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On the year-to-year variations in water temperature in
the shelf area of Georges Bank and Nova Scotia in 1962 - 1968

by

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Summary

Results from data collected by AtlantNIRO research and scouting vessels give the variations of water temperature in the shelf area of Georges Bank and the Scotian Shelf in 1962-1968. The increase or decrease of advection of warm Gulf Stream waters and of cool waters of Labrador origin onto the shelf plays the leading role in the formation of these variations. Seasonal variability of average temperature for the 100 m bottom layer, the minimum temperature of the intermediate cold layer, the depth of the 5°C isotherm as well as the average temperature of the off-bottom layer in the individual locations of the area of Georges Bank and Nova Scotian Shelf were taken as the indices of thermic background. From the investigations it is concluded that, of the period between 1962 and 1968, the relatively cold years are 1964, 1965, 1966 and the relatively warm ones are 1962, 1963, 1967 and 1968.

Introduction

It is well known that the waters of the Northwestern Atlantic Shelf continue to be one of the most important areas for Soviet and foreign fisheries. Simultaneously with the beginning of fishing in 1962 on Georges Bank and the Scotian Shelf AtlantNIRO has carried out investigations of the environment for fisheries. One of the significant characters of the environment is the water temperature, its year-to-year and seasonal variability. Since the 1950's a cooling trend has been observed in the area of Georges Bank, the Gulf of Maine and the Scotian Shelf (Lauzier, 1965a, 1967; Welch, 1967; Chase, 1967; Colton, 1967, 1968). However, this process has proceeded rather irregularly from year to year. Against a background of the cooling, both relatively warm and relatively cold years have been observed. This investigation deals with the variations in water temperature in the period between 1962 and 1968.

Material and Methods

Material for the investigation consisted of the data from seasonal standard bathymetric surveys of the area which were made once a season annually and of the data from the bathythermographic stations made by ANIPPR vessels during the year when scouting for concentrations of commercial fishes. The available data on water temperatures allowed us to establish the locations in the area of shelf waters where observations might represent the temperature for the whole area. On the Scotian Shelf such locations are the Scotian Channel, Sambro Deep, Hally Passage and Cabot Strait. In the area of Georges Bank they are East Channel and Georges Basin Deep. In these locations, we may fix the advection of the warm Gulf Stream waters, the increase or decrease of which affects, first, the temperature of the off-bottom layer and, second, the temperature of the top intermediate water layer of Labrador origin (Briantsev, 1963). The degree of interaction of these two water masses play a significant role in determining temperatures which distinguish one year from another. The variability of the minimum temperature of the cold intermediate layer in the East Channel and Sambro Deep, the depth of the 5°C isotherm in the Sambro Deep (Fig.1) and the average off-bottom temperature of individual locations on Georges Bank and the Scotian Shelf (Fig. 2,3) were taken as indices of annual temperature conditions.

The off-bottom temperature for each location given in Fig. 2 and 3 was the average for a square of 30' longitude by 20' latitude. Due to the lack of observational data, one or two neighbouring squares were added to some selected squares provided that the depth of the whole area was not changed significantly. In addition the temperature data for standard sections and surveys were used to compare similar seasons.

Results of observations

The results of observations on the Scotian Shelf show that, during the 1962-1966 period the highest temperatures were recorded in 1962-1963. After 1963 temperatures decreased in the whole layer in all seasons as compared with the two previous years. The cooling tendency was established as early as the end of 1963. In the winter of 1964 the off-bottom temperature was the lowest (3.5°C) during the 1962-1965 period. In other seasons of 1964, although the temperature had increased by several tenths of a degree it was still the lowest.

Table I shows the variability of the mean temperature of the 100 m bottom layer for Sambro Deep (Halifax Section). The index was lower in all seasons of 1964 than in the two previous years.

Table I

Mean Temperature (C°) of 100 m-bottom layer
Sambro Deep, Halifax Section

Seasons \ Years	Years							
	1961	1962	1963	1964	1965	1966	1967	1968
Winter	4.5	5.5	6.0	3.5	5.5	3.2	5.1	6.3
Spring	4.5	5.5	5.6	4.0	4.0	3.5	4.8	8.1
Summer	4.5	6.0	5.7	4.0	4.0	3.6	6.3	7.7
Autumn	5.0	5.5	5.5	4.8	4.5	4.5	6.5	8.1
Mean	4.6	5.6	5.9	4.0	4.5	3.7	5.7	7.6

The variability of the average depth of the 5°C isotherm for Sambro Deep also shows that the volume of the warm bottom water-mass was significantly less in almost all the seasons than in corresponding seasons of previous years (Fig.1b). According to other data (Lauzier, 1965b), the superficial temperature at the coastal stations (ICNAF Div. 4X, 4V, 4W) in 1964 was the lowest since 1948. Temperature increased slowly till spring 1965. Since then it has decreased almost to the 1964 level, that is, 1965 was nearly as cold as 1964. The development during 1961-1968 is well illustrated by the variation in depth of the 5°C isotherm and by the variation of minimum temperature in the cold intermediate layer. In 1965 the volume of warm water increased somewhat, however, it was closer to that for 1964 than that for 1962 and 1963. Fluctuations of the minimum temperatures in the cold intermediate layer correspond to the variations in average depth of the 5°C isotherm.

In 1963 the minimum temperature of the intermediate layer was 3°, and in 1964-1965 it decreased to 0.5°. Cooling was observed also in the area of Georges Bank after 1963. On the Scotian Shelf, cooling appeared with the increased advection of cold Labrador waters which had spread along the north-eastern, eastern and south-eastern slopes of the bank. Thus, in the East Channel, the minimum temperature was an average of 2°C lower in 1964 than in 1963.

The results of surveys made at the end of spring of 1963 and 1964 over the southeastern slopes of Georges Bank showed that off-bottom water temperature decreased by 3°-5°C in 1964. In summer of 1965 the minimum temperature of intermediate layer was 1° lower than in 1964 in the area of northern slopes. In the locations adjacent to the northwestern slopes of the bank, cold water of the intermediate layer spread to the bottom in summer of 1965. It was greater in volume and lower in temperature by 1°C from that of the summer of 1964. During the summer the off-bottom water temperature of the southeastern slopes was 5°-8°, that is, it was the same as in 1964, and on the southern locations it was 1°C lower.

Temperature observations in 1966 showed that the process of cooling continued. In winter and spring of 1966 this index was considerably lower than that for the same periods of 1965. According to the results of hydrographic surveys in the area of the Scotian Shelf made on 6-10 and 22-25 February as well as on 3-6 and 7-10 March of 1966, the off-bottom temperature of the Scotian Gulf was 1.3° lower than in 1965. The data from the Halifax Section which was occupied 5 times during the winter and spring showed that the off-bottom temperature did not reach 5°C during this interval, although this value was observed annually for 5 previous years. According to the data on other sections made on the Scotian Shelf, the off-bottom temperature was also lower than 5°C. In the winter the difference in the average value of the off-bottom temperature of Sambro Deep was 2.3°, in spring it was 0.5°, in summer it was 3°, and in autumn the index was the same for both years.

The temperature difference in the area of Georges Bank in 1966 as compared with 1965 consisted of a shift in the time of the spring warming and of a warm water advection weakening into the slope locations. In addition, in summer of 1966 a cold intermediate layer was observed in all sections crossing the bank and US Shelf to the vicinity of Long Island at 30-75 m in the south and between 45 and 180 m in the north. The temperature of this layer did not change significantly in a westward direction and was 2° to 2.5° lower than the level of 1965. Thus, 1966 was colder by the thermic background than 1965 and colder than 1964 by some indices.

The 1967 winter observations in the area of Georges Bank showed that the temperature was much higher than in 1966. On the section along the East Channel (Fig. 4), the temperature in water column was 1° higher and on the section along 70°W, it was 4°-6° higher. Temperature conditions in the water masses of the central and eastern parts of the banks were similar to those for 1965.

On the Scotian Shelf, cooling was weaker in 1967 than in 1966, and the temperature of surface layer was 2°-2.5° higher than in 1965-1966. Such an increase was mainly due to the intensive inflow of Gulf Stream water into the East Channel, the Scotian Gulf and Cabot Strait. In the Halifax section, the off-bottom temperature in Sambro Deep was 1°C higher, and the temperature of the whole layer was on the average 3°-5°C higher. In Cabot Strait, the surface and bottom temperatures were 2°C higher. The shallow parts of Georges Bank area and particularly those of the Scotian Shelf cooled to a lesser extent in the first half of 1967 than in 1965, and parts with depths of 100-200 m in the whole area were constantly affected by the advection of warm Gulf Stream water, the temperature of which was 14°C in the west and 6°C in the east. In the spring of 1967 the advection zone expanded and reached the sectors with depths of 50-70 m in May. The period of spring temperatures was, on the whole, close to the 1965 level with the exception of April which was similar to the cold April of 1966.

In the summer of 1967, warming was noted not only in the bottom waters of the Scotian Shelf, but also in the surface water mass. The surface waters of a considerable part of the Shelf, with the exception of the shallow areas of Browns, Roseway and La Have and Sable Island Banks, had temperatures 2°-3° higher than in 1966. Observations in Halifax section showed a temperature increase of 1° in the nucleus of Labrador waters and of 2°-3° in the off-bottom layer.

In the section through Cabot Strait joining St. Pierre and Banquereau Banks, the August surface temperature was 5° higher than in 1965, and the subsurface temperature due to the advection of Gulf Stream waters had temperatures of 6.1°-7.5° in the nucleus (Fig. 9).

In the area of Georges Bank, in contrast to the summer of 1966, there was a stronger inflow of Gulf Stream water into the deep part of the Gulf of Maine through the East Channel where the nucleus of the cold intermediate layer either was not observed in the normal temperature range or it was noted to be in a rather converted form.

In the autumn of 1967 (November) intermediate and especially off-bottom temperatures of deep waters continued the same as in August and in some cases it was even higher than in August. Apparently, the inflow of Gulf Stream water in the August-November period did not weaken and it continued to be at least at the same level as in August. Therefore, the warming in the Georges Bank and the Scotian Shelf areas in 1967 which was the most striking in the first half of the year, spread over the whole zone with the exception of a narrow coastal belt inside 50 m isobath and of the shallow parts of the Scotian banks.

In 1968 the advection of Gulf Stream waters onto the shelf increased. Compared to the 1967 conditions, temperatures of the 100 m - bottom layer were 0.5°-1.0°C higher in the East Channel, 0.5° higher in the Scotian Channel, 2°-3° higher in Cabot Strait (Figs. 4, 6, 8). The minimum temperature of the cold intermediate layer (Halifax section) was also higher than in 1966 and 1967. In the spring the lowest value over the period 1962-1968 was 0.9°C in 1966, 1.8°C in 1967 and 3.1°C in 1968. In Sambro Deep the volume of warm water as shown by the depth of the 5°C isotherm was maximum in spring of 1968 over the period 1961-1968. During the spring the areas of shelf with the depth up to 75 m continued to be influenced by the warm water advection as a result of which the maximum temperature of bottom waters reached 8.5°C in Sambro Deep, 9.9°C in the East Channel, 8.9°C in Cabot Strait, 5.7°C in the deepwater part of Gulf of Maine. Data from summer-autumn surveys (two in July, one in August and one in October) showed that during the summer and autumn the Gulf Stream waters went out by a wide front into the southern slopes of the shelf extending to the shallows with depths of 60-70 m. Their inflow through the East Channel increased in October and spread not only into the deeps to the north of Georges Bank, but also went out of their limits. Figures 5, 7 and 9 present the summer-autumn conditions in the section through the East Channel, in the Halifax section and in the section along Cabot Strait. They show the advection of waters into the deep-water parts of the shelf. Thus, the analysis of seasonal temperature data shows a powerful and long advection of Gulf Stream water onto the area of Georges Bank and the Scotian Shelf that mainly provided higher temperatures in the water masses in 1968 than in 1966 and 1967.

Thus the period 1962-1968 has the following temperature characteristics:

1962 and 1963 - relatively warm years;
1964, 1965, 1966 - relatively cold years;
1967 and 1968 - relatively warm years.

Over the above-mentioned period the warmest years were 1963 and 1968, and the coldest were 1964 and 1966.

Discussion

The temperature history of the waters of the area investigated is undoubtedly very important and its variations one way or the other may influence directly or indirectly some of the biological processes. In particular, the decrease in abundance of silver hake (*Merluccius bilinearis*) in the area of Georges Bank may be attributed, with other causes, to the cooling which has been observed since the 1950's and especially remarkable in 1962-1963. As the indices for the determination of yearly thermic background we may use the very different thermic characters of water masses depending on the specificity of the area, on the number and frequency of observations, and on the amount of space covered by these observations.

Since it is impossible to make observations over a large area with sufficient frequency at present, it is necessary to select representative sectors of the shelf. Observations on these sectors, even if casual, help to single out the temperature of waters in the area and to trace its year-to-year and seasonal variability.

As mentioned above, the East Channel, Georges Basin Deep, the Scotian Gulf (Sambro Deep) and Cabot Strait should be added to the present sectors in the area of Georges Bank and the Scotian Shelf.

Analysis of incidental observations showed agreement between the variation of the minimum temperature of the cold intermediate layer and the depth of 5°C isotherm for the two above-mentioned sectors. In addition, there is agreement with the year-to-year temperature trend. V. A. Briantsev has proposed, as a temperature index, the average temperature at the 100 m level at especially selected representative points on the standard sections in the area of Georges Bank and the Scotian Shelf.

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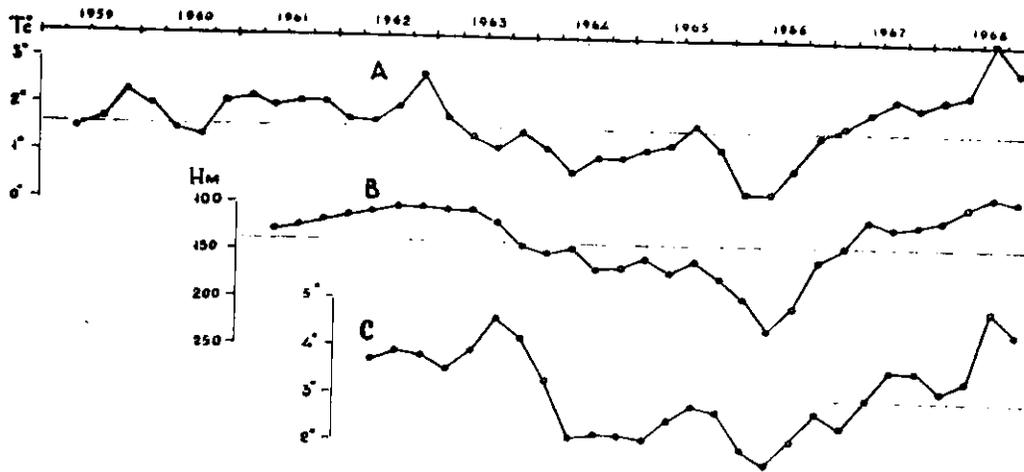


Fig. 1. A. Seasonal variability of minimum temperature in the nucleus of cold intermediate layer, Sambro Deep.
 B. Seasonal variability of the average depth of the 5°C isotherm, Sambro Deep.
 C. Seasonal variability of minimum temperature in the nucleus of cold intermediate layer, the East Channel. Dotted lines represent mean values of the characters for the period of observations.

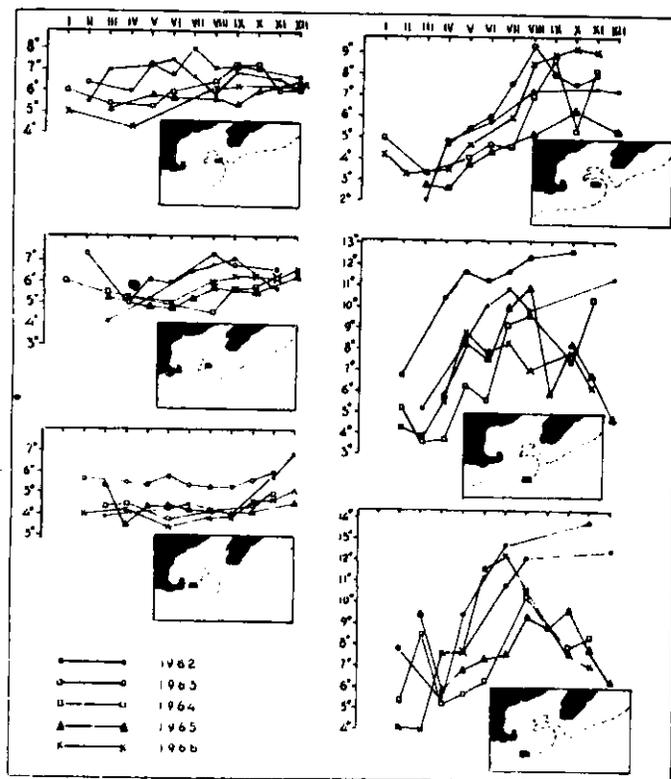


Fig. 2 Average temperature of off-bottom water layer on some sectors of the area of Georges Bank in 1962-1966.

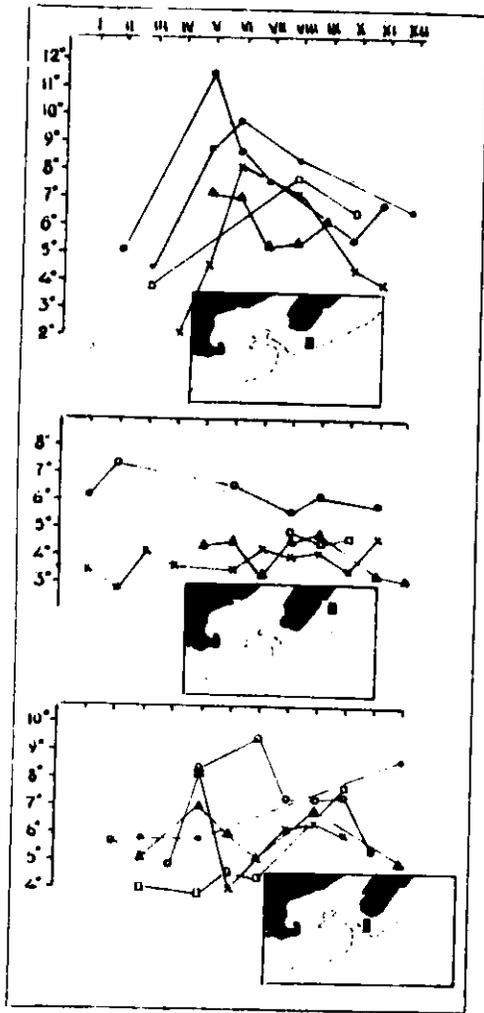
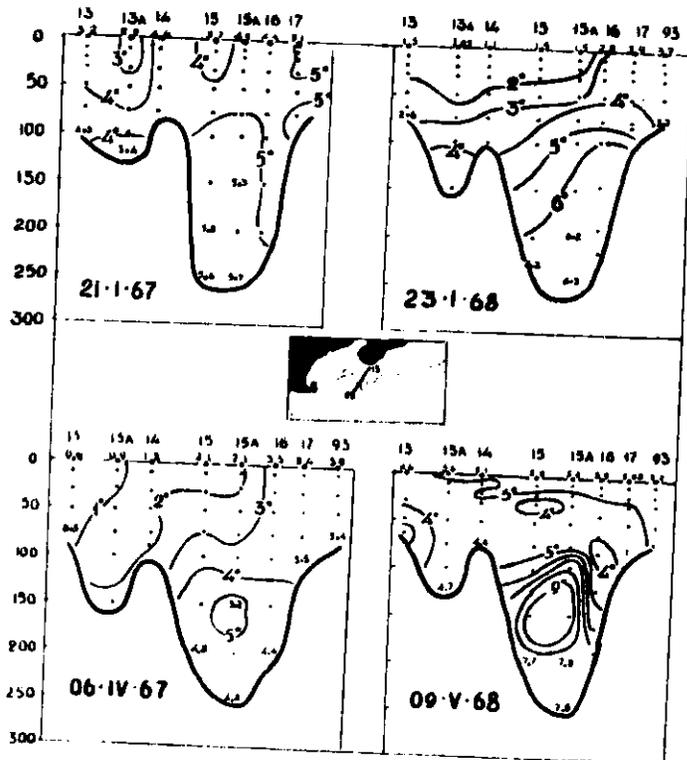


Fig. 3. Average temperature of off-bottom water layer on some sectors of the area of the Scotian Shelf.

Fig. 4. Water temperatures in the section through the East Channel in winter and spring of 1967 and 1968.



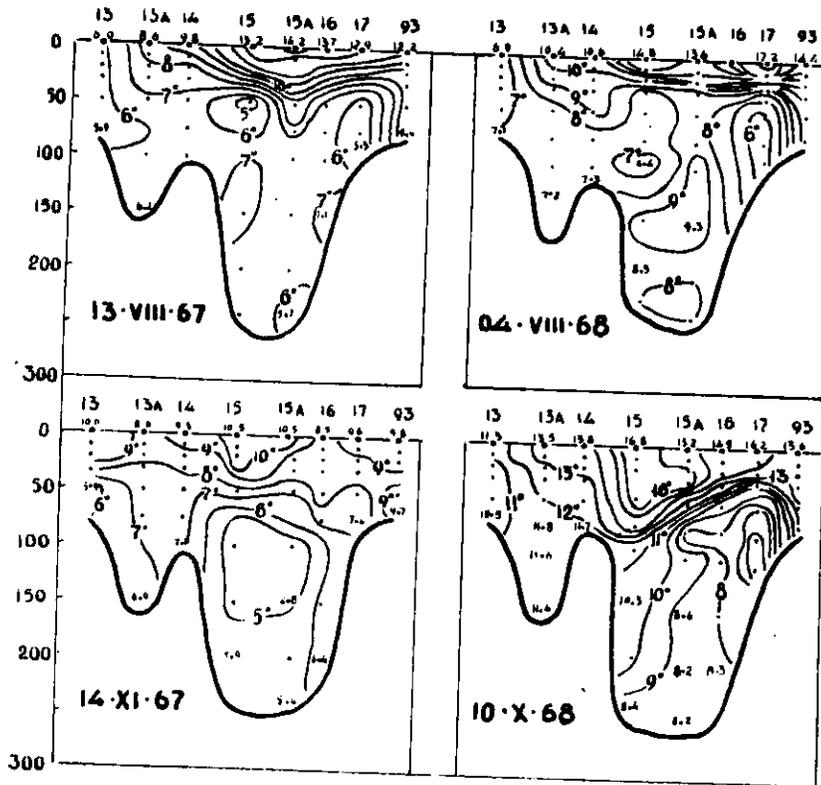


Fig. 5. Water temperatures in the section through the East Channel in summer and autumn of 1967 and 1968.

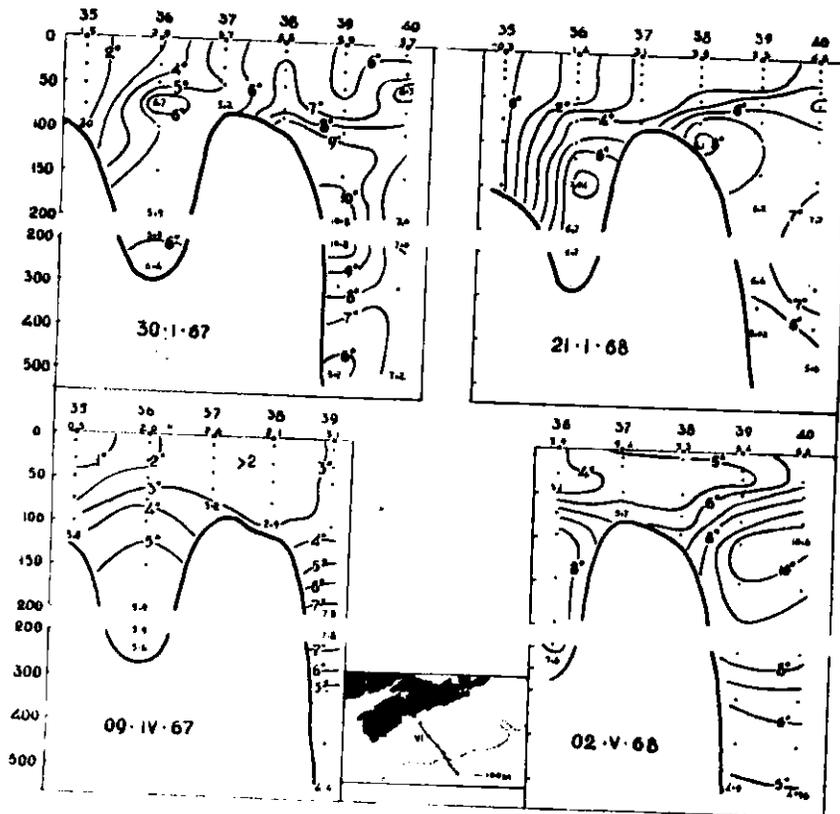


Fig. 6. Water temperatures in the Halifax section in winter and spring

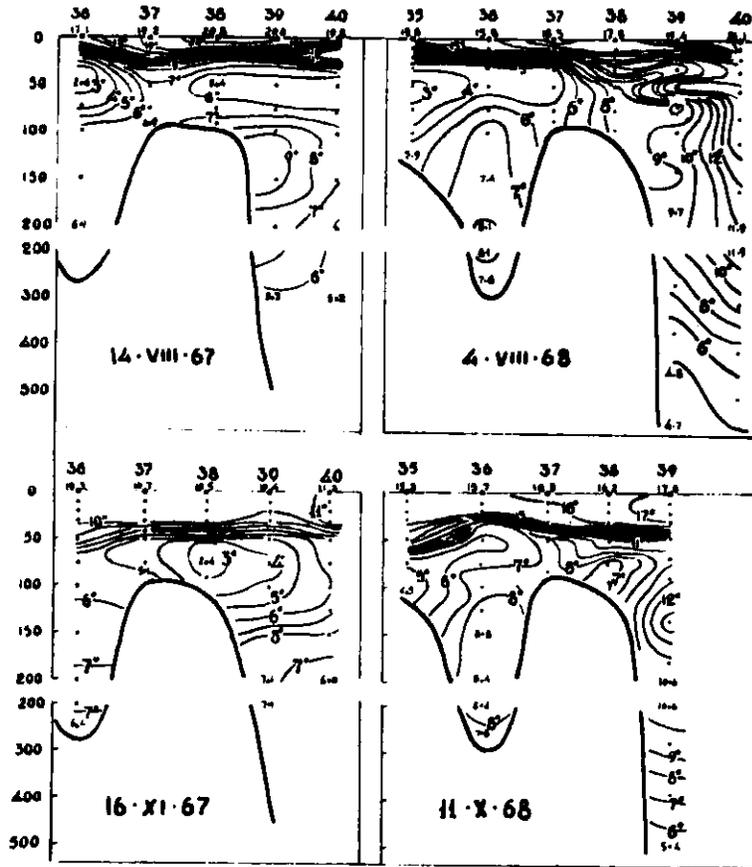


Fig. 7. Water temperatures in the Halifax section in summer and autumn of 1967 and 1968.

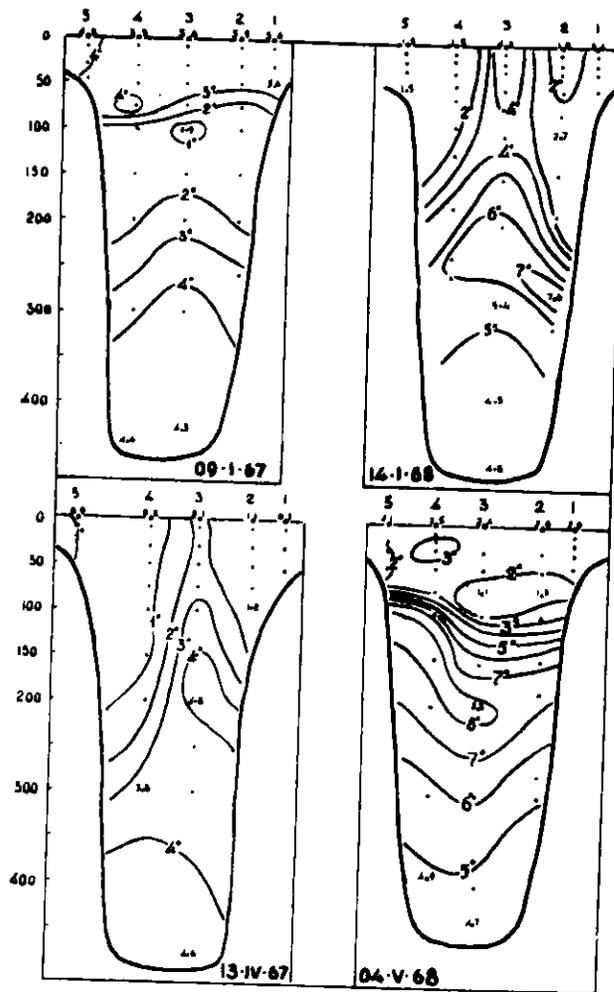


Fig. 8. Water temperatures in the Cabot Strait section in winter and spring of 1967 and 1968.

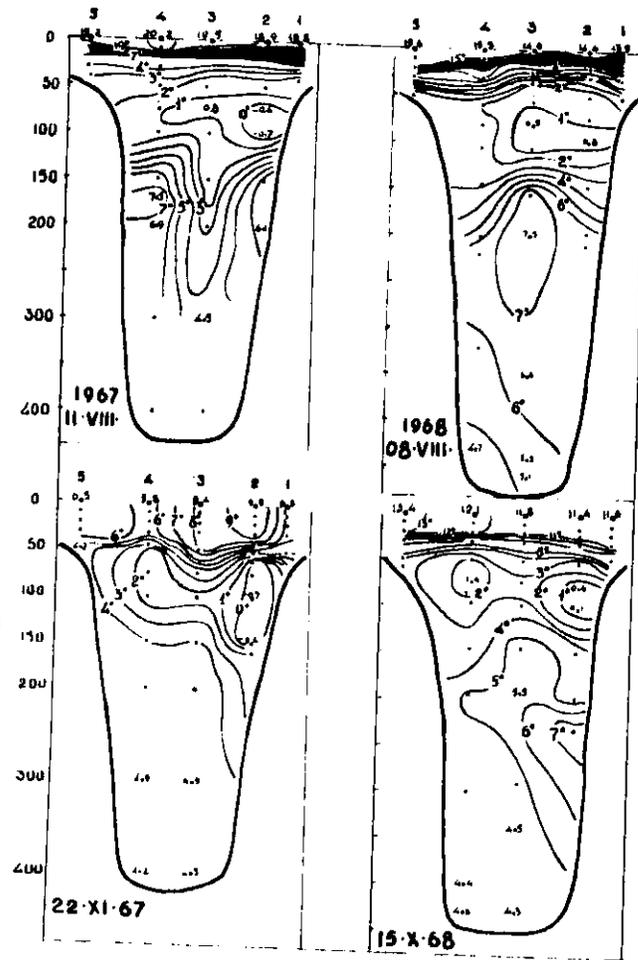


Fig. 9. Water temperature distribution in the Cabot Strait section in summer and autumn of 1967 and 1968.