + 262.4$$

which has a standard error $\sigma = \pm 260.4$ spec.

This equation makes it possible to forecast tentatively the strength of the Labrador cod commercial stock 4 - 5 years in advance. The indices of meridional atmospheric circulation for the first 4 months of the current year are the initial information for compiling the forecast.

Actual indices and those of the strength of Labrador cod year classes estimated by the regression equation are given

in Fig.1. Unfortunately, it is as yet impossible to estimate quantitatively the accuracy of calculating the strength of year classes of 1969 and the following years because of the absence of necessary data for 1976 when there was no specialized fishing for cod by Murmansk large refrigerator trawlers. The preliminary information on the strength of Labrador cod year classes obtained during Soviet fish counting trawlings in Divs. 3KL (Konstantinov and Noskov, 1979), proves the correctness of calculations forecasting the appearance of a poor 1970 year class and strong 1973-1974 year classes. The estimated data, testifying to the appearance of a very poor year class in 1976 are confirmed by the unprecedented low abundance of fish at the age of 2+ and 3+ in the catches of assessment surveys carried out in 1978 and 1979 respectively.

On the basis of calculations testifying to the appearance of an abundant 1978 year class the increase of the Labrador cod commercial stock in 1982-1983 should be expected.

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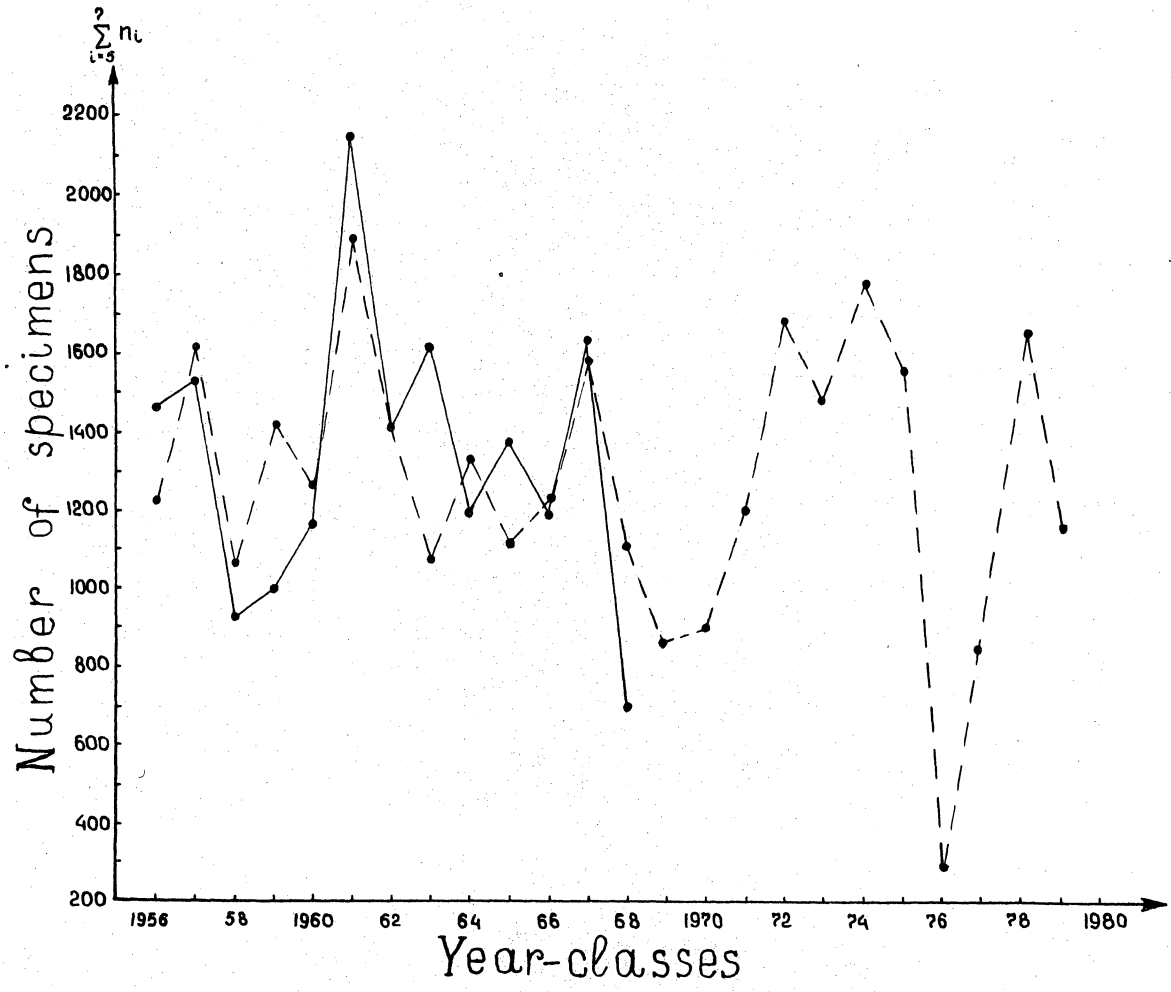

Fig. 1. Actual (solid line) and calculated (broken line) indices of the Labrador cod year classes strength.