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Year-to-Year Variability of Water Temperatures on the Scotian Shelf in Summer 1978-1981 and Fall 1977-1984

by

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Abstract

BT measurements of the water temperatures made during the USSR-Canada summer and fall surveys to study spawning efficiency and determine the Scotian young silver hake abundance were used to analyse year to year variability of the water temperatures by depth in summer 1978-1981 and fall 1977-1984.

The methods were based on square by square data processing with computation of anomalous temperatures for each square and further averaging for surveyed area and for separate peculiar shelf parts. Longterm mean temperatures for selected depths over the 1962-1972 period were used as a norm.

As a result, tendences of summer and fall temperatures against the norm are estimated, differences in patterns of their year to year variability, and comparison of these variations with some biological features are given.

Introduction

During the past eight years the Atlantic Scientific Research Institute of Marine Fisheries and Oceanography (AtlantNIRO, USSR) and Bedford Institute of Oceanography (BIO, Canada) conducted a cooperative complex research of fluctuations of the Scotian silver hake abundance. From 1978 to 1981, the studies involved estimation of silver hake abundance at different developmental stages from eggs to young fish and determination of zooplanktonic food and water temperatures. In 1977, and over the 1982 to 1984 period cooperative research was limited to estimating the young fish abundance and studies on zooplankton and water temperatures. The main objective was assessment of a recruiting year class.

The data from ecological surveys conducted during the summer-fall period involved the water temperature measurements, zoo- and ichthyoplankton sampling and estimates of the young silver hake abundance.

The present paper deals with the analysis of variability of the water temperatures on the Scotian shelf as one of the factors of abiotic conditions controlling the silver hake growth. The main task is to display these variations over the 1977-1984 period and to draw a parallel between these and the abundance of plankton, eggs, larvae and young silver hake.

Materials and methods

During the surveys which entirely or partly covered the Scotian Shelf area between the Laurentian and North-Eastern channels, BT measurements were made. The surveys which provided the data for the present paper are listed in Table 1.

In order to reveal year to year fluctuations of the temperatures above the shelf "by square" processing of observations was made. For this purpose a grid of 30'x 20' "squares" (118 "squares" in all) was plotted, with heavy line outlining a number of "squares" on the Sable Island shoal, where massive spawning of silver hake takes place, and a feeding area along the continental slope (fig. 1).

This observation area was divided into two parts representing a summer and fall seasons. Observations made before 15 September were regarded as summer data, and those made onwards showed the fall pattern. Temperature measurements were averaged by square for each season and year for the depths of 0, 50, 75 m and near the bottom. Depth horizons were selected with regard for vertical structure of the water, where the 0 m level corresponds to conditions peculiar to the upper layer of the shelf water of local origin, the 50 m level corresponds to the lower boundary of seasonal thermocline, the 75 m level can be taken as the nucleus of a cold intermediate layer of the Labrador water, and the near-bottom temperatures (mostly 100 m and more) characterize the massive of the warm bottom slope water. Besides, such a stratification was required to make comparison between monthly means calculated earlier for the same depth levels for the 1962-1972 period by Karaulovsky and Sigaev (1976).

The final stage of data processing involved calculation of temperature anomalies for each "square". Table 2 gives the number of "squares" surveyed by year and season. Anomalies were calculated based on the above-mentioned monthly means and then averaged for the area surveyed during the season and for separate locations. Based on the results, diagrams of year to year pattern of temperature anomalies by season and depth for three groups of "squares" were plotted (fig. 2).

Results

The pattern of anomalies shown in fig. 2 reflects marked year to year variability reaching 4° and more both in summer and in the fall. The analysis of the summer and fall anomalies displays some peculiarities of their year to year variability.

A distinct difference can be noted between the anomalies patterns at the surface and at lower depths during the summer season. The drop of surface temperature in summer over the 1978-1981 period was accompanied by a steady increase of the temperature at 50, 75 m and near the bottom. These opposite tendencies were typical of the entire area covered during the summer surveys (fig. 2-1), and of the spawning ground and continental slope (fig. 2-3,5), which indicates that they are real.

As is evident from summer diagrams, the highest recorded surface temperatures were in 1978, and the lowest in 1984. At the other depths the lowest values were observed in 1978, and the highest in 1981.

The fall temperature anomalies for the same period considerably differ from the summer ones both in pattern and extent. Unlike in summer, the fall anomalies of the surface temperatures do not exhibit a certain tendency; quite the contrary, they markedly change from year to year. This variability could be observed throughout the area surveyed in the fall (fig. 2-2), and in both additional locations (fig. 2-4,6) which, as in the case of summer anomalies, is indicative of its stability and reality. From 1978 to 1980-81 temperature anomalies at lower depths demonstrate a tendency to increase similar to that observed in summer. Anomalies at 75 m depth were the closest to the summer pattern. Another difference between the fall and summer anomalies is that over the 1978 to 1981 period the values of the fall anomalies had been mostly positive and largerly exceeded the summer values.

The plots of the fall anomalies over the entire 1977 to 1984 reference period give an apparent differences between the variations at the surface and at lower depths. Unlike the surface, where the anomalies changed from year to year, fluctuations of the temperatures at lower depths were characterized by a definite cyclic pattern reiterating every 2-3 years. At least the plots show a wave of temperatures with a lowering corresponding to 1977-78 and 1982-83, and the peak which corresponds to 1980-81. Thus, temperatures tended to increase at 50 m, 75 m and near the bottom from 1977-78 through 1980-81. Then, the drop of temperatures persisting till 1982-83 was again replaced by a trend of decreasing temperatures. This temperature wave is represented in all the three groups of the fall diagrams. Years, when extremes of temperatures occurred, are given in table 3.

Discussion

Comparison of estimates of temperature changes at different depths of the water column above the Scotian Shelf and results of other studies pertinent to year to year fluctuations of oceanographic values in the Northwest Atlantic in the reference period would have been useful. However completely comparable published data have not been available yet. Information contained in reviews refers to separate years by month and represents longterm annual data. Firstly, most papers deal with the surface temperatures and rarely with the temperatures of subsurface layers. Secondly, in our case, the temperature anomalies for the previous decade (1962-1972) have been considered, therefore, the comparison can result just in quantitative assessment of trends. From the overview by Trites and Drinkwater (1984) it can be concluded that the sea surface temperature (SST) anomalies in the fall 1982 at coastal stations of Nova Scotia were higher than in 1983, which is consistent with our data. According to McLain and Ingham (1983), temperature anomalies in six one-degree squares on the Scotian Shelf slope were negative in February through August and in November 1982.

Comparing the water temperatures at station 27, St. John's, Newfoundland, for 1981-83 in overviews by Trites and Drinkwater (1983, 1984) one can see that in the fall of 1982 the temperatures were lower throughout the water column than in 1981 and 1983. This fact is confirmed by the temperature distribution data at the standard transect 8-A for November 1982, where all layers showed a negative anomaly (Burmakin, 1984). Cooling of the water in the Great Newfoundland Bank area in 1982 might have influenced the temperature of surface layers of the Scotian Shelf waters.

Year to year temperature changes observed in the water column in summer and in the fall were compared with the temporal variation of some biological indices, namely, the Zooplankton biomass estimate in summer, eggs number and abundance of larval and young silver hake (Noskov et al., 1982; Noskov and Sherstjukov, 1984). A qualitative correlation only existed between the total zooplancton biomass abundance and surface temperature in summer periods of 1978-81 (fig. 2-2). During this period the water temperature (fig. 2-1) and biomass abundence (1533, 1023, 1033 and 917 sp/m^3 respectively) tended to decrease. Another example may be a correlation between fluctuations of 0-group haddock abundance in Division 4x (Scott, 1984) and the fall temperatures at the sea surface from 1979 through 1983 (fig. 2-2), according to which the years of increase and decrease of haddock abundance and temperatures coincide. There exists a close agreement between the changes of 0-group haddock abundance of Sable Island (Scott,

1984) and longterm temperature variation at 75 m (fig. 2-4) and 50 m (fig. 2-6) depths. The observed correlations should not be regerded as persistent dependencies, but a check-up would have been desirable in the following years.

To summarize the above-stated it can be concluded that through the reference period the longterm summer temperatures at the sea surface and at lower depths were in opposite phase. Longterm variation of surface temperatures in the fall is characterized by a marked year to year variability, and the temperature pattern for the lower depths represents a wave between 1977-78 and 1982-83 with the peak in 1980-81. Unfortunately, the summer surveys, which had been the source of the water temperature data, were ceased in 1981. Thus an opportunity has been lost to assess temperature conditions in the oncoming years during the periods of summer zooplankton growth, spawning of commercial fish species and the other biological processess, and to compare these with the fall conditions.

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Table 1 List of surveys and number of stations with water temperature measurements.

No.	Year	Survey data	No. of stations	Survey pattern
1	1977	20.IX-20.X	162	Ecological
2	-"-	03-14.XI	96	Daily stations
3	1978	06-25.VIII	147	Ecological
4	-"-	29.VIII-15.IX	149	-"-
5	-"-	24.IX-17.IX	100	Inventory survey of fry
6	1979	04-19.VIII	126	Ecological
7	-"-	24.VIII-10.IX	125	-"-
8	-"-	14-30.IX	98	Inventory survey of the groundfish
9	-"-	4-27.X	100	Inventory survey of fry
10	1980	15-31.VIII	130	Ecological
11	-"-	4-22.IX	126	-"-
12	-"-	28.IX-18.X	100	Inventory survey of fry
13	1981	24.VIII-12.IX	79	Ecological
14	-"-	22.IX-9.IX	99	-"-
15	-"-	19.X-6.XI	98	Inventory survey of fry
16	1982	23.IX-14.XI	62	-"-
17	1983	28.X-23.XI	64	-"-
18	1984	18.X-25.XI	136	Inventory survey of fry

Table 2 Number of squares and observations by year, season and depth

Year	Summer				Fall			
	0 m	50 m	75 m	Bottom	0 m	50 m	75 m	Bottom
1977	-	-	-	-	83	83	75	83
1978	78	78	78	78	50	50	50	50
1979	89	87	81	89	53	53	53	53
1980	82	78	70	82	40	40	40	40
1981	71	70	64	71	39	39	39	39
1982	-	-	-	-	63	62	56	63
1983	-	-	-	-	33	33	32	33
1984	-	-	-	-	70	67	61	70

Table 3 Years of extreme water temperatures in 1977-1984 on Scotian shelf in summer and fall

Depth (m)	Summer		Fall	
	min	max	min	max
		Survey area		
0	1981	1978	1984	1980,1982
50	1978	1981	1977,1982	1979
75	1978	1981	1978,1982	1981
Bottom	1978	1981	1978,1982	1980
		Spawning ground		
0	1981	1978	1984	1982
50	1978	1981	1978,1982	1980
75	1978	1981	1977,1983	1981
Bottom	1978	1981	1978,1982	1980
		Part of slope		
0	1981	1978	1983,1984	1982
50	1978	1981	1977,1983	1984
75	1978	1981	1977,1982	1980
Bottom	1978	1981	1978,1982	1980

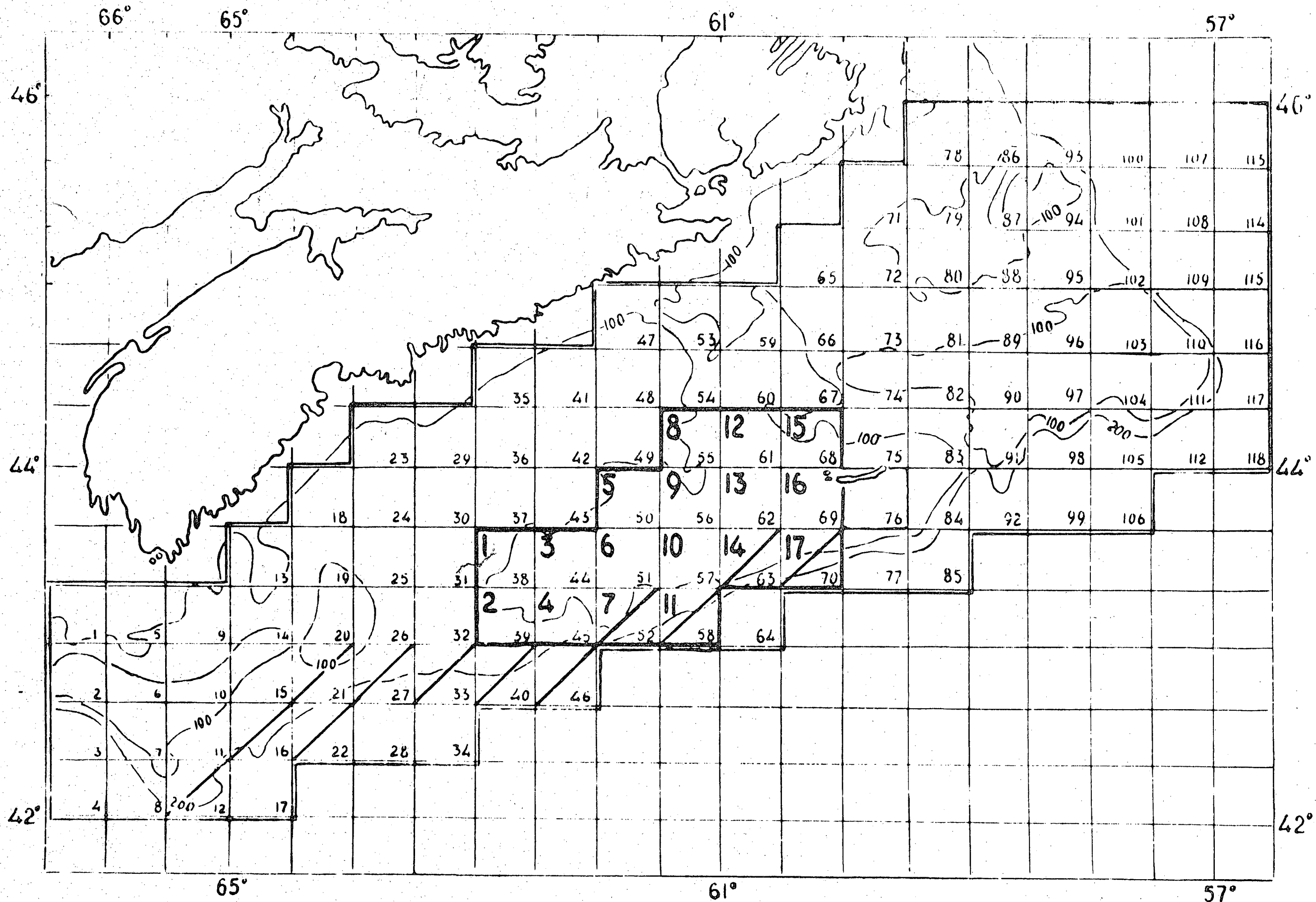

Fig. 1. A grid of squares for processing water temperature data from Scotian Shelf area (heavy line outlines silver hake spawning ground; oblique lines denote squares on shelf slope).

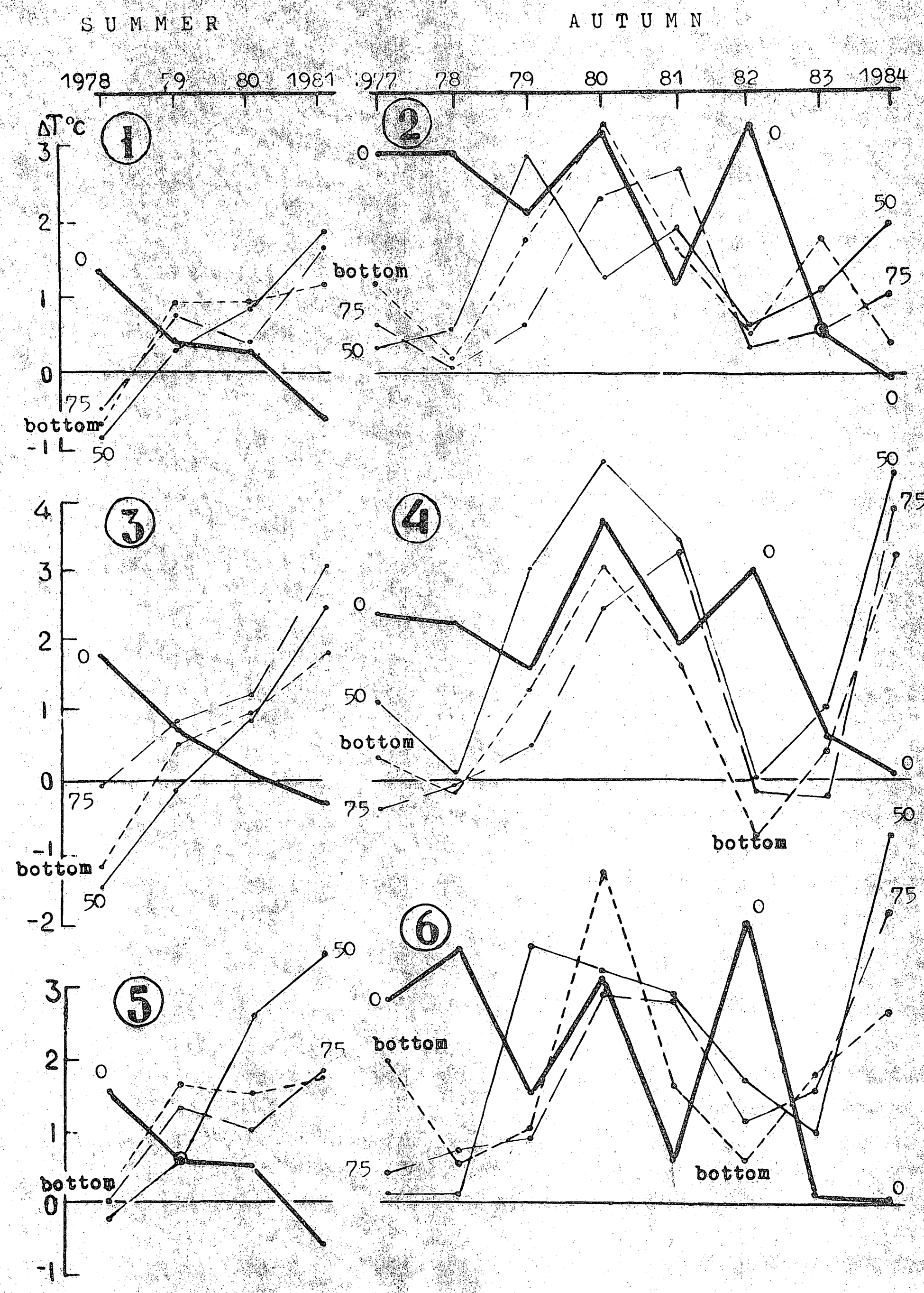

Fig.2. Summer and fall temperature anomalies at the surface, 50 m, 75 m and near the bottom calculated against the norm for 1962-1972. 1,2 - slope area; 3,4 - silver hake spawning ground; 5,6 - part of slope.