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Non-fishery Factors Impact - Possible Explanation of Cod Stock Reduce in NAFO Divisions 2J+3KL

by

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Abstract

In this paper variability of environmental factors and cod age-groups abundance are discussed. Correlation of the above variability is shown. The global pattern of the latter is assumed. Correlation in trends of variations in cod recruitment in Subdivisions 2J3KL and 3NO, water salinity and temperature at station 27, ice conditions along the coast off Labrador and Newfoundland evidence the likely effect of non-fishery factors upon the cod stock decrease in Subdivision 2J3KL. The decrease of cod stock in the latter area is explained by long-term reduce of recruitment, caused by weakening of Gulf Stream advection and cod immigration into the southern areas due to intensification of Labrador waters influx.

Introduction

The Report of NAFO Scientific Council at the Statutory Session (8-22 June, 1994) provided possible explanations of the general cod mortality increase in Subarea 2J3KL. Impact of non-fishery factors represents one of them.

In the work of Myers et al. (1992) the direct relation between recruitment of cod in the Atlantic area off Canada and summer salinity of sea water within the layer of 0-50 m at station 27, located at Newfoundland Island near St.-Johns. It is assumed that hight salinity stratifies water and promote in a surface layer a retention of large amount of nutrients, required to develop plankton - major food of cod at early stages of life cycle. Overall impact of cod spawning biomass, salinity in the year of larvae hatching and in the year of the first age-group surviving define 71% of cod biomass variability. In the paper of Borovkov et al.(1989) the relation between fish distribution and near-bottom water temperature is shown. In particular, fish biomass decrease in Subdivision 2J3KL was observed from 1983 to 1988 caused by low water temperature. The results of the above papers provide a basis for searching reasons of a cod stock decrease and non-fishery factors impact, including environmental ones.

Material and Methods

Materials obtained in trawling surveys from Subarea 3J3KL (Bishop et al., 1993) and 3NO (Baird et al., 1992) and data on 3 years old fish abundance in Subareas 2J3KL (Myers et al., 1992) and 3NO (Davis et al., 1993) are used in the work. Data on sea water salinity in the layer of 0-50 m at Station 27 and ice conditions off Labrador and Newfoundland are obtained from the publication by Myers et al. (1992), and those on water temperature at Station 27 in January - from the publication by Sigaev (1992), To reveal trends and critical points in the above parameters variability, the time series of the latter are transformed into the series of integral-differential values f(x), using the following algorythm:

1. The average value of a time series is defined:

$$\bar{S} = \frac{\sum_{i=1}^{N} y_i}{N}, \quad i = 1, 2, \dots N$$

2. Deviations of each time series value from the average are estimated:

$$\Delta y_i = y_i - \bar{S}, \quad i = 1, 2 \dots N$$

3. Consecutive deviations are summed up to obtain the integral-differential values of $f(x_i)$:

$$f(x_1) = \Delta y_i ; \quad f(x_2) = \Delta y_1 + \Delta y_2 = f(x_1) + \Delta y_2 ;$$

$$f(x_3) = \Delta y_1 + \Delta y_2 + \Delta y_3 = f(x_2) + \Delta y_3 ;$$

$$\dots\dots\dots$$

$$f(x_N) = \Delta y_1 + \Delta y_2 + \dots + \Delta y_n = f(x_{N-1}) + \Delta y_n$$

Results

Abundance of cod estimated in trawling surveys

Figure 1 shows the curves of cod abundance indices on age-groups in Subareas 2J3KL and 3NO. In Subarea 2J3KL trends of the curves reveal comparable natural transfer of abundance values from any age-group to a subsequent one. In Subarea 3NO the natural pattern was disturbed in the second half of 1980s. For example, a divergence between age-groups 3 and 4 is observed in the latter area. While the trend to decrease is observed in the third age-group abundance that of the fourth age-group increases. The increase of abundance values is observed in age-groups 4, 5, 6 and 7 during the same year. The break of sequence in the natural pattern from a younger age-group to an older one in Subdivision 3NO and replenishment of the latter between Subdivisions in the age groups 5-6 and 6-7 may be related to fishery or to fish redistribution. Since no increase of the young age-groups proportion is observed in catches, it may be assumed that the above-mentioned event is caused by cod redistribution and most likely by migration of the latter.

Salinity, water temperature and ice conditions

Figure 2 presents the curves of integral-differential indices of salinity in the layer of 0-50 m and water temperature at Station 27 in January, as well as the indices of ice conditions along the Labrador and north Newfoundland coasts. Water temperature increases in relation to salinity increase. Ice condition is inversely related to salinity and temperature, i.e. ice cover dicreases when water salinity and temperature rises which is a result of ice melting at higher water temperatures.

Salinity and cod stock recruitment

Figure 3 shows the curves of integral-differential indices of salinity in the layer of 0-50 m at Station 27 and those of the third age group abundance of cod. The curve of 3 years old fish abundance is shifted to the left for 3 years as compared to the curve of salinity index to match the temporal scale of salinity by years to a year of cod birth. Comparison of the curves shows a similarity in trends of the latter. More abundant year-classes occure during the period of salinity increase and at the lower salinity the oposite trend is observed.

Discussion

The results of the integral-differential curves comparison are in agreement with the conclusions, presented in the work by Myers et al.,(1992). The water bioproduction variability mechanizm is represented by the following sequence of events. Inflow of warm and salinity water into the Labrador and Newfoundland areas increases ice melting and associated income of nutrients into surface water layer where conditions favourable to phyto- and zooplankton development appear. Subsurface saline water maintains sustained stratification, retains highly productive waters near sea surface and creates a favourable feeding basis for cod and early stages of life cycle. Inflow of cold water decreases subsurface layers productivity and recruitment abundance. It is evidently illustrated in Figure 3. Salinity decrease is correlated to recruitment abundance reduce.

Borovkov et al. (1989) showed that spreading of Labrador cold water results in migration of fish aggregations. Since water of the Labrador current is characterized by low salinity as compared to that of Gulf Stream variability of the latter evidences also variability of the cold water inflow.

Comparison of salinity and the fourth age group abundance curves in Subarea 3NO shows that increase (decrease) of abundance occures during the period of salinity decrease (increase) (Fig.4). In the period of salinity decrease the abundance of older age groups also increases. It seems relate to fish migration from the North to the South from Subarea 2J3KL to Subarea 3NO. This event may be confirmed by the results of Borovkov et al.(1989) presenting the decrease of fish biomass in Subdivision 2J3KL during 1983-1988, caused by low temeperature of near-bottom water.

Therefore, it may be stated that from late 1960s to late 1980s the trend to decrease of cod survival at early stages of life cycle is observed which means a sustained decrease of the stock recruitment. Besides regular strengthening of the Labrador current results in cod migration from Subarea 2J3KL to southward areas. In general the above non-fishery factors played an important role in cod stock reduce in Subarea 2J3KL by early 1980s.

Prospects

As is shown in the previous section, water advection is an initial link in the mechanism defining biological productivity of the Labrador and Newfoundland areas. Warm (cold) water inflow results in increase (decrease) of biological production. Warm water most likely comes with the North Atlantic and Irminger currents. The latter form together with the Labrador one the cyclonic eddy. The complete cycle of water temperature anomalies turnover within the eddy equals to 2 years (Chuvashina et al., 1989). The Gulf Stream is the source of warm water entrance into the eddy while the Gulf Stream outflow is directly related to that of the North Atlantic current (Baryshevskaya, 1982). Rings are the integral feature of Gulf Stream According to Bulatov (1987), rings play an important role in the meridial transport of heat, and their number is related to the Gulf Stream outflow (the higher outflow results in more rings). Therefore, the rings number may evidence the Gulf Stream water transport. Variations of average annual number of warm rings, obtained from the work by Bulatov (1987) and transferred into series of integral-differential values, is in agreement with variability of the diurnal periods duration, i.e. with the Earth rotation velocity (Fig.5).

As is seen from the Figure, decrease of rings number is in agreement with reduce of the Earth rotation while increase of the number is related to acceleration of the latter. The best agreement in trends of the curves is observed when the number of rings shows 1 year delay relative to the diurnal period duration. Since the number of rings defines the Gulf Stream outflow, it may be assumed that in a year after the Earth rotation acceleration start, warm water inflow into the North Atlantic current and further into the cyclonic eddy with complete cycle of the temperature anomalies turnover of 2 years, will increase. Therefore, warm water inflow into the Labrador and Newfoundland areas may be expected in 3 years after the Earth rotation acceleration start. Comparison of salinity and diurnal duration curves at 3 years shift shows a coincidence of the Earth rotation acceleration periods and salinity increase which may support the assumption on the mechanism of Gulf Stream warm water inflow into the Labrador and Newfoundland areas.

Decrease of salinity which defines the Labrador current strengthening, associates to the period of the Earth rotation decrease. To confirm the latter conclusion, the data on radioisotope ^{14}C (the tracer of Labrador water) accumulation in the mollusc (Arctica islandica) at Georges Bank are utilized (Weidman and Jones, 1993). Curve of ^{14}C accumulation is in good agreement to the curve of diurnal duration (Fig. 6), i.e. during the period of the Earth rotation decrease the Labrador water outflow is increased.

Relations, revealed between hydrophysical, biological features and the Earth rotation velocity define the global pattern of varaiability in hydrosphere and aquatic ecosystems.

The results of this study and of earlier one (Vyalov, 1993) allow to assume that a long-term fish production of the ocean ecosystems is controlled by the entire ocean circulation while variability of the latter is in agreement to the Earth rotation velocity. In accordance with the above hypothesis, it may be noted that the start of the Earth rotation acceleration in late 1970 approaching its peak in middle 1980s, seems to be an indicator of increasing warm water inflow into NAFO Subareas and occurence of favourable conditions to cod survival at early stage of life cycle. The assumption is confirmed by increase of the first age-group abundance from 1988 to 1990 (according to the trawling surveys results). Since the Earth rotation velocity has been decreasing from 1989, taking in account 3-years shift, the conditions favourable to cod survival at early stages of life-cycle should retain till 1993. Decrease of one-year old cod abündance according to the trawling surveys results after 1990 may be explained by occurence of young fish outside the study area (Report SCS, 1994). If it is true, the cod spawning stock shoul be recruited until 2000. After 1993, as the data on the Earth rotation velocity evidence, the condition will be unfavourable to recruitment of the spawning stock which may result in another decrease of the cod stocks after 2000.

Conclusion

Decrease of the cod stock in Subarea 2J3KL is explained by a long decrease of recruitment stipulated by the warm Gulf Stream water advection reduce. Besides, the process is likely to be affected by cod migration into southern areas which is caused by the cold Labrador water inflow.

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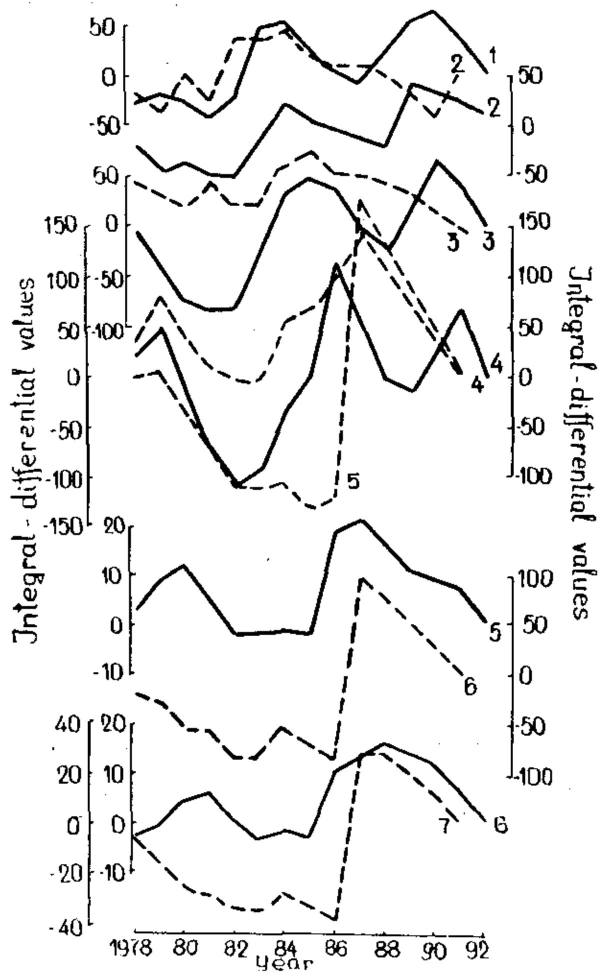

Fig. 1. Integral-differential curves of cod age-groups abundance in Subdivisions 2J3KL (bold line) and 3NO (dotted line).

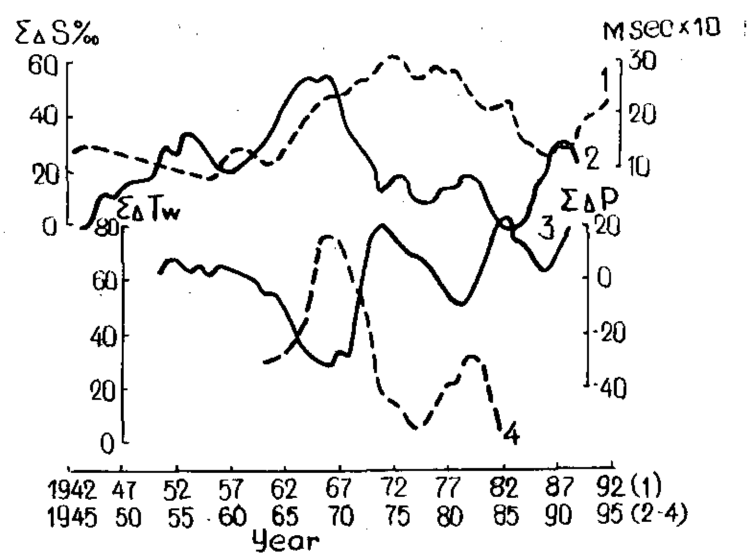

Fig. 2. Curve of the Earth diurnal period (1), integral-differential curves of sea water salinity within 0-50 m layer at the station 27 (2), sea ice area along the coastline of Labrador and Newfoundland (3), water temperature at the station 27 in January (4).

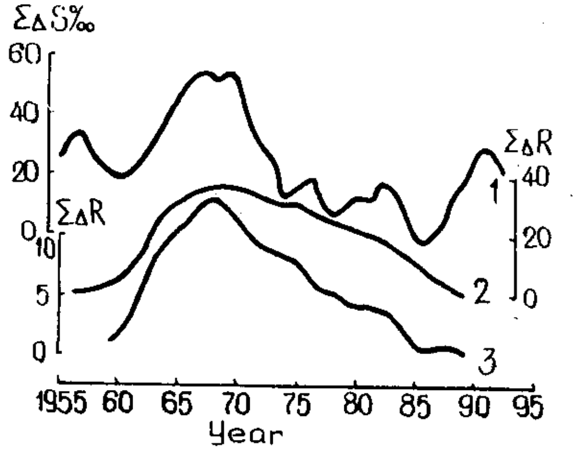

Fig. 3. Integral-differential curves of sea water salinity within 0-50 m layer at the station 27 (1), abundance of the third age-group cod in Subdivisions 3NO (2) and 2J3KL (3).

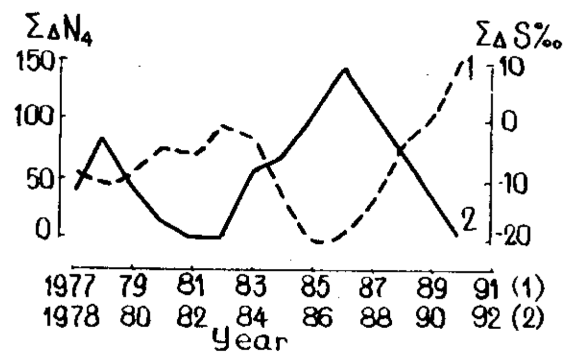

Fig. 4. Integral-differential curves of sea water salinity within 0-50 m layer at the station 27 (1), abundance of fourth age-group cod in Subdivision 3NO.

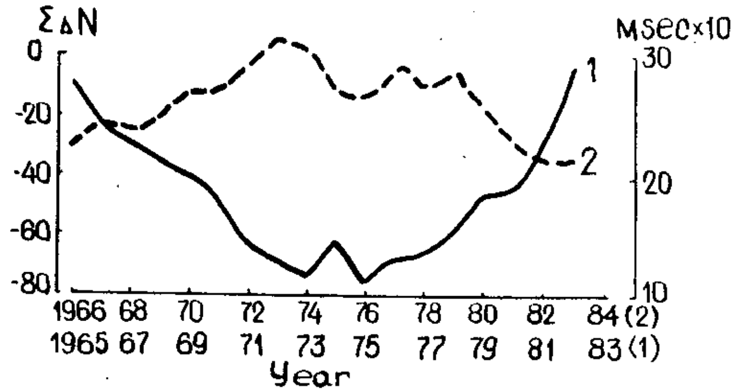

Fig. 5. Integral-differential curve of the Gulf Stream warm rings number (1), curve of LOD the Earth diurnal period (2).

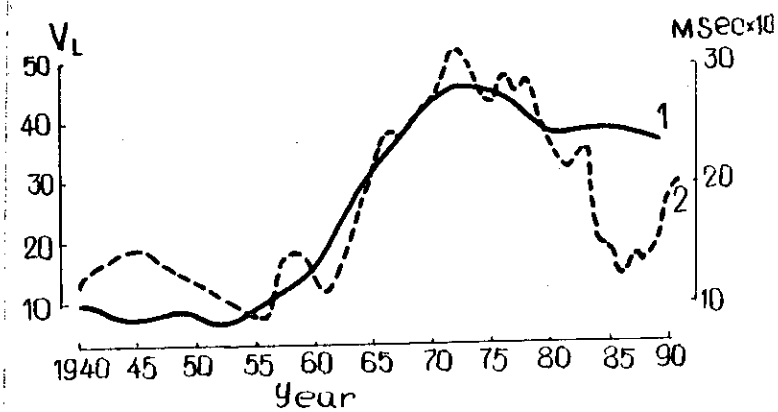

Fig. 6. Curve of the Labrador water tracer at Georges bank (1), curve of LOD (2). (Stephenson and Morrison, 1984, recent data by Sidorenkov N.S. from Roshydrometcenter).