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Contributions to the hydrography of the waters of the Scotian shelf. General hydrography - 1936.

Author

H. B. Hachey.

CONTRIBUTIONS TO THE HYDROGRAPHY OF THE WATERS OF THE SCOTIAN SHELF

General Hydrography 1936

By

H. B. Hachey

Introduction.

Hydrographic observations were made at the regular stations on the Scotian shelf on three cruises made in May, June and August. The western half of the area was covered in February, in April, and in part in November and December. The February and June cruises were part of a co-operative scheme with the Woods Hole Oceanographic Institution, whereby the "Zoarces" was to cover the Scotian shelf and the "Atlantis" was to continue the observations much farther offshore. In February both boats failed to carry out the complete program in the eastern section, but were successful in completing the western portion. In June, complete data were secured for the Scotian shelf.

The data of the May and August cruises of 1936 allow a comparison of conditions with those of previous years. As the data of the June cruise offer some information as to the general trend of conditions between May and August, they will be treated of concurrently in illustrating the prevailing features of the waters during the spring and summer of 1936.

General Conditions of the 1936 Season:

In so far as surface water temperatures of the Canadian Atlantic coast for 1936 are concerned ("An Analysis of

Surface Water Temperatures for the Atlantic Coast of Canada for the Year 1936" M.S.S. Rept. to the Biol. Bd. of Canada), the comparatively mild winter was reflected in the higher mean surface water temperatures of the winter months at points relatively free from ice. An early "spring break-up" was reflected in early and rapidly rising temperatures, resulting in monthly means to the end of June which were somewhat higher than average. By the end of July however, mean surface water temperatures were generally lower than average, an exception being St. Mary's Is., where the monthly mean of 12.0°C was 2.7 degrees higher than the average of the previous five years. This general condition, of temperatures lower than normal, prevailed throughout August. Temperatures for September and October were either normal or less than normal. November means were generally lower than normal, while December monthly means were generally higher than normal. The amount of ice on the coast in spring was seemingly very light. This was reflected in the comparatively high monthly mean temperature of the surface waters at Scatari Is. for April (1.5°C as compared to a five year average of 0.2°C).

The May Cruise of 1936.

The May Cruise of 1936 was carried out within the period May 21st. to May 25th. about a week later than in the previous year. The collected data are furnished in a previous report by the writer ("Some Canadian Hydrographic Data Atlantic Coast-1936", M.S.S. Rept. Biol. Bd. Canad.).

(a) The horizontal distribution of temperature and salinity.

The distribution of temperature and salinity for May,

at depths of 0 m. and 50 m. is shown in plan in figures 1 and 2 respectively. On the surface, the water temperatures are generally between 5°C and 6°C, while the salinities corresponding with such temperatures range roughly between 31.25 o/oo and 32.00 o/oo. The distribution of salinities on the surface indicate the influence of less saline waters from the eastward, the graduation being from a maximum of greater than 32.00 o/oo to the west (as well as offshore) to a minimum of less than 31.25 o/oo inshore to the eastward. At depths of 50 m., the colder waters of less than 1.0°C are found inshore and to the east, while temperature of greater than 3.0°C are found offshore and to the west. At a depth of 50m. the salinity ranges from a low of 31.76 o/oo, inshore to the east, to a high of 32.27 o/oo offshore and to the west.

The surface water temperatures over the Scotian shelf in May, 1936 were generally higher than the corresponding ones of 1935. In particular, temperatures even lower than 1.0°C were observed in the eastern portion of the area in 1935. Such a marked difference in surface water temperatures probably reflects both the comparatively early "spring break-up" of 1936, and a comparatively light ice movement from the Gulf of St. Lawrence. The surface salinities in May, 1935 were generally 0.40 o/oo lower than those of 1936. These lower salinities in 1935 coupled with a comparatively extreme horizontal salinity gradient, as compared to 1936, indicate that the flooding of the Scotian shelf, by less saline waters from the eastward was the more extensive in 1935. At 50 m. the comparative picture between 1935 and 1936 was much the same as for the surface. Much colder waters prevailed

(lower than -0.5°C in 1935) and salinites were somewhat lower in 1935.

(b) The vertical distribution of temperature and salinity.

1. Temperature.

The vertical distribution of temperature, as observed during the May cruise is shown in figure 3. In section 121-124, temperatures less than 5.0°C extend to depths of greater than 155 m., but a surface layer, varying between 10 and 35 metres in thickness is of a temperature greater than 5.0°C. Traces of water of a temperature greater than 5.0°C are found at station 123, at depths greater than 155 m. The minimum temperatures in the section are in the vicinity of 3.0°C, some two degrees higher than in the corresponding section of the previous year. In section 58-50, the temperatures are generally lower than 5.0°C, and minimum temperatures are greater than 1.0°C. As compared to a similar cruise of the previous year, minimum temperatures in 1936 are approximately one degree higher, but the deeper bottom water temperatures are somewhat lower. In section 124-50, the layer of surface water, with temperatures greater than 5.0°C, is slightly more than twenty five metres in thickness. Temperatures of less than 5.0°C extend to depths of approximately 140 m., and the lowest temperature observed in 1.6°C. In May, 1935, temperatures of less than 5.0°C extended to depths of only 100 m. in this section. In section 127-129, waters of temperatures less than 5.0°C extend to depths of 140 m. At station 128, this water layer has a thickness of approximately seventy five metres. The lower fifty metres at this station consist of temperatures between 5.0°C and 6.9°C. Water of a temperature less than 2.0°C is to be found only at the inshore end

of the section. In section 134-131, all the water (with the exception of a thin surface layer inshore) is of a temperature less than 5.0°C. A large body of water of a temperature less than 1.0°C extends from the 50 m. level to the 150 m. level. Compared with a similar section in 1935, temperatures, on the whole, are somewhat higher. In section 129-131, the surface layer, of temperatures greater than 5.0°C, is approximately thirty five metres in thickness at station 129, thirty metres at station 130, and of zero thickness at the eastern station 131.

2 Salinity.

The vertical distribution of salinity, as observed during the May cruise is shown in figure 4. In section 121-124, the "upper layer" (waters of salinity less than 32.00 o/oo) is twenty five to fifty metres in thickness at the offshore station, (considerably thinner than in 1935), but such salinities are absent at the inshore station 121. Salinities of greater than 34.00 o/oo are present at the greater depths at station 123. These are to be compared with the higher salinities of somewhat greater than 33.50 o/oo of 1935, and of the order of 34.50 o/oo in 1934.

In the section 58-50, the "upper layer" is approximately forty metres in thickness, somewhat thicker, on the whole, than in 1935. The maximum bottom water salinity of 33.71 o/oo is considerable lower than the comparative figure for 1935 (greater than 34.00 o/oo). The water of a salinity between 32.00 o/oo and 32.50 o/oo is of lesser importance in 1936 than in the corresponding period of 1935. In the section 124-50, the "upper layer" is somewhat greater than fifty metres in thickness, and while this is a feature of the section, we find, on comparing

the salinities as found in 1936 with those of the previous year, that salinities of between 32.00 o/oo and 32.50 o/oo are of less importance in the section in 1936. As in 1935, the water of a salinity, less than 32.50 o/oo is the prominent feature of the various sections. With the exception of the surface waters, whose temperatures are influenced by vernal warming, waters of salinity less than 32.50 o/oo are all the waters of comparatively low temperatures.

The June Cruise - 1936

The June cruise over the Scotian shelf was carried out as part of a cooperative arrangement with the Woods Hole Oceanographic Institution, who were simultaneously investigating the adjacent slope waters. In so far as the Scotian shelf was concerned, the regular stations were occupied between June 10th. and June 18th. The collected data are furnished in an M.S.S. report referred to in an earlier part of this paper.

(a) The vertical Distribution of Temperature and Salinity.

1. Temperature

The distribution of temperature, in the various sections on the Scotian shelf in June 1936, is shown in figure 5. In all sections vernal warming has been responsible for an increase in the temperature of, at least, the upper twenty five metres of water. Temperatures higher than 10.0°C are to be found in the surface waters in all sections, but of particular prominence in the offshore sections 124-50 and 129-131. In most sections too, waters colder than those of May are found to prevail at intermediate depths of all sections. This clearly indicates that movements of colder waters

to the area have taken place at intermediate depths in the interval May - June. In some sections too, bottom waters, warmer than those found during the May cruise are present. This is particularly evident in sections 121-124 and 127-129, wherein the greater change of the temperatures of waters of intermediate depths has taken place.

2. Salinity.

The distribution of salinity, for June 1936, in the various sections on the Scotian shelf, is shown in figure 6. In all sections water of a salinity less than 31.50 o/oo has become more prominent since May. In all sections, except 124-50, bottom waters of higher salinities have entered. Even in section 124-50, it will be found that the layer of water of a salinity greater than 33.50 o/oo has thickened considerably in the interval, May to June. Salinities of less than 32.50 o/oo are less prominent, in the June sections 121-124, 124-50, and 129-131, than in the corresponding May sections. In the other sections, the relative importance of water of salinity less than 32.50 o/oo in May and June is approximately the same.

(b) Changes in Temperature and Salinity in the Interval May - June.

In the report for 1935 (M.S.S. Rep. Biol. Bd. Canad.) the changes in salinity and temperature, as observed in the interval May - July 1935, were referred to as indicative of wholesale replacement of the waters of the Scotian shelf, and while the changes noted in the interval May - June, 1936 are not as extensive, the same indications of replacement are evident. This idea of replacement

is of particular interest in connection with what we have referred to as the "intermediate layer". It has been pointed out that colder waters moved into the various sections in the May-June interval. As this cold water is of particular importance to the oceanographic problem as a whole, it has become of prime importance to attempt to follow the annual and seasonal changes in the nature and extent of the "intermediate layer".

The August Cruise - 1936

The August cruise consisted in occupying the regular hydrographic stations on the Scotian shelf. The cruise was completed within the interval August 22nd. - August 27th. The collected data are furnished in an M.S.S. report referred to in an earlier part of this paper.

(a) The Horizontal Distribution of Temperature and Salinity.

The distribution of temperature and salinity for August is shown in plan for a depth of 0 m. in figure 1. Offshore surface temperatures are greater than 18.0°C in August, and the eastern part of the area consists generally of surface temperatures between 16.0°C and 18.0°C. In the western portion of the area there is an intensive horizontal temperature gradient from less than 10.0°C on the immediate coast to greater than 17.0°C offshore. When we consider the distribution of surface salinity, we find the intensive horizontal salinity gradient to exist in the eastern portion of the area, where the salinity varies from less than 29.50 o/oo to greater than 31.25 o/oo. The western and offshore areas have surface salinities between 31.25 o/oo and 31.50 o/oo. Compared to the surface distribution

of temperature and salinity of the May cruise. August temperatures are of course considerably higher, but the salinities are considerably lower. In August conditions are such as to enable a differentiation of waters in the different areas, and in particular it is readily appreciated that the source of waters of lower salinities is to the eastward. Comparing the surface features of the waters in August of 1936, with the corresponding ones of 1935, the same general picture is presented, although the surface salinities of August 1936, are somewhat lower than those of 1935.

The distribution of temperature and salinity for August is shown in plan for a depth of 50 m. in figure 2. The greater portion of the Scotian shelf, at a depth of 50 m., has water temperatures of less than 4.0°C. Offshore, temperatures at this depth may be higher than 6.0°C. These temperatures at a depth of 50 m. for August are approximately two degrees higher than the corresponding ones for May. The salinities, at a depth of 50 m. range between 32.00 o/oo and 32.50 o/oo, values which are approximately 0.25 o/oo higher than the corresponding ones for May. Compared with the May cruise, warmer and more saline waters are found at a depth of 50 m. in August. In August 1935, much colder waters prevailed at a depth of 50 m. with minimum temperatures as low as 0.0 C. The salinities observed in August 1935 at a depth of 50 m. were approximately 0.20 o/oo lower than the corresponding ones of 1936.

(b) The Vertical Distribution of Temperature and Salinity.

1. Temperature

The vertical distribution of temperature, as observed during the August cruise, is shown in section in figure 7. In the

section 121-124, the maximum temperature of the surface waters has increased to 14.7 C (an increase of approximately four degrees since June). The isotherm of 5.0°C has changed but little in position in the interval June - August, so that the main feature in the "upper layer" is the increased temperature stratification. In fact, with the exception of the increased amount of bottom waters of a temperature less than 4.0°C at station 121, conditions in the "intermediate" and "bottom layers" show little change since June. Compared to the corresponding section of 1935 the outstanding features are the somewhat cooler waters of the "upper layer", the generally warmer waters of the "intermediate layer" and the generally cooler waters of the "bottom layer". On the whole however the contrasts are not very well marked. In the section 58-50, the position of the isotherm of 5.0°C which fixes the lower level of the "surface layer", has changed but little in the interval June - August. High stratification is evident in this "upper layer" however, due to the presence of a layer of water of a temperature greater than 15.0°C. In the same interval, the position of the isotherm of 5.0°C at the lower levels has been raised approximately ten metres. The "intermediate layer" (temperatures less than 5.0°C) has therefore decreased in thickness in the interval June - August. Considerable increase in temperature has taken place in the intermediate water with minimum temperatures now less than 3.0°C, as compared with less than 1.0°C in June. Warmer bottom waters have also entered at the greater depths. As compared to temperature conditions in August 1935, the section in 1936 contains somewhat warmer waters in the "intermediate layer", and somewhat colder

(at least as much as one degree) bottom waters at the greater depths. In section 124-50, temperatures of less than 2.0°C have dissappeared in the interval June - August, increased temperatures prevail in the "upper layer", the lower boundary of which (the lower isotherm of 5.0°C) has changed but little in position, and bottom waters remain about the same. Comparing this section with the corresponding one of 1935, the most marked differences are the generally higher temperatures of the "intermediate layer" (almost two degrees difference) and the generally lower temperatures of the "bottom layer" (almost one degree difference). In section 127-129, the cold intermediate water of less than 1.0°C has been replaced in the interval June - August by water whose minimum temperature is less than 3.0°C. The 5.0°C isotherm in the "upper layer" has been displaced downward by as much as twenty five metres, and a thick band of water of a temperature greater than 15°C is found in the "surface layer" of the section. Bottom temperatures have decreased slightly in the interval, although no significant displacement of the 5° isotherm in the "bottom layer" is to be noted. Comparative August sections in 1935 and 1936 again illustrate that colder water prevailed at intermediate depths in 1935, while at the greater depths the temperatures were somewhat higher than in 1936. In the section 134-131 the "surface layer" has been thickened by about twenty five metres by a sinking of the isotherm of 5.0°C within the interval June - August. From this isotherm downwards, some increase in temperature has occurred reflecting replacement of the waters of these depths. Comparing this section with that of the previous year, it will be remarked

that the "upper layer" is much thicker (roughly 50 m. as compared to 25 m) in 1936. The deeper waters were generally warmer in 1936. The section 129-131 in August reflects a considerable thickening of the "surface layer" and an intensive replacement of bottom waters (temperature increase of about 3.0°C) within the interval June - August. As compared to 1935, the waters in this section were generally warmer in 1936.

2 Salinity

The vertical distribution of salinity as observed during the August cruise is shown in section in figure 8. In section 121-124 the higher levels of the isotherms of 32.00 o/oo and 32.50 o/oo indicate a general increase of the salinity in this section within the interval June - August. Fresher immediate surface waters are shown by the isohaline of 31.50 o/oo. But little change has occurred below the 100 m. level. As compared to a similar section of the previous year, the waters below 100 m are of higher salinity in 1936. In section 58-50 but little change has taken place in the upper twenty five metres in the interval June - August. A downward displacement of the isohalines of 32.00 o/oo (as much as twenty five metres) at station 126 is offset by a rise of the same isohaline at station 58. An upward displacement (as much as ten metres) of the isohaline of 32.50 o/oo has occurred in the interval June - August and this together with increased bottom salinities would indicate a general increase in the salinities of this section. In the section 124-50, we find that a slight freshening of the waters has taken place since June, as indicated by the increased depth of the isohaline of 31.50 o/oo. Other than this,

the waters of the section have increased in salinity, since June, as all other isohalines are found at higher levels in August. In the section 127-129, indications of surface waters of lower salinities than those observed in June are found at station 127. At intermediate depths, in August, the isohalines of 32.00 o/oo, 32.50 o/oo, and 33.00 o/oo are found at higher levels, indicating a replacement of waters since June. On the other hand, the deeper waters have decreased in salinity since June as the isohalines of 33.50 o/oo and 34.00 o/oo are at somewhat lower levels in August. In the section 134-131 the outstanding trend of events in the interval June - August is the inflow of surface waters of lower salinity producing extensive salinity stratification in the upper thirty metres. Other than this, salinity conditions at other depths seem to have been quite stable. The intense stratification of the upper thirty metres is an outstanding feature of this section in 1936 as compared to 1935. In section 129-131, intensive freshening of the waters of the whole took place in the interval June - August. Waters of a salinity greater than 32.50 o/oo ~~is~~ are no longer present in the section and the salinities in general are considerably lower than those in a similar section in 1935.

Discussion

Provisionally, in earlier reports, the year 1934 on the Scotian shelf has been classified as a "warm water" year and 1935 as a "cold water" one. All indications point to 1936 as of "intermediate" classification. An outstanding feature of the observations on the Scotian shelf has been the freshening of the

surface waters as the season progresses. This would seem to indicate a general movement of fresher waters from the eastward. Then too, an intensive lowering of temperature of the "intermediate layer" may occur in the interval between the spring and autumn cruises and this can only indicate an extensive replacement by waters of eastward origin. Variations in bottom conditions are always indicative of shoreward or offshoreward movements in the "bottom layer". Such interpretations are offered further substantiation by the dynamical treatment of the data. As yet, however, the data have not been dealt with thoroughly from this point of view. In the treatment of the general hydrographic data, the main idea is to present in these general reports a description of the waters at various seasons, to outline general seasonal trends, and to present outstanding annual differences as observed. The matter of summarizing and discussing the data of the various cruises is now in hand for the purposes of outlining the hydrographic features of the waters of the Scotian shelf.

Summary

1. Higher mean surface temperatures were experienced during the winter months at points relatively free from ice. These were followed by early and rapidly rising temperatures which resulted in monthly means, to the end of June, which were somewhat higher than average. Surface water temperatures lower than normal prevailed throughout August, September and October. Surface water temperatures were either normal or less than normal. November temperatures were generally lower, while December surface water temperatures were

generally higher than normal. In spring, the amount of ice on the coast was apparently light.

2. In May, the surface water temperatures for 1936 were generally higher than those of 1935, while surface salinities were approximately 0.40 o/oo greater than in 1935. On the basis of higher salinities in 1936, and the lack of a horizontal salinity gradient comparable with 1935, the flooding of the Scotian shelf by surface waters from the eastward was probably not very extensive in 1936. At sub-surface depths, temperatures and salinities in 1936 were both higher than in 1935. Minimum temperatures of waters of intermediate depths were as much as two degrees higher, while salinities at the greater depths were approximately 0.50 o/oo higher in 1936 than in 1935.

3. In August, although similar conditions prevailed in the surface temperatures in 1935 and 1936, generally lower salinities were present in 1936. The waters at intermediate depths, in 1936, were approximately three degrees warmer than in 1935, while salinities were approximately 0.20 o/oo higher. These comparatively high temperatures and salinities in 1936, at intermediate depths, probably reflect a comparative lack of movement of the waters at this depth. This point will receive further attention in the dynamical treatment of the data.

4. Vernal warming controls temperatures in the "Surface layer", which extends to depths of approximately twenty five metres during the seasonal progress from spring to summer. Where temperature changes are involved below the twenty five metre level, the phenomenon is either one of mechanical vertical mixing as experience inshore, or movement of foreign waters to the area,

sometimes experienced offshore. Changing temperatures in the "intermediate" and "bottom" layers with the progress of the season from spring to summer reflect the processes of replacement of these waters.

5. On the basis of data from May to August, cruises for the years 1934, 1935, and 1936, the year 1934 is classified as a "warm water" year, 1935 as a "cold water" year, and 1936 as an "intermediate" year.

Appendix

The April distribution of temperatures and salinities in sections 121-124, 124-50 and 50-58 is shown in figures 9 and 10 which are appended to this report.