

**FISHERIES RESEARCH BOARD
OF CANADA**

MANUSCRIPT REPORTS OF THE BIOLOGICAL STATIONS

No. 455

Title

The General Hydrography of the Waters of the Bay of Fundy

Author

H. B. Hachey

(revised by H. B. Hachey and W. B. Bailey)

1952

FISHERIES RESEARCH BOARD
OF CANADA



DEPARTMENT OF FISHERIES AND MARINE SERVICES

1967

EARLY LIFE

POWER POINT

—RAC CONTENT—CANADA—

Author

1967, 1968

(Revised by Dr. G. H. Ross and Dr. G. H. Ross)

ATLANTIC OCEANOGRAPHIC GROUP

St. Andrews, N. B.

THE GENERAL HYDROGRAPHY OF THE WATERS OF THE BAY OF FUNDY

by

H. B. Hachey

(revised by H. B. Hachey and W. B. Bailey)

The General Hydrography of the Waters of the Bay of Fundy

by

H. B. Hachey

(revised by H. B. Hachey and W. B. Bailey)

Introduction

This report, based on surveys in the Bay of Fundy by Hachey in 1929 and 1930, is essentially a re-issue of the original manuscript report of the work carried out at that time (Hachey 1931). The original work (Hachey 1931) has been re-arranged with some alterations in general presentation to make it available to interested groups. The only major work in the Bay of Fundy, since these surveys, was made by the International Pessamoquoddy Fisheries Commission in 1932 (Watson 1935). Thus this work stands as a major contribution to the knowledge of the general hydrography of the Bay of Fundy.

The enormous tides of the Bay of Fundy have made these waters well known the world over. The conditions produced by these tides make the region one of the utmost interest and importance to the oceanographer. However the rapid changes in the hydrographic conditions caused by the ebb and flood of large masses of water over such an extensive area presents a problem that allows present sampling methods to give only a picture of the general hydrographic conditions in this area.

Considerable hydrographic data have been collected also, over a period of years, in connection with problems of marine biology, and these data are also used to present a long term picture of the hydrographic conditions.

Description of the Region

The Bay of Fundy (figure 1) is an area of the Atlantic Ocean, separating the province of Nova Scotia from New Brunswick and the State of Maine. The mouth of the Bay, usually defined by a line drawn from

Chebogue Point on the south, to the Point of Main on the north, has a width of 87 miles (161 km.), and an average depth of 47 fathoms (85 m.). The area of the Bay is about 3,000 sq. mi. (7,770 sq. km.). At its head, the Bay of Fundy divides into Chignecto Bay on the north with average depths ranging from 20 to 8 fathoms (36-15 m.), and Mines Channel leading into Mines Basin to the east and south with average depths ranging from 30 to 5 fathoms (55-9 m.). At Cape Chignecto, where the Bay forks, the width is 30 miles (48 km.), with an average depth of 22 fathoms (40 m.). Above Cape Chignecto, the contraction in width and shallowing in depth takes place even more rapidly than in the Bay itself.

Passamaquoddy Bay, situated close inside the entrance of the Bay of Fundy on the northwestern shore, is a large enclosed bay averaging 15-20 fathoms (27-36 m.) in depth and communicates with the Bay of Fundy by two main channels, Western Passage and Letite Passage.

An important feature which plays a major role in influencing the hydrographic conditions in the Bay of Fundy is Grand Manan Island together with its off-lying shoals. These features together occupy nearly half the entrance to the Bay, which divides into two channels, Grand Manan Channel and Southeastern Channel.

On the southeastern side of the mouth of the Bay of Fundy is St. Mary Bay, connected to the Bay of Fundy by Grand Passage and Petite Passage. The depth of St. Mary Bay gradually decreases from about 20 fathoms (36 m.) at its mouth to the shallow upper end. Just above St. Mary Bay, on the same side of the Bay of Fundy, Digby Gut opens into Annapolis Basin. Directly across the Bay from Digby Gut is the estuary of the Saint John River.

The bottom configuration appears to play an important part in

determining the distribution of physical-chemical properties in the Bay of Fundy. The 50 fathom (91 m.) contour rounds the northwestern portion of Nova Scotia at a distance of 30 miles (48 km.) from the shore. It then follows the general direction of the coastline approaching to within 1 mile (0.6 km.) of the shore in the vicinity of Digby Neck. From a position just north of Petite Passage it proceeds in a northeasterly direction, crossing over to the New Brunswick side just south of the Saint John Estuary, at a distance of about 10 miles (16 km.) from the shore. It then runs parallel to the shore, projects into Grand Manan Channel, approaches the northernmost tip of Grand Manan, rounds the eastern side of the Island, and passes out of the Bay, running parallel to the coast of Maine at a distance of about 20 miles (32 km.) from the shore. The 100 fathom (185 m.) contour reaches to the mouth of the Bay of Fundy from the Gulf of Maine. In the southeastern channel between Grand Manan Island and Brier Island, there exists an area in which the depths are generally greater than 100 fathoms (182 m.). From a line between Digby and Saint John, eastward a gradual shallowing takes place to the head of the Bay.

Fresh water enters the Bay from five areas, as follows:

- (a) Saint John area
- (b) Passamaquoddy area
- (c) Chignecto area
- (d) Minas area
- (e) Annapolis area

The Bay of Fundy receives the drainage from an area over 25,000 sq.mi. (64,417 sq.km.) of which the Saint John River System is by

far the most important, draining an area of more than 15,000 sq.mi. (38,850 sq.km.). A large amount of fresh water is supplied in the Passamaquoddy area through the St. Croix, Magaguadavic, and Digde-guesh rivers. The Chignecto area receives water from the Petitcodiac river while the most important supply in the Mines area is from the Shubenacadie river. In the Annapolis Basin, the Annapolis River and several large streams provide the source of fresh water in this area.

Tides

The tides in the Bay of Fundy (Dawson 1908; Marmer 1926) are unique throughout the world. The mean range of these tides varies from 9.0 ft. (2.7 m.) at the mouth to 44 ft. (13.3 m.) at the head. During the time of spring tides the mean range is increased by approximately 14%.

The causes for these exceptional tides, which are the greatest in the world, are explained by the combination of various factors. Primarily, the extreme tides are the result of the natural period of the Bay of Fundy and the period of the ocean tide being practically the same. This results in resonance which is kept within bounds by the frictional forces involved. In addition there is a further piling up of waters near the head of the Bay resulting from the narrowing and shallowing of the Bay of Fundy in this area. It is of interest to note that tides in the Bay of Fundy are fundamentally of the stationary wave type, with the times of slack water nearly the same throughout the Bay, and the tidal amplitude increasing with the distance from the mouth of the Bay.

Tidal currents in the Bay of Fundy show no direct relationship with the tidal amplitude and are greatly influenced by shoals and

islands. These currents run generally in and out of the Bay veering only when the currents are weak. The currents range from 1 knot (1.8 km. per hr.) near the mouth to 7 knots (12.7 km. per hr.) in the narrow channels.

Nature of the Bottom

The general nature of the bottom of the Bay of Fundy, as obtained from data given on the latest charts of this region, is shown in figure 1. Three important types of bottom are found in the Bay of Fundy:

(a) mud - the chief area extends from the mouth of the Saint John River and follows the coast of New Brunswick, extending almost to Grand Menan. To the eastward of Grand Menan there also exists an area of mud, of considerable extent. A bottom of a similar nature is seen to exist in the Chignecto Channel and extends in a south-westerly direction, in patches, along the coast of New Brunswick. Isolated patches of mud also occur in Mines Basin, Passamaquoddy Bay, St. Mary Bay and in two areas near the mouth of the Bay of Fundy. In each case the mud bottom is representative of deposition by the waters from the various drainage areas.

(b) sand and stones - the major portion of the bottom of the Bay of Fundy consists of sand and stones. This applies particularly to the bottom in the deeper portions of the Bay.

(c) rocks and ledges - the chief areas having a bottom of this nature are found in the vicinity of Grand Menan, and the western coast of Nova Scotia. A similar bottom is found in small areas scattered over the region near the head of the Bay.

Review of Earlier Hydrographical Investigations

Through surveys made by the Royal Navy in 1848, 1862, 1865 and 1866, the nature and configuration of the bottom was determined, while tides and tidal currents were investigated by the Canadian Department of Marine and Fisheries (Dawson 1908, 1917; Anderson 1930). Investigations into the physical and chemical aspects of oceanography in the Bay of Fundy began in 1916 (Craigie 1916; Craigie and Chase 1918; and Vachon 1918). Mavor (1922) made use of Dawson's results to determine the resultant movements in certain localities. He extended this work by drift bottle investigations, and from the combined results worked out the general circulation of the waters of the region. Mavor (1923) furnished a general picture of the hydrographic conditions in the Bay of Fundy by studying the distributions of temperature and salinity. Intensive work in years around 1930 have attempted to account for the factors controlling the conditions as found.

Data

The data in this paper were collected over a period of years, and are discussed in the following order:

- (a) A general survey of the Bay of Fundy in 1929.
- (b) A survey of the Passamaquoddy region in 1929.
- (c) A survey of the freshet waters of the Saint John River Estuary in 1930.
- (d) Temperature and salinity variations in the waters of the Bay of Fundy during the period between 1924 and 1930.
- (e) Surface water temperatures in the Bay of Fundy during the period between 1929 and 1931.

A General Survey of the Bay of Fundy in 1929

The general survey of the Bay of Fundy was carried out between August 21st and September 19th, 1929. As will be seen from the presentation of the data, this approximates to a survey of extreme summer conditions. The locations of the stations in the survey network are shown in figure 2.

I. Vertical Distribution

The vertical distribution of temperature, salinity and density, for the five sections across the Bay of Fundy are shown in figures 3, 4, and 5.

Section 938-943 across the mouth of the Bay shows the same distribution pattern for the three variables. For purposes of discussion, the waters in this section may be considered under four categories. Between stations 938 and 940 the waters are highly mixed and have relatively small differences in temperature and salinity. This water in all probability is flowing out of the Bay of Fundy along the north shore after having been thoroughly mixed in the Grand Manan Shallows. The waters between stations 940 and 942 are typical of the water in the upper 50 m. in the central part of the Bay of Fundy as can be seen in section 968-963. This water, on the basis of the horizontal distribution of density (figure 13), is water that has come from the north central part of the Gulf of Maine, the higher densities (σ_t) being attributable to an influence from the Atlantic through the Fundian Channel. The water in the deeper portion of the section at station 941, having temperatures less than 7.0° C. and salinities greater than 33.1° / ∞ , is typical of the colder and more saline water which, at this season, as the result

of intense vertical mixing, tends to produce sub-normal temperatures in the Bay of Fundy. Finally, there is a body of water found to the eastward of station 942. This body of water, with temperatures between 10° and 7° C. and salinities between 32.1 and $33.0^{\circ}/\text{oo}$, is found to enter the Bay of Fundy, after undergoing considerable mixing in passing around the southern coast of Nova Scotia.

At stations 940 and 942 considerable upwelling is seen to be taking place as indicated by the nearness of the higher density water to the surface (figure 5). Considerations of the slopes of the isopycnals indicate that there are three water movements through this section. On the left, from station 940 to the coast of Maine the waters are moving out of the Bay of Fundy, while from station 942 to the coast of Nova Scotia the waters are moving into the Bay of Fundy. These movements are also indicated by the temperature and salinity characteristics. Between stations 940 and 942 there appears to be clockwise circulation about station 941, which partakes of the nature of counter currents.

Section 956-962, in the central part of the Bay of Fundy, shows a greater influence by river outflow as indicated by the increased temperatures and lowered salinities in the main body of water. This transition is more readily noted in the decrease in density (σ_t) (figure 5). The strong tidal mixing is not as appreciable in the central part of the Bay as it is south of Grand Menan, and the waters are more stratified, as is seen in sections 956-962 and 968-963. On approaching the head of the Bay of Fundy the influence of the tides becomes greater until the waters are nearly completely mixed as in section 658-664. In the central portion of the Bay of Fundy, there is considerable upwelling along the Nova Scotia coast

where the isopycnals (figure 5) are seen to be lifted to higher levels.

In general it is seen that the warmest waters are observed in the shallow bays at the head of the Bay of Fundy. These waters, which are low in salinity, hold to the New Brunswick shore, while along the Nova Scotia coast, where considerable tidal mixing and upwelling is taking place, the waters are colder and more saline. The warmer lighter waters proceeding out of the Bay of Fundy along the New Brunswick coast are thoroughly mixed, in the shallow areas south of Grand Manan, with the colder and more saline waters at the mouth of the Bay to form a body of water with temperatures between 10.5°C . and 8.0°C . and with corresponding salinities generally between 32.5 and $33.0 /_{\infty}$.

II. Horizontal Distribution

(a) Temperature

The horizontal distribution of temperature at 1, 25 and 50 m. is illustrated in figures 6, 7, and 8. As shown by the sub-surface isotherms for 1 metre (figure 6), the temperatures at the head of the Bay of Fundy are greater than 13.0°C ., with the waters of Chignecto Basin and Mines Channel greater than 14.0°C . From the mouth of the Bay inwards, the temperatures decrease rapidly from 15°C . or greater to values of less than 10.0°C . in the area south-west of Grand Manan. Another rapid change in temperature occurs between the deeper waters and the coast of Nova Scotia. It is to be noted that the isotherms tend to follow the general direction of the bottom contours well into the Bay. Temperatures lower than 10.0°C . may be found in the inshore waters in the vicinity of the Nova Scotia coast, as well as near the New Brunswick and Maine coasts. Increasing

temperatures are found in the area from Grand Menan to the estuary of the Saint John River and from there to the head of the Bay. The colder sub-surface waters are thus found to be in the Grand Menan region and along the northwestern outer portion of the Nova Scotia coast.

At the 25 metre level (figure 7) the waters, from a line between the Saint John and Digby regions to the head of the Bay, show a progressive increase in temperature from 9.5° to 13.5° C., with the waters in Chignecto Basin and Minas Channel greater than 14.0° C. From the Digby region to the Saint John estuary a progressive temperature increase from 8.5° to greater than 10.0° C. takes place across the Bay. South of Grand Menan and stretching along the coast of Maine there is located a patch of water with temperatures less than 9.5° C., which represents the mixture of warmer waters from the Bay of Fundy and colder waters from greater depths in the Gulf of Maine.

The isotherms for the 50 metre level (figure 8) show a gradation in temperature from 6.5° C. at the mouth of the Bay to a temperature of about 9.0° C. in the area between Saint John and Digby. The depths near the head of the Bay are, in general, too shallow to allow observations at this depth. The isotherms at this depth also tend to follow the general direction of the bottom contours as was noted in the previous horizontal distribution.

The difference between the distribution of temperature at 50 metres and the distribution at 1 and 25 metres is worthy of considerable attention. The distribution at 50 metres illustrates forcibly that the deeper waters of the open ocean, that are carried to the Bay of Fundy, are rapidly warmed before reaching any great distance into the Bay. On the other hand, the distribution at depths of 1

and 25 metres point out that the shallower (sub-surface) waters of the open ocean proceeding into the Bay of Fundy are lowered in temperature. This lowering of the temperature of the upper layers coupled with the rise in the temperature of the lower layers indicates that mixing of the waters of the various layers takes place on a considerable scale. Granting this, it is evident that there are two important regions where mixing takes place on a large scale. One to the southwest of Grand Manan, and one over an area extending from Digby outward along the coast of Nova Scotia. As was seen in the vertical distributions, considerable mixing in the main water mass takes place generally in the whole Bay of Fundy area.

(b) Salinity

The distribution of salinity at depths of 1, 25 and 50 metres is shown in figures 9, 10 and 11. The waters at the head of the Bay of Fundy at a depth of 1 metre (figure 9) have a salinity as low as 31.0 ‰ in Chignecto Channel, and as low as 31.7 ‰ in Mines Channel. At the mouth of the Bay, salinities are as high as 32.89 ‰. From the region between Saint John and Digby to the head of the Bay, the gradation in salinity is most marked, ranging from a maximum of 32.5 ‰ to a minimum of less than 31.0 ‰ in the Chignecto region.

In figure 10 the isohalines for the 25 metre level show much the same distributional pattern as at 1 metre with the exception that the isohalines near the head of the Bay tend to run across the Bay.

At the 50 metre level (figure 11) the isohalines tend to follow the direction of the bottom contours. The salinities in this deeper portion of the Bay of Fundy, have an extremely small range (32.9 - 33.0 ‰).

(c) Density (σ_t)

Figures 12, 13 and 14 show the distribution of density (σ_t) at the 1, 25, and 50 metre levels. In the Bay itself at 1 m., densities vary from less than 22.5 in Chignecto Channel to a value greater than 24.9 in the Digby area. Southwest of Grand Manan there exists a body of denser water, clearly the result of strong tidal mixing in the area south of Grand Manan, of the warmer and lighter surface waters flowing out of the Bay and the colder and heavier water from below 50 metres flowing into the Bay. This heavier surface water is due to upwelling and must sink below or mix with lighter waters as it passes away from this area. Another pertinent point in the surface distribution of density is the gradation along the 50 fathom (91 m.) contour which runs into the Bay along the coast of Nova Scotia. A distribution such as this clearly points out the importance of the bottom configuration in producing mixing in this area. The density distribution at 25 metres (figure 14) has a range from greater than 25.8 outside the Bay to less than 23.5 at the head of the Bay. As was found in all other cases the isopycnals at the 25 and 50 m. levels tend to follow the general direction of the 50 fathom bottom contour. This is not very marked at 25 m.

III. Discussion

The distribution of waters of various temperatures and salinities, as found in a given region, is determined by the movements from the various sources of supply. Wind action and tidal movements may be responsible for the piling of waters in certain areas, but the resultant movements are determined by the prevailing Archimedean and Coriolic forces. The distribution of density tends to bring

about movements which are further controlled by the rotation of the earth. As a result of the relationship between the distribution of density and water movements, certain principles have been derived to assist in the hydrodynamical analysis of water masses. One elementary principle states that if one faces in such a direction that the lighter waters are on the right hand then one is looking in the direction in which the current is flowing. In the Bay of Fundy region the enormous tides result in large and complicated current systems. However, for purposes of hydrographical analysis we are interested only in the resultant movements, or circulation, and by making the following basic assumptions we are able to arrive at a simple and clear method for evaluating resultant water movements:

- (a) The net amount of salt water introduced and removed from the Bay of Fundy is, during a complete tidal cycle, equal to zero.
- (b) The outflow of water from the Bay of Fundy is by necessity greater than the inflow of salt water due to the introduction of large quantities of fresh water from the various drainage basin.
- (c) The outflowing waters are less saline than the inflowing due to the mixing of the waters that must occur in any tidal region.
- (d) The lighter water is on the right of the direction of the current.

It therefore follows that, in general, the resultant outflow keeps to the surface layers while the inflowing waters keep to the lower levels. Also, the lighter waters are to be found proceeding from the head of

the Bay, keeping close to the New Brunswick coast to the region of the Saint John Estuary, thence to Grand Manan. At this point according to Mavor (1922) the waters round Grand Manan to the eastward and then flow southward along the Coast of Maine. The incoming waters must then enter along the Nova Scotia Coast and hold to this coast reaching well into the Bay. This inflow of salt water is necessary to replace the salt water consumed in the mixing with the fresh water from the drainage basins and which has passed out of the area. Since the outflow is along the New Brunswick coast and the inflow along the Nova Scotia Coast, there must be a crossing over from the Nova Scotia side to the New Brunswick side. This crossing in actuality takes place throughout the entire length of the Bay, but is more pronounced in the region north of the line between Digby and Saint John to the head of the Bay. This movement is clearly shown by the distribution of density (σ_t) at all levels, where the isopycnals by necessity have a tongue-like shape reaching well into the Bay. In the area to the southwest of Grand Manan a cyclonic circulation is in evidence in the upper layers (figure 12). This heavier water, is therefore, dissipated as it breaks away from this area in its anti-clockwise movement, sinking below the lighter waters of the surrounding region. The distribution of density (σ_t) at 25 and 50 metres (figures 13 and 14) shows that this water is carried southward along the coast of Maine.

Tidal mixing and upwelling have been shown to play an important part in determining the hydrographic conditions in the Bay of Fundy regions. The distribution of temperature at 25 m. (figure 7) shows that upwelling is effective at this depth, while at 50 metres (figure 8) the effect of the upwelling of the deeper waters is still in evidence. The surface densities (figure 12) illustrate upwelling

in the region southwest of Grand Manan. At 25 metres (figure 13) and 50 metres (figure 14), this upwelling is not as well marked, due to the fact that there is less variation in density at these depths than in the surface layers. As has been noted in viewing the vertical distributions (figures 3, 4, and 5) mixing takes place progressively as the waters reach into the Bay, so that the upper portion of the Bay as a whole is shown to produce a fairly well mixed water with the waters at the head being thoroughly mixed. It is to be noted, however, that considerable differences in temperature and salinity are to be found between the water in Mines Channel and those found in Chignecto Channel.

The area of the Saint John Estuary and the area near the mouth of Passamaquoddy Bay have been omitted in plotting the results for the Bay of Fundy. These areas require special attention and will be discussed in later pages.

A Survey of the Passamaquoddy Region

The Passamaquoddy area consists of Passamaquoddy Bay and that part of the Bay of Fundy extending from the entrances to Passamaquoddy Bay to the southern extremity of Grand Manan, and including the Grand Manan Channel. The waters of this region are of particular importance to an understanding of the hydrographic conditions in certain areas in the region around Grand Manan. Considerable attention was given to this region during the summers of 1928 and 1929. However, much of the data were very difficult to interpret. The data on which this paper is based were collected during the period of September 5-7, 1929, and are considered the best data obtained for late summer conditions. The location of stations occupied during the survey are

shown on the chart of the area in figure 15.

I. Vertical Distribution

The vertical distribution of temperature, salinity and density (σ_t) for each of the sections occupied in the Passamaquoddy area are shown in figure 16.

In section 948-897 the waters are relatively stratified to a depth of 75 metres. Temperatures range from a high of 12.0° C. at the surface to less than 7.5° C. at the bottom (120 m.), with corresponding salinities of 32.3 and 33.0 ‰. The density distribution in this section, which runs from White Head Island to Pt. Lepreau, affords an opportunity to determine the general direction of the water movements through this section. From the slopes of the isopycnals it is seen that there are two main water movements, one into the section around Pt. Lepreau and one out of the section around White Head. The extent of these two movements varies with depth. In the upper 25 metres the inward movement extends almost as far south as station 949 while below this level to the bottom, both movements reach as far as station 951. Thus, on the basis of the area of this section, we may say that the greatest inward movement is in the upper 25 metres while the greatest outward movement is below this level.

In section 953-955, across the southern entrance to the Grand Manan Channel, it is seen that the waters in this area are for all intents and purposes homogeneous in respect to temperature, salinity and density. So well mixed are these waters that the Archimedean forces acting on this body of water would be so slight as to be negligible. Thus such a water mass is mainly subject to movements

by the winds and tides.

Across the northern entrance to Grand Manan Channel (section 882-885) the waters are not as thoroughly mixed as they are at the southern end due to the encroachment of waters from north of the Channel. Even so, the waters in this section well illustrate the effect of tidal mixing. Temperatures in this section range from greater than 10.5° C. at the surface, near the centre of the channel, to less than 10.0° C. near the bottom, with corresponding salinities between $32.6^{\circ}/\text{oo}$ and $32.7^{\circ}/\text{oo}$. From the slopes of the isopycnals it is difficult to form any definite conclusion as to the water movements through this section, and to a lesser degree with the ensuing sections. An interpretation of the residual water movements is more readily made from the horizontal distributions of density (σ_t) to be described later.

Sections 890-893 and 893-897, in the waters north of Grand Manan Channel, show a greater degree of stratification, with temperatures ranging from greater than 12.0° at the surface to 9.0° C. at the bottom, while corresponding salinities range from 32.3 to $32.9^{\circ}/\text{oo}$.

II. Horizontal Distribution

The horizontal distribution of temperature, salinity and density (σ_t) in the Passamaquoddy region are given for depths of 1, 25 and 50 metres in figures 17 to 25.

(a) Temperature

The gradation in temperature at 1 metre (figure 17) is from the Grand Manan Channel where temperatures are between 10.0° C. and 10.5° C., to the region near Pt. Lepreau where temperatures are greater than 12.0° C. It is to be noted that the waters proceeding

from the Saint John region are higher in temperature than those proceeding from the Passamaquoddy region. At the 25 metre level (figure 18) the temperature gradient is in a considerably different direction than at one metre. From the mouth of Passamaquoddy Bay to the open waters of the Bay of Fundy the temperatures increase to between 10.0° and 11.0° C., in a narrow band north of Grand Manan, and then decrease to temperatures less than 10.0° C. on proceeding toward the deeper waters of the Bay of Fundy. Hence, the waters proceeding from the region of the Saint John Estuary and Passamaquoddy areas are warmer than those at the same level in the open waters of the Bay. At 50 metres (figure 19) the waters in the Grand Manan Channel have temperatures about the same as at the surface and are thus seen to be fairly uniform in temperature, as was observed in figure 16 (section 882-885). There exists a relatively strong temperature gradient between the waters north of the Grand Manan Channel and offshore waters. As at 25 metres, the waters at 50 metres are warmer in the Passamaquoddy area than in the waters of the same depth in the open Bay (greater than 10.0° C. as compared to less than 8.0° C.).

(b) Salinity

The distribution of salinity at a depth of 1 metre is shown in figure 20 where the greatest salinity is seen to be in the waters to the east of Grand Manan. The waters proceeding from Passamaquoddy Bay are of greater salinity (greater than 32.4° /oo) than the waters proceeding from the Saint John region (less than 32.4° /oo). The waters between Grand Manan and the mainland range in salinity between 32.5 and 32.7° /oo.

The greatest salinities at the 25 metre level (figure 21) are

found in the offshore waters. The waters near the entrance to Passamaquoddy Bay have salinities slightly higher (less than 32.5° /oo) than the waters proceeding from the Saint John region (less than 32.4° /oo) while the salinities in the Grand Manan Channel range from 32.5 to 32.7° /oo).

At 50 metres (figure 22) the waters of lowest salinity (less than 32.50° /oo) are to be seen proceeding from the Passamaquoddy region. Between Grand Manan and the mainland the waters have salinities ranging from 32.60 and 32.70° /oo, while the salinities in the offshore waters are greater than 32.9° /oo.

(c) Density

The horizontal distribution of density (σ_t) at 1 metre (figure 23) shows that the lightest water at this level is to the east of the area under investigation and flowing from the Saint John region.

Figure 24 illustrating the distribution of density (σ_t) at 25 metres shows that the waters from the north of the area are flowing southwestward and sweeping in toward Passamaquoddy Bay just north of Grand Manan. The low densities in the approaches to Passamaquoddy Bay indicate that the waters in the region are flowing away from the area to the east of Grand Manan. Since the area is so strongly influenced by the tides it is impossible, using normal procedures, to get adequate data that will support an analysis presupposing simultaneous observations.

At 50 metres (figure 25) the waters are seen to be moving towards the entrance to Passamaquoddy Bay from the northeast past Ft. Lepreau, and from the south through Grand Manan Channel.

III. Discussion

In viewing the overall conditions as found in the Passamaquoddy area, it is found that the waters are brought into the area in the upper 25 metres from the north and east and to a certain extent from the Grand Manan Channel. This water after mixing near the mouth of Passamaquoddy Bay passes out of the area eastward of Grand Manan. Because of the strong tidal mixing and upwelling, the waters near the mouth of Passamaquoddy Bay are denser than the waters further from the shore. This is a result of the denser waters from the centre of the Bay of Fundy being drawn into the deep channel between Grand Manan and Campobello Island and caught up in the mixing process in this area. With regards to residual movements in Grand Manan Channel, these seem to be very slight if at all, and what movements there are appear to be directed northward, at the time of this survey.

The Effect of Spring Freshets

It has been pointed out that the drainage waters from various areas are of great importance in dealing with the hydrography of the Bay of Fundy. The data considered up to this point were collected in the late summer of 1929. It is to be expected that at the time of Spring Freshets these drainage waters would be of greater importance to the region, also there would be a greater contrast between the drainage waters and the waters peculiar to the Bay itself. Due to the difference in the area of the drained regions, certain rivers supply a larger amount of fresh water than others. This would result in a greater contrast in salinity between the waters flowing from the various areas dealt with. In the Spring, there is little contrast in the temperature of the waters from the various sources, and at the

same time, conditions are changing so rapidly that the results obtained over a period of time could not be counted upon to give reliable results. Consequently, of the data collected in a survey carried out during the freshet of 1930, only salinity values are used. The locations of the stations occupied during this survey of the area from April 17th to May 8th, 1930, are given in figure 15.

The horizontal distribution of salinity at 0, 10, 25 and 50 metres is shown in figures 26, 27, 28 and 29 respectively. In the surface distribution (figure 26) the most prominent body of water resulting from the spring freshets is that proceeding from the Saint John River region. The main movement is outward from the Saint John Estuary, swinging to the right as it progresses, and definitely outlined as far as the eastern extremity of Grand Manan. The salinity of the main outflow varies between a value less than $27.5 \text{ }^{\circ}/\text{oo}$ and a value greater than $31.6 \text{ }^{\circ}/\text{oo}$, while the waters from the Passamaquoddy region have salinities greater than $31.8 \text{ }^{\circ}/\text{oo}$. The temperatures of the various waters range from 0.95 ° to 6.63 ° C. at the surface, and from 1.25 ° to 4.90 ° C. at the bottom, thus the relative values of the densities would be roughly in the same proportion as the salinities. Consequently, the waters from the Saint John region eventually cover or mix with the waters from the Passamaquoddy area. There appears to be considerable movement of the fresher and therefore lighter waters from the Saint John area to the Passamaquoddy area. The greatest movement, as has been previously pointed out, is from the Saint John area towards Grand Manan. The water from the Passamaquoddy area penetrates into Grand Manan Channel, and then flows into the Bay of Fundy around the north shore of Grand Manan. It

then tends to proceed down the eastern coast of Grand Manan where it is covered over or mixed with the other waters in that region.

At a depth of 10 metres (figure 27) the range in the distribution of salinity varies between 31.5 to greater than 31.8 ‰. The waters at this depth closely follow the movements at the surface, but they are not on as large a scale.

At 25 metres (figure 28) the outflow from the Saint John River is not as prominent as at higher levels. Thus it may be stated that the fresher water from the Saint John River is carried away in the upper 25 metres and joins with the waters from Passamaquoddy Bay before passing east of Grand Manan at these depths. The water movements at this depth are approximately the same as those in the upper layers.

The distribution of salinity at 50 metres (figure 29) is indicative of a "draw in" of waters to the Saint John and Passamaquoddy area. Waters with salinities as high as 32.20 ‰ reach well into the mouth of the Saint John River, and the entrance to Passamaquoddy Bay.

It has been shown that the movements from the Passamaquoddy and Saint John areas take place in the upper 25 metres. The actual physical and chemical conditions of the waters that make up this outflow will vary, but the fact remains however, that the waters proceeding from the drainage systems gradually become more saline as they progress into the Bay, which means that salt water from the depths is being used up. Consequently, there must be a resultant inflow to make up for this consumption of salt water. As has been demonstrated, this "inflow" or "draw in" takes place at a depth of

about 50 metres. The "draw in" of surface waters to the Passamaquoddy area has also been demonstrated, and it is to be borne in mind that the surface waters drawn into the Passamaquoddy area are from the upper portion of the Bay of Fundy.

Results of Drift Bottle Experiments in the Passamaquoddy Area

In order to furnish a check on the surface water movements in the Passamaquoddy area, drift bottle experiments were carried out in the Spring of 1930. An ordinary type of catsup bottle with a metal drag attached, and containing a post card, was used in the experiments. A piece of red cloth was placed in the neck of the bottle and sealed with a waxed cork. The bottles were put out according to a definite plan, and the plotted returns used to furnish a picture of the surface circulation of the region. The lines along which these bottles were placed, in groups of four at one mile intervals, are illustrated in figures 30, 31, 32, 33 and 34. The times at which the bottles were released and the time at which they were found is used to determine the maximum time of drift. Those bottles returned within the shortest period of time were used to determine the most probable direction and rate of drift. These form the basis upon which the various drifts were plotted. Mavor's (1922) results are also used as a basis for plotting the resultant movements. It is to be borne in mind that drift bottles are carried to and fro by the tides, and that the resultant movement or circulation over a period of time is represented by the paths of the various bottles. The results of the returns from the various drift bottle lines will be dealt with by dividing the investigation into five series A, B, C, D, and E.

I. Series A

The base for this series of drift bottles (figure 30), on which four bottles were thrown out at each of fifteen points at intervals of one mile, runs along a line from the coast of Grand Menan eastward. A total of 60 bottles were put out of which 27 or 45% were returned. It is seen that the resultant movement indicated for this region is outward, with those on the outer half of the line recurving to the coast of Nova Scotia and those on the inner half generally rounding the southern tip of Grand Menan and working down the coast of Maine. Following the movement of a large number of bottles, it is seen that at least three make a complete circuit of the lower half of the Bay of Fundy. The suggested movements demonstrate a cyclonic circulation around the basin and a clockwise movement around the eastern and southern coast of Grand Menan. In a particular case, a bottle set out at point 9 was picked up at Parker's Cove, giving it a minimum rate of travel of 4 miles per day (5.6 km. per day).

II. Series B

The base for this series of bottles is shown in figure 31. Four bottles were set out at each of twenty-two points on a line running northeasterly from Grand Menan for 8 miles and then in a northwesterly direction for a distance of 13 miles toward the New Brunswick coast. Fifty-four per cent of a total of 84 bottles set out on these lines were returned. The bottles put out over the last 13 miles (24 km.) of the line demonstrated a well defined movement of the surface waters toward the entrance to Passamaquoddy Bay. A large number of bottles found their way along the east coast of Grand Menan, some rounding Grand Menan, while others crossed over to the

coast of Nova Scotia. It is to be noted that in the vicinity of White Head some of the bottles on reaching this area proceed toward the Maine Coast while others cross the Bay of Fundy to Nova Scotia. This feature is to be noted in all of the series made in this experiment.

III. Series C

Four bottles were thrown out at each of nine points on a line between the coast of Maine and Grand Manan (figure 32). Of a total of 36 bottles that were released 39% were returned. All bottles tended towards the coast of Grand Manan, and rounding the northern tip of Grand Manan, some almost circled Grand Manan to reach the coast of Maine, while others reached the coast of Nova Scotia. Two of the bottles put out from point 9 were returned from the eastern side of Grand Manan on May 12th, 1930, and May 13th, 1930. They therefore had travelled at a rate of not less than 6 miles per day (9.6 km. per day) and 5 miles per day (8.0 km. per day), respectively.

IV. Series D

Figure 33 shows the base lines of Series D beginning near the main coast of New Brunswick and ending at Grand Manan. Four bottles were put out at each of nineteen points and of these 50% were returned. The general movement was towards the entrance to Passamaquoddy Bay. A number of bottles reached the eastern coast of Grand Manan and from this region proceeded either to the coast of Maine or the coast of Nova Scotia. Several bottles reached into Grand Manan Channel almost half way down the north side. A bottle put out at point 14 was picked up on May 8th, 1930, off Grand Manan, and has thus

travelled at a minimum rate of 3 miles per day (4.8 km. per day). Another bottle, set out at point 14 was picked up at New River Beach on June 22, 1930, and therefore had covered a distance of at least 120 miles (193 km.) in a period of not less than 48 days.

V. Series E

The base line in this series (figure 34) runs from the northeastern point of Maine to the northern tip of Grand Menan. A total of 28 bottles were put out of which 64% were returned. It will be noticed that these bottles from the extreme western end of the line made their way down the coast of Maine. Some reach well into Passamaquoddy Bay, while others rounded the northern point of Grand Menan and by following the east coast, found their way around the southern tip of Grand Menan to reach the coast of Maine. One bottle reached the Nova Scotia Coast. One bottle put out at point 7 on the extreme eastern end of the line, crossed over to the coast of Maine. This bottle, no doubt, had drifted to the entrance of Passamaquoddy Bay and thence down the coast to the point at which it was found. A bottle put out at point 6 was picked up on May 9th, 1930, off Campobello Island and therefore had travelled at a minimum rate of 2½ miles per day (3.6 km. per day).

VI. Discussion

The plotted results from the drift bottle experiments are subject to some correction. It is obvious that the exact path of any one bottle is unknown. A general picture is derived from the more or less direct joining of the points of release and return. Coupled with this, the information, derived from the bottles that drifted for the shortest length of time, is used to give a more rigid picture of the water movements. A summary of the definite results of the

investigation follows:

(a) All of the drift bottles indicated a tendency of the waters to circulate the island of Grand Menan in a clockwise direction. The complete circuit of Grand Menan is not suggested by the results from any one bottle. The physical nature of the bottom to the southwest of Grand Menan is probably responsible, as it has been previously shown that the surface waters to the southwest of Grand Menan circulate in an anti-clockwise direction.

(b) The movements of the bottles suggest a cyclonic circulation about the basin determined by the 50 fathoms (91 m.) contour in the Bay of Fundy.

(c) An intense movement towards the mouth of Passamaquoddy Bay is definitely illustrated, while it will be noted that the water movement along the coast of Campobello Island is outward.

(d) An inward movement in the main waters between Grand Menan and the mainland is noted in keeping with the clockwise circulation about Grand Menan. However, the waters in contact with the coast of Maine have an outward movement.

Annual Variations in Temperature and Salinity

Variations in temperature and salinity that occurred in the Bay of Fundy between the years 1924 and 1930 inclusive, are illustrated by reference to data obtained monthly from Station 5. The variations in the conditions of the more stratified and deeper waters toward the mouth of the Bay are illustrated by observations made at Station 3 (Mavor 1923) between the years 1916 and 1918 inclusive. The locations of these stations are shown in figure 15.

I. Temperatures at Station 3

In figure 35(a) the temperatures at Station 3 are plotted for depths of 0, 50, and 150 metres for the period of November 1916 to May 1918. In November 1916, the temperatures at depths 0 and 50 metres were practically the same (7.6 °C.), while at 150 metres the temperature was 6.3 °C. Early in December, however, the temperature was fairly uniform throughout (6.1 - 6.7 °C.). It will be noted that temperatures increase with depth until the last week in March when conditions are approximately the same throughout (7.0 °C.). The minimum temperature of 1.5 °C. in the surface layer is reached in early February, while the minimum is reached at 50 m. in late February, and at 150 m. in early April. In the period from the time the waters are of uniform temperature until the time the minimum surface temperature is reached, the changes in temperature represent one phase of the temperature cycle that occurs in inshore waters. After this date, the effect of insolation begins to be noticeable and the surface temperatures begin to rise. It is not until the end of April that water temperatures at 50 metres are greater than those at 150 metres. The temperatures continue to rise until the peak is reached in the surface layers in late August which marks the end of the second phase in the temperature cycle. However, the subsurface waters continue to rise until about the end of September which represent the third phase. Thereafter the temperatures decrease uniformly at all depths until December when uniform temperature conditions are approached with temperatures between 5.6 and 6.2 °C., marking the end of the fourth phase. Following the changes from this point on, we find that in 1917 the temperature of the water is fairly uniform until late in January with temperatures between 2.4 and 2.7 °C., the

minimum temperature being reached in early April ($2.0 - 2.4^{\circ} \text{C}.$). Thus, while the cycle is maintained throughout the years, the dates and temperatures at the ends of the various phases may vary considerably from year to year.

II. Salinities at Station 3

In figure 35(b) the salinities at Station 3 are plotted for depths of 0, 50, and 150 metres for the period, November 1916 to May 1918. In November 1916, the salinities at 0 and 50 metres are the same ($32.7^{\circ} / \text{oo}$), while the salinity at 150 metres is greater ($33.0^{\circ} / \text{oo}$). The maximum value of $32.8^{\circ} / \text{oo}$ is reached in the surface waters in early December, while the maximum value of the salinity at depths of 50 and 150 metres is reached in early January with values of 33.0 and $33.3^{\circ} / \text{oo}$, respectively. Salinities then decrease in the upper levels and a minimum value of $27.9^{\circ} / \text{oo}$ is reached in the surface waters in the early part of May. In the waters at the 50 metre level a minimum value of $31.8^{\circ} / \text{oo}$ is reached in early September. At the 150 metre level the waters attain a salinity of $32.7^{\circ} / \text{oo}$ in early July, and then increases sharply to a value of $33.3^{\circ} / \text{oo}$ in early August. The decrease in salinity in the surface layer is accompanied by a decrease in the salinity of the waters at 50 metres. The increase in the salinity of the bottom layer in July is associated with an increase in salinities in the upper layers. The increase in the salinity of the bottom layer is indicative of replacement of the water at this level by a supply of more saline water from the open ocean. The replenishment is limited, however, as is shown by the decrease in the salinity of all layers from September until January. An increase in the salinity of all layers takes place from the latter part of January until early April.

due to the lack of fresh water run-off from the land. Freshet effects are again evidenced in early May.

III. Discussion

It may be seen that the variations in temperature and salinity, as reflected at Station 3, are indicative of vertical mixing of the waters of the various levels. This mixing is brought about by the following two agencies:

- (a) Tidal mixing and upwelling which are common throughout the Bay.
- (b) Mixing resulting from seasonal changes in density.

The density of the water is determined by its temperature and salinity, the minimum density occurring during the summer and the maximum in the winter time. As the densities fluctuate between these maxima and minima, there are times when the surface waters, which have the greater range, have the same density as the subsurface waters. This greatly facilitates vertical mixing through tidal and wind action so that in time a thick isopycnic layer is developed, at times reaching nearly to the bottom. This mixing causes an interchange between the waters at various levels. In 1916, this interchange was completed by the latter part of March. The interchange may not have occurred from top to bottom throughout, but it did take place in certain layers, at least throughout a period extending from early November to late March. The intensive interchange must have taken place in late November and was slowed considerably by a freshening of the surface waters and an increase in the salinity of the bottom waters. From early April onwards the heating and freshening of the surface layers bring about stable conditions that are not overcome until late November when interchange between the surface water and the water at the 50 metre

level is able to take place. It is not until late January that the water in the lower levels can be displaced through vertical mixing.

The increase in the salinity of the bottom layers can only take place when a supply of water of greater salinity is available. The replacement by outside waters undoubtedly takes place continuously, but the magnitude of the supply appears to vary considerably. In figure 35(b), we note that in early January, 1916, the salinity of the bottom layer increased to a considerable extent. Comparable increases occur again in early August 1917, and again in early April 1918. A considerable difference in salinity at the various levels is to be noted in comparing the conditions of January, 1917, with those of January 1918.

IV. Temperatures at Station 5

Typical temperature-depth curves of water conditions at Station 5 for each month for the years 1924 through 1930 are shown in figure 36. It will be noted that throughout the period the coldest surface water is always found in February or March. The coldest water at a depth of 20 metres is found in March in all years with the exception of 1930 when the coldest water at this depth was found in February. At a depth of 90 metres the coldest water was found in February in 1924, in April in 1929, and in March for all other years. The warmest surface waters occur in August or September, in all years except in 1927 and 1930, when the peak was reached in October. The warmest water at 90 metres occur in September or October. The maximum and minimum temperatures of each level for each year of the complete period is given as follows:

Year	Surface		20 Metres		90 Metres	
	Min.	Max.	Min.	Max.	Min.	Max.
1924	1.2	10.9	1.5	10.2	1.7	9.9
1925	1.1	11.3	1.0	10.8	1.2	9.2
1926	0.1	11.8	-0.1	10.2	-0.7	9.7
1927	1.3	11.1	1.0	10.3	1.2	9.3
1928	2.6	11.9	2.3	11.4	2.7	10.1
1929	1.9	11.8	1.9	11.0	2.1	8.8
1930	0.6	12.8	0.7	11.5	1.2	11.2

V. Salinities at Station 5

In figure 37 the salinities are plotted against depth for the years 1924 to 1930 inclusive for Station 5. The freshest waters are found at the surface in either April or May. At 20 metres the less saline waters are found in April, May, June or even July. The lowest salinity at a depth of 90 metres, may be found in any month within the period from January to July. The waters of highest salinities are to be found at all depths in the period extending from September to February. The changes in salinities are not nearly as regular as the corresponding changes in temperatures, and there may be considerable difference from month to month. The maximum and minimum values of the salinities for each level for each year of the complete period is given as follows:

Year	Surface		20 Metres		90 Metres	
	Min.	Max.	Min.	Max.	Min.	Max.
1924	27.30	32.84	31.00	32.72	32.03	32.75
1925	31.00	32.63	31.31	32.88	31.94	33.17
1926	25.88	33.01	30.86	32.72	32.20	33.19
1927	29.34	32.61	30.88	32.72	32.09	33.12
1928	29.09	32.88	31.55	33.01	32.16	33.40
1929	31.51	32.77	31.69	32.77	32.39	33.15
1930	31.04	32.43	31.40	32.54	31.91	32.52

(f) Discussion

In referring to the tables showing the maximum and minimum

values of the temperatures and salinities throughout the period dealt with, it will be noted that there are considerable variations in the conditions from year to year. With regard to the temperature values alone, it is seen that there is a direct relationship between the temperatures of the surface waters and the temperatures of the waters in the lower levels. This means that there must be some means of transfer of heat in one direction or another between the various levels. During the summer months when the sun's heat is being absorbed by the surface layers, very little of this heat can be transferred by conduction or direct radiation to the lower levels, due to the increased stability of the waters in the surface layers. The direct relationship noted between summer temperatures at the surface and summer temperatures at the bottom indicates that a highly efficient mixing process is at work in the Bay of Fundy. On comparing the maximum temperatures given for the various years it is seen that the years in which a higher surface temperature prevails, are also those in which high temperatures are found in the waters at the greater depths. The lowering of the temperatures at the surface tends to set up ordinary convection currents so that the process of mixing of the waters at the various levels is enhanced. Colder surface temperatures are also shown to be indicative of colder bottom temperatures. At this point it might be argued that variations of surface temperatures in this region would be indicative of the variations in the bottom temperatures. It is readily seen that though the heat transferred from the water at the surface determines the temperatures of the waters of the Bay of Fundy, the temperatures of the bottom waters carried into the Bay control the temperatures of the deep waters in the Bay. The actual part played by the various agencies depends in the first case upon climatic

conditions and in the second upon the amount of deeper water that is carried into the Bay. This argument is further enhanced by inspection of the tables of salinity values. The salinity, in the main, is determined by the relative amounts of fresh and salt waters carried into the Bay by their respective agencies. Evaporation enters as a negligible factor. The amount of fresh water supplied is limited, and varies considerably from year to year. The lower salinity values found at the surface hold only for the times of river freshets which are of short duration. Consequently, there is nothing in the way of a direct relationship between salinity values at the surface and those found at greater depths. In other words, the movement of the outside waters into the Bay is the main factor in the determination of the salinity of the waters at the greater depths, and the waters from the greater depths are the prime factors in the determinations of the salinities of the waters in the whole Bay.

Representative Surface Water Temperatures

Four points in the Bay of Fundy were chosen such that they would indicate the temperature regime in their respective areas. The surface temperatures for these points are plotted in figure 38. Lurcher Lightship data are indicative of conditions in the Bay near the western coast of Nova Scotia, while Grand Manan data are indicative of conditions to the southwest of the Island. Conditions at the head of the Bay are indicated by data taken at the Isle Haute, while the conditions in Passamaquoddy Bay are represented by data from St. Andrews.

The main features brought out by these data are that periodicity of the temperatures in the four areas are approximately identical,

and that the annual temperature ranges vary from one area to another. In particular, it is seen that at Isle Haute, at the head of the Bay, the temperatures ranged from greater than 14.0^o C. in August, 1929, to less than -1.0^o C. in February, 1930. At St. Andrews, the temperatures ranged from greater than 13.0^o C. in August and September, 1929, to -1.0^o C. in January and February of the following year. In 1929, at Grand Manan, the highest daily average temperature was 11.0^o C. in late September, with the lowest of -1.0^o C. in February 1930. At Lurcher Lightship the highest daily average temperature of 12.0^o C. was recorded in August 1929, while the lowest was 2.0^o C. in February, 1930. Thus, in comparing the annual ranges for the various points, the efficiency of mixing in different areas in the Bay of Fundy can be appreciated. These annual ranges are as follows:

Isle of Haute	-1.0 ^o C.	15.0 ^o C.
St. Andrews	-1.0	14.0
Grand Manan	-1.0	13.0
Lurcher Lightship	2.0	15.0

The range in temperature at Isle Haute, St. Andrews, and Grand Manan show a gradation from 16^o C. at the head of the Bay to 13^o C. at the mouth. These results further illustrate the results of progressive mixing of the waters that take place in the Bay. During the summer months, the bottom waters at the mouth of the Bay have comparatively low temperatures. Mixing, with the resultant bringing up of bottom water, tends to keep the surface temperatures low. As a result of this mixing, the bottom waters further up the Bay have slightly higher temperatures than those at the mouth. Consequently, their effect on the temperature of the surface water is not as great.

During the winter months the bottom waters from outside are of comparatively high temperature. The quantity of outside bottom water brought into the Bay during the winter months is probably at a minimum due to the relatively small amount of surface outflow. Consequently, the mixing process exerts a minimum effect on the surface temperatures, with the result that little difference is to be found between the minimum daily average temperature at different parts of the Bay. The general cold surface waters present throughout the summer months is productive of a considerable amount of fog in the Bay of Fundy region. It is probable that the minimum amount of fog occurs at the head of the Bay while the maximum occurs at the mouth. This factor must be taken into account in dealing with the average daily water temperatures at different parts of the Bay. The range in temperature at Lurcher Lightship is 13.0 C. a minimum for the whole region. Temperatures in the vicinity of 15.0 C. were obtained over a very short period in 1931 only, as may be seen from the plotted results. The absence of fog in this region during this time is a probable explanation of this short temperature rise. Lurcher Lightship is so located that the waters in this area are always effected to a considerable degree by the waters from the open ocean. This fact is clearly shown by the temperatures in the winter months, with a minimum value of 2.0 C.

Summary of Results

- (a) The large tides coupled with the nature of the bottom configuration are responsible for the specific hydrographic conditions found in the Bay of Fundy.
- (b) The bottom of the Bay consists of three important types: mud, sand and stones, rocks and ledges.

(c) Inflowing waters from the open ocean hold close to the Nova Scotia Coast.

(d) Outflowing waters round Grand Manan to the east and tend to flow along the Coast of Maine.

(e) As the waters are carried out into the Bay a progressive mixing takes place with the result that the waters at the head of the Bay are found to be thoroughly mixed.

(f) Mixing on a considerable scale has been shown to occur over a considerable area to the southwest of Grand Manan, and also over an area extending along the northwestern coast of Nova Scotia.

(g) Waters from the Saint John Estuary flow out in the surface layers and reach to the east of Grand Manan. Deep bottom water is drawn in to the region of the Saint John Estuary, particularly at times of Spring freshets.

(h) Waters from the entrance to Passamaquoddy Bay tend to hold close to the coast of Campobello Island. Before proceeding far they sink to lower levels or mix with adjacent waters. Surface water proceeding from the upper end of the Bay of Fundy is drawn into the entrance to Passamaquoddy Bay. Deep bottom waters are also drawn in at the lower levels.

(i) The circulation in the main portion of the Bay of Fundy is in an anti-clockwise direction. The circulation of the water around Grand Manan is in a clockwise direction. To the southwest of Grand Manan the waters which cover a considerable area are circulating in an anti-clockwise direction. These latter waters are heavier than surrounding ones and sink to lower levels when they are released from the region.

(j) Spring freshet results bring out the importance of the waters in the region of the Saint John Estuary to the general conditions in the Bay of Fundy.

(k) Variations in temperature and salinity throughout a period of seven years indicate the changes that took place throughout this period. Variations in the temperature conditions at different points in the Bay indicate the differences in the prevailing temperatures.

Acknowledgements:

All data was collected under the direction of Dr. A. G. Huntsman who was responsible for the development of the general hydrographic work, as carried out by the Atlantic Biological Station. His direction and kindly suggestions are gratefully acknowledged. It is a pleasure also, to refer to the efficient co-operation of Mr. A. E. Calder, Master of the M.V. "Prince" and later of the M.V. "Zoarces".

References

- Andersen, F. Tide Tables for the Eastern Coasts of Canada for the Year 1931. Ottawa, 92 pp. 1930.
- Craigie, E. Horne and W. H. Chase. Further Hydrographic Investigations in the Bay of Fundy. Contr. Can. Biol. (1917-1918), Ottawa, 127-136, 1918.
- Dawson, W. Bell. Tables of Direction and Velocity of Currents and Time of Slack Water in the Bay of Fundy. Ottawa, 15 pp. 1908.
- Hachey, H. B. The General Hydrography of the Waters of the Bay of Fundy. Atlantic Biological Station. Original Manuscript 389, 1931.
- Marmer, H. A. The Tide. New York, 282 pp. 1926.
- Mavor, J. W. The Circulation of the Waters in the Bay of Fundy.
Part I, Contr. Can. Biol. N. S. I, 103-124 pp. 1922.
- The Circulation of the Waters in the Bay of Fundy.
Part II. Contr. Can. Biol. N.S. I, 355-375 pp. 1923.
- Vachon, A. Hydrography in Passamaquoddy Bay and Vicinity New Brunswick. Contr. Can. Biol. (1917-1918) Ottawa, 295-328 pp. 1918.

Table I.

<u>Station</u> <u>No.</u>	<u>Date</u> <u>1929</u>	<u>Time</u>	<u>Depth</u> <u>M.</u>	<u>Salinity</u>	<u>Density</u>	<u>Temperature</u> <u>°C.</u>
658	Sept. 29	3.26 p.m.	0	29.99	22.19	14.80
			1	30.08	22.27	14.75
		3.21	25	31.58	23.47	14.49
664	Sept. 19	9.00 p.m.	0	32.05	24.02	13.60
			1	32.09	24.00	13.80
		8.55	20	32.14	24.08	13.61
665	Sept. 19	8.25 p.m.	0	31.76	23.63	14.40
			1	31.74	23.55	14.70
		8.20	25	31.76	23.58	14.61
666	Sept. 19	7.52 p.m.	0	31.83	23.71	14.30
			1	31.78	23.61	14.56
		7.47	25	31.82	23.65	14.51
667	Sept. 19	6.57 p.m.	0	31.94	23.87	13.90
			1	31.96	23.86	14.05
		6.52	25	31.92	23.82	14.10
668	Sept. 19	6.24 p.m.	0	32.03	24.03	13.50
			1	31.96	23.93	13.70
		6.19	25	31.96	23.93	13.70
669	Sept. 19	5.31 p.m.	0	31.89	23.82	13.95
			1	31.82	23.86	13.90
		5.25	25	32.10	24.07	13.50
670	Sept. 19	4.55 p.m.	0	31.91	23.85	13.90
			1	31.87	23.78	14.10
		4.50	25	32.03	24.01	13.60

Table I (continued)

<u>Station</u> <u>No.</u>	<u>Date</u> <u>1929</u>	<u>Time</u>	<u>Depth</u> <u>M.</u>	<u>Salinity</u>	<u>Density</u>	<u>Temperature</u> <u>°C.</u>
671	Sept. 19	4.01 p.m.	0	31.53	23.43	14.50
			1	31.49	23.35	14.75
		3.55	25	31.83	23.76	14.05
897	Sept. 7	1.11 p.m.	0	32.27	24.33	12.90
			1	32.29	24.49	12.09
		1.05	25	32.39	24.69	11.47
933	Aug. 21	3.26 p.m.	0	32.30	24.25	13.40
			1	32.29	24.30	13.10
		3.20	25	32.38	24.97	9.69
934	Aug. 21	5.11 p.m.	0	32.16	24.03	13.95
			1	32.14	24.17	13.16
		5.05	25	32.95	25.46	9.54
935	Aug. 21	2.00 p.m.	0	32.52	24.65	12.20
			1	32.43	24.66	11.80
		1.55	25	32.59	25.18	9.49
		1.50	50	-	-	8.88
936	Aug. 21	11.58 p.m.	0	32.65	24.43	13.80
			1	32.68	24.49	13.66
		11.53	25	32.66	25.10	10.29
		11.48	50	32.92	25.59	8.49
		11.43	75	33.10	25.86	7.59
11.35	100	33.19	25.97	7.34		

Table I (continued)

<u>Station No.</u>	<u>Date 1926</u>	<u>Time</u>	<u>Depth M.</u>	<u>Salinity</u>	<u>Density</u>	<u>Temperature °C.</u>
937	Aug. 21	9.29 a.m.	0	32.70	24.17	15.20
			1	32.66	24.13	15.26
		9.24	25	32.77	25.11	10.79
		9.18	50	33.01	25.94	6.50
		9.12	75	33.28	26.27	5.55
		9.06	100	33.71	26.61	5.61
		8.58	125	33.87	26.70	5.81
		8.50	150	34.00	26.72	6.00
		8.41	170	34.02	26.74	6.00
938	Aug. 21	11.44 p.m.	0	32.45	24.90	10.50
			1	32.43	24.92	10.30
		11.39	25	32.50	25.06	9.74
		11.32	45	32.57	25.13	9.69
939	aug. 26	1.56 a.m.	0	32.68	25.22	9.70
			1	32.72	25.26	9.60
		1.51	25	32.77	25.38	9.06
		1.45	50	32.81	25.45	8.81
		1.39	75	---	---	8.06
		1.31	100	33.12	25.63	7.95
940	Aug. 26	3.51 a.m.	0	32.84	25.28	10.10
			1	32.81	25.26	10.00
		3.46	25	32.88	25.86	9.11
		3.40	50	33.08	25.86	7.50

Table I (continued)

<u>Station No.</u>	<u>Date 1929</u>	<u>Time</u>	<u>Depth M.</u>	<u>Salinity</u>	<u>Density</u>	<u>Temperature °C.</u>	
941	Aug. 26	6.00 a.m.	0	32.70	24.74	12.40	
			1	32.70	24.74	12.40	
		5.55	25	32.83	25.14	10.80	
			5.49	50	33.03	25.81	7.60
			5.43	75	33.08	25.98	6.65
			5.35	100	33.46	26.32	6.31
942	Aug. 26	8.01 a.m.	0	32.81	25.29	9.85	
			1	32.81	25.31	9.75	
		7.55	25	32.95	25.61	8.55	
			7.49	50	32.99	25.75	7.81
			7.43	75	33.21	26.08	6.60
943	Aug. 26	9.40 a.m.	0	32.75	25.14	10.50	
			1	32.72	25.18	10.10	
		9.34	25	32.83	25.47	8.85	
			9.28	50	32.90	25.58	8.46
			9.21	75	33.08	25.80	7.95
948	Sept. 7	8.04 a.m.	0	32.32	24.52	12.05	
			1	32.32	24.55	11.95	
		7.58	25	32.59	25.07	10.19	
949	Sept. 7	9.13 a.m.	0	32.68	24.83	11.90	
			1	32.68	24.87	11.70	
		9.08	25	32.74	25.18	10.15	
			9.01	50	32.84	25.38	9.49
			8.55	75	33.03	25.73	8.15
				100	33.15	25.90	7.64

Table I (continued)

<u>Station no.</u>	<u>Date 1929</u>	<u>Time</u>	<u>Depth M.</u>	<u>Salinity</u>	<u>Density</u>	<u>Temperature °C.</u>
950	Sept. 7	10.26 a.m.	0	32.47	24.65	12.00
			1	32.39	24.64	11.75
		10.21	25	32.63	25.02	10.65
		10.15	50	32.92	25.63	8.26
		10.09	75	33.08	25.83	7.70
		10.02	100	33.10	25.90	7.31
		9.54	120	33.15	25.95	7.30
951	Sept. 7	11.23 a.m.	0	32.34	24.49	12.30
			1	32.29	24.48	12.14
		11.18	25	32.72	25.25	9.69
			50	32.99	25.73	7.96
		11.07	75	33.08	25.86	7.55
		11.01	100	33.04	25.83	7.49
952	Sept. 7	12.12 p.m.	0	32.32	24.52	12.10
			1	32.32	24.59	11.70
		12.07	25	32.59	24.95	10.90
		12.01	50	32.75	25.36	9.14
		11.55	70	32.92	25.62	8.33
953	Sept. 6	11.17 a.m.	0	32.70	25.12	10.35
			1	32.70	25.16	10.10
		11.12	25	32.68	25.15	10.10
		11.05	50	32.63	25.12	10.03
954	Sept. 7	12.10 p.m.	0	32.68	25.12	10.30
			1	32.59	25.07	10.15
		12.04	25	32.68	25.17	10.00

Table I (continued)

<u>Station No.</u>	<u>Date</u> <u>1929</u>	<u>Time</u>	<u>Depth</u> <u>M.</u>	<u>Salinity</u>	<u>Density</u>	<u>Temperature</u> <u>oC.</u>
954	Sept. 7	11.59	50	32.61	25.11	10.00
		11.53	75	32.63	25.13	9.99
955	Sept. 7	12.54 p.m.	0	32.56	25.00	10.40
			1	32.57	25.05	10.15
		12.49	25	32.57	25.04	10.20
		12.44	50	32.59	25.03	10.40
956	Sept. 10	6.33 p.m.	0	32.27	24.57	11.60
			1	32.41	24.70	11.45
		6.28	20	32.61	24.66	11.42
957	Sept. 10	7.34 a.m.	0	32.32	24.52	12.05
			1	32.41	24.58	12.10
		7.29	25	32.61	25.07	10.25
		7.23	50	32.77	25.36	9.20
		7.18	75	33.06	25.81	7.75
958	Sept. 10	8.40 a.m.	0	32.20	24.53	11.50
			1	32.59	24.64	11.50
		8.35	25	32.65	24.97	11.00
		8.30	50	33.12	25.23	7.96
		8.25	75	33.06	25.88	7.21
		8.18	100	33.13	25.96	7.00
960	Sept. 10	10.21 a.m.	0	32.52	24.83	11.20
			1	32.59	24.92	11.03
		10.19	25	32.83	25.40	9.26
		10.11	50	32.92	25.57	8.65
		10.06	75	33.13	25.89	7.55
		9.58	100	33.19	25.95	7.50

Table I (continued)

<u>Station</u> <u>No.</u>	<u>Date</u> <u>1929</u>	<u>Time</u>	<u>Depth</u> <u>M.</u>	<u>Salinity</u>	<u>Density</u>	<u>Temperature</u> <u>°C.</u>
961	Sept. 10	11.17 a.m.	0	32.48	24.89	10.70
			1	32.61	25.01	10.59
		11.12	25	32.97	25.64	8.46
		11.07	50	32.99	25.71	8.06
		11.01	75	33.06	25.78	7.90
962	Sept. 10	12.36 p.m.	0	32.59	25.06	10.20
			1	32.84	25.38	9.49
		12.30	20	32.92	25.46	9.29
963	Sept. 12	7.28 p.m.	0	32.84	25.34	9.70
			1	32.86	25.35	9.70
		7.23	20	32.92	25.42	9.59
964	Sept. 12	8.42 a.m.	0	32.72	25.00	11.15
			1	32.72	25.02	11.00
		8.37	25	32.95	25.56	8.39
		8.31	50	32.97	25.59	8.75
		8.25	75	32.99	25.63	8.58
965	Sept. 12	9.54 a.m.	0	32.61	24.74	12.05
			1	32.54	24.70	12.00
		9.49	25	32.92	25.50	9.05
		9.44	50	32.99	25.66	8.40
		9.38	75	33.12	25.76	8.38
966	Sept. 12	11.07 a.m.	0	32.54	24.66	12.20
			1	32.54	24.69	12.05
		11.02	25	32.84	25.36	9.59
		10.56	50	32.99	25.68	8.30
		10.50	75	33.10	25.79	7.98
967	Sept. 12	12.18 p.m.	0	32.57	24.72	12.05
			1	32.56	24.73	11.90
		12.13	25	32.86	25.47	8.95
		12.07	50	32.95	25.60	8.65
		12.00	75	32.97	25.62	8.54
968	Sept. 12	1.21 p.m.	0	32.32	24.52	12.05
			1	32.32	24.55	11.90
		1.15	25	32.39	24.68	11.54
969	Sept. 16	7.33 a.m.	0	31.69	24.04	12.00
			1	31.65	24.17	12.00
		7.18	20	32.16	24.47	11.70
970	Sept. 16	8.30 a.m.	0	32.07	24.09	13.30
			1	32.03	24.08	13.20
		8.25	25	32.83	25.37	9.49
		8.18	50	32.84	25.41	9.29

Table I (continued)

<u>Station No.</u>	<u>Date</u> <u>1929</u>	<u>Time</u>	<u>Depth</u> <u>M.</u>	<u>Salinity</u>	<u>Density</u>	<u>Temperature</u> <u>oC.</u>
971	Sept. 16	9.43 a.m.	0	32.54	24.72	11.90
			1	32.61	24.80	11.75
		9.28	25	32.68	24.94	11.20
			50	32.84	25.36	9.59
			75	32.84	25.36	9.59
972	Sept. 16	11.06 a.m.	0	32.66	24.73	12.35
			1	32.56	24.75	11.85
		11.00	25	32.86	25.35	9.69
			50	32.84	25.36	9.62
973	Sept. 16	12.12 p.m.	0	32.75	25.02	11.20
			1	32.75	25.14	10.49
		12.06	20	32.75	25.16	10.37

Table II.

<u>Station No.</u>	<u>Date</u> <u>1929</u>	<u>Time</u>	<u>Depth</u> <u>M.</u>	<u>Salinity</u>	<u>Density</u>	<u>Temperature</u> <u>oC.</u>
853	Sept. 5	11.47 a.m.	0	32.36	24.66	11.45
			1	32.38	24.73	11.10
		11.42	25	32.38	24.73	11.15
			50	32.47	24.82	11.05
			75	32.36	24.72	11.20
			100	32.43	24.81	10.94
873	Sept. 5	1.09 p.m.	0	32.54	24.73	11.80
			1	32.47	24.77	11.35
		1.04	25	32.54	24.98	10.69
			50	32.59	25.10	9.98
874	Sept. 5	1.42 p.m.	0	32.43	24.75	11.30
			1	32.45	24.79	11.10
		1.37	25	32.48	24.93	10.50
			50	32.57	25.06	10.15
			75	32.59	25.09	10.04
880	Sept. 7	3.00 p.m.	0	32.32	24.34	13.00
			1	32.41	24.64	11.80
		2.54	25	32.59	25.10	10.01
882	Sept. 6	9.26 a.m.	0	32.72	25.12	10.45
			1	32.68	25.16	10.05
		9.21	25	32.72	25.22	9.85
			50	32.77	25.27	9.79

Table II (continued)

<u>Station</u> <u>No.</u>	<u>Date</u> <u>1929</u>	<u>Time</u>	<u>Depth</u> <u>M.</u>	<u>Salinity</u>	<u>Density</u>	<u>Temperature</u> <u>oC.</u>
883	Sept. 6	8.47 a.m.	0	32.61	24.94	11.00
			1	32.59	24.95	10.90
		8.42	25	32.59	25.01	10.55
			50	32.68	25.11	10.35
			75	32.68	25.14	10.14
884	Sept. 6	8.08 a.m.	0	32.57	24.92	10.95
			1	32.56	24.93	10.80
		8.04	25	32.56	24.99	10.45
			50	32.74	25.26	9.69
			75	32.74	25.27	9.64
885	Sept. 6	7.32 a.m.	0	32.61	25.03	10.45
			1	32.61	25.04	10.40
		7.27	25	32.68	25.11	10.35
			50	32.66	25.12	10.14
887	Sept. 5	2.41 p.m.	0	32.56	24.93	10.80
			1	32.54	24.96	10.55
		2.36	25	32.57	25.06	10.15
			50	32.61	25.09	10.10
			75	32.74	25.26	9.69
890	Sept. 5	6.31 p.m.	0	32.54	24.83	11.30
			1	32.43	24.77	11.20
		6.25	25	32.52	24.85	11.10
			50	32.63	25.14	9.90
			75	32.66	25.23	9.53
891	Sept. 5	5.54 p.m.	0	32.41	24.73	11.30
			1	32.38	24.72	11.20
		5.46	25	32.43	24.77	11.20
			50	32.59	25.04	10.34
			75	32.63	25.15	9.68
892	Sept. 5	5.05 p.m.	0	32.38	24.54	12.15
			1	32.30	24.53	11.95
		5.00	25	32.65	25.17	9.79
			50	32.83	25.48	8.73
893	Sept. 5	4.36 p.m.	0	32.39	24.56	12.25
			1	32.32	24.50	12.20
		4.31	25	32.48	24.87	10.80
			50	32.75	25.34	9.30
			75	32.95	25.62	8.48

Table II (continued)

<u>Station</u> <u>No.</u>	<u>Date</u> <u>1929</u>	<u>Time</u>	<u>Depth</u> <u>M.</u>	<u>Salinity</u>	<u>Density</u>	<u>Temperature</u> <u>°C.</u>
894	Sept. 5	3.52 p.m.	0	32.43	24.73	11.40
			1	32.47	24.79	11.20
		3.47	25	32.48	24.88	10.75
		3.41	50	32.57	25.05	10.19
		3.36	75	32.63	25.15	9.88
895	Sept. 5	3.16 p.m.	0	32.56	24.82	11.45
			1	32.50	24.84	11.05
		3.11	25	32.56	24.99	10.49
		3.06	50	32.56	25.00	10.44
		3.00	75	32.63	25.09	10.19
896	Sept. 7	2.06 p.m.	0	32.41	24.45	12.80
			1	32.36	24.53	12.15
		2.00	25	32.47	24.84	10.96
897	Sept. 7	1.11 p.m.	0	32.27	24.33	12.90
			1	32.29	24.49	12.09
		1.05	25	32.39	24.69	11.47
948	Sept. 7	8.04 a.m.	0	32.32	24.52	12.05
			1	32.32	24.55	11.95
		7.58	25	32.59	25.07	10.19
949	Sept. 7	9.13 a.m.	0	32.68	24.83	11.90
			1	32.68	24.87	11.70
		9.08	25	32.74	25.18	10.15
		9.01	50	32.84	25.38	9.49
		8.55	75	33.03	25.73	8.15
			100	33.15	25.90	7.64
950	Sept. 7	10.26 a.m.	0	32.47	24.65	12.00
			1	32.38	24.64	11.75
		10.21	25	32.63	25.02	10.65
		10.15	50	32.92	25.63	8.26
		10.09	75	33.08	25.83	7.70
		10.02	100	33.10	25.90	7.31
		9.54	120	33.15	25.95	7.30
951	Sept. 7	11.23 a.m.	0	32.34	24.49	12.30
			1	32.29	24.48	12.14
		11.18	25	32.72	25.25	9.69
			50	32.99	25.73	7.96
		11.07	75	33.08	25.86	7.55
		11.01	100	33.04	25.83	7.49

Table II (continued)

<u>Station</u> <u>No.</u>	<u>Date</u> <u>1929</u>	<u>Time</u>	<u>Depth</u> <u>M.</u>	<u>Salinity</u>	<u>Density</u>	<u>Temperature</u> <u>°C.</u>
952	Sept. 7	12.12 p.m.	0	32.32	24.52	12.10
			1	32.32	24.59	11.70
		12.07	25	32.59	24.95	10.90
			50	32.75	25.36	9.14
			70	32.92	25.62	8.33
953	Sept. 6	11.17 a.m.	0	32.70	25.12	10.35
			1	32.70	25.16	10.10
		11.12	25	32.68	25.15	10.10
			50	32.63	25.12	10.03
954	Sept. 6	12.10 p.m.	0	32.68	25.12	10.30
			1	32.59	25.07	10.15
		12.04	25	32.68	25.17	10.00
			50	32.61	25.11	10.00
			75	32.63	25.13	9.99
955	Sept. 6	12.54 p.m.	0	32.56	25.00	10.40
			1	32.57	25.05	10.15
		12.49	25	32.57	25.04	10.20
			50	32.59	25.03	10.40

Table III

<u>Station</u> <u>No.</u>	<u>Date</u> <u>1930</u>	<u>Time</u>	<u>Depth</u> <u>M.</u>	<u>Salinity</u>	<u>Density</u>	<u>Temperature</u> <u>°C.</u>
864	April 28	12.16 p.m.	0	31.98		3.85
			10	32.00		3.25
			25	32.21		3.35
			50	32.21		3.50
			70	32.29		3.70
873		1.56 p.m.	0	32.12		3.75
			10	32.14		3.76
			25	32.18		3.50
			50	32.25		3.49
880	April 29	8.17 a.m.	0	32.05		3.65
			10	32.05		3.71
			25	32.03		3.40
			40	32.16		3.09
881	April 29	8.48 a.m.	0	31.98		3.55
			10	31.98		3.66
			25	32.03		3.35
			50	32.29		3.55

Table III (continued)

<u>Station</u> <u>No.</u>	<u>Date</u> <u>1930</u>	<u>Time</u>	<u>Depth</u> <u>M.</u>	<u>Salinity</u>	<u>Density</u>	<u>Temperature</u> <u>°C.</u>
882	May 1	9.39 a.m.	0	32.27		3.75
			10	32.21		3.85
		9.33	15	32.21		3.84
883	May 1	10.17 a.m.	0	32.03		4.15
			10	32.14		3.80
		10.12	25	32.23		3.75
		10.07	50	32.27		3.55
		10.00	75	32.25		3.75
884	May 1	10.54 a.m.	0	32.20		3.95
			10	32.25		3.75
		10.49	25	32.25		3.76
		10.43	50	32.29		3.40
		10.36	75	32.29		3.75
885	May 1	11.27 a.m.	0	32.29		3.65
			10	32.25		3.76
		11.22	25	32.29		3.50
		11.16	50	32.23		3.75
887	May 1	2.28 p.m.	0	32.21		3.95
			10	32.21		3.90
		2.22	25	32.25		3.85
		2.16	50	32.27		3.80
		2.09	75	32.28		3.80
893	May 1	12.11 p.m.	0	31.91		4.45
			10	31.94		4.05
		12.06	25	32.14		3.70
		12.00	50	32.52		3.80
894	May 1	12.59 p.m.	0	31.85		4.45
			10	31.91		4.15
		12.53	25	32.00		3.80
		12.47	50	32.10		3.75
		12.41	75	32.29		3.54
		12.34	100	32.45		3.75
895	May 1	1.46 p.m.	0	32.12		3.95
			10	32.14		3.60
		1.41	25	32.10		3.80
		1.35	50	32.14		3.80
		1.28	75	32.14		3.80
		1.20	100	32.29		3.80

Table III (continued)

<u>Station</u> <u>No.</u>	<u>Date</u> <u>1930</u>	<u>Time</u>	<u>Depth</u> <u>M.</u>	<u>Salinity</u>	<u>Density</u>	<u>Temperature</u> <u>°C.</u>
948	May 8	3.42 p.m.	0	31.46		4.95
			10	32.05		4.20
		3.35	25	32.27		4.00
953	May 2	11.29 a.m.	0	32.27		3.85
			10	32.25		3.50
		11.24	25	32.27		3.80
		11.18	50	32.25		3.80
954	May 2	10.48 a.m.	0	32.27		3.95
			10	32.27		3.49
		10.43	25	32.25		3.80
		10.37	50	32.27		3.80
		10.31	75	32.27		3.80
955	May 2	10.06 a.m.	0	32.27		3.95
			10	32.25		3.44
		10.01	25	32.25		3.75
		9.55	50	32.23		3.74
956	April 29	2.12 p.m.	0	32.05		3.85
			10	32.00		3.50
		2.06	20	32.14		3.39
966	April 26	9.30 a.m.	0	31.35		2.85
			10	31.49		2.60
		9.25	25	32.48		3.41
		9.20	50	32.79		3.60
		9.14	75	32.79		3.66
		9.07	100	32.79		3.85
967	April 26	10.53 a.m.	0	31.76		2.85
			10	31.76		2.41
		10.47	25	31.89		2.46
		10.41	50	32.42		3.36
		10.35	75	32.79		3.36
		10.28	100	32.75		3.56
968	April 26	12.03 p.m.	0	31.92		3.05
			10	31.92		2.70
		11.57	25	31.92		2.50
		11.52	50	32.12		2.85
969	April 17	8.14 a.m.	0	----		1.05
			10	31.53		1.22
		8.08	25	31.53		1.25

Table III (continued)

<u>Station</u> <u>No.</u>	<u>Date</u> <u>1930</u>	<u>Time</u>	<u>Depth</u> <u>M.</u>	<u>Salinity</u>	<u>Density</u>	<u>Temperature</u> <u>oC.</u>
970	April 17	9.28 a.m.	0	31.76		0.95
			10	31.74		1.08
		9.22	25	31.76		1.13
			50	31.83		1.49
			75	31.85		1.65
971	April 17	10.41 a.m.	0	31.85		1.10
			10	31.85		1.43
		10.35	25	31.85		1.39
			50	31.87		1.39
			75	31.85		1.39
975	April 17	8.40 a.m.	0	31.53		0.95
976	April 17	9.55 a.m.	0	31.80		1.05
977	April 25	11.30 a.m.	0	31.36		2.45
			10	31.71		1.90
		11.25	25	32.03		2.20
			50	32.14		2.76
978	April 25	10.55 a.m.	0	30.28		2.05
979	April 25	10.27 a.m.	0	27.47		2.45
			10	31.65		2.15
		10.22	25	32.14		3.16
			50	32.54		3.41
			75	32.56		3.16
980	April 26	9.40 a.m.	0	30.62		2.45
981	April 26	9.12 a.m.	0	30.30		2.05
			10	31.38		2.76
		9.07	25	32.61		3.46
			50	32.68		3.51
			75	32.68		3.41
			100	32.70		3.76
982	April 26	11.17 a.m.	0	31.83		3.15
984	April 29	9.47 a.m.	0	32.00		3.95
			10	32.05		3.50
		9.42	25	32.09		3.45
			50	32.30		3.45
			75	32.61		3.50
983	April 26	9.57 a.m.	0	31.73		2.75

Table III (continued)

<u>Station</u> <u>No.</u>	<u>Date</u> <u>1930</u>	<u>Time</u>	<u>Depth</u> <u>M.</u>	<u>Salinity</u>	<u>Density</u>	<u>Temperature</u> <u>oC.</u>
985	April 29	10.28 a.m.	0	32.92		3.65
			10	31.84		3.10
			25	32.09		3.36
			50	32.14		3.25
			75	32.30		3.55
986	April 29	11.18 a.m.	0	31.83		4.25
			10	31.83		3.25
			25	31.87		3.15
			50	32.23		3.25
			75	32.30		3.51
			100	32.61		3.76
987	April 29	12.23	0	31.73		4.35
			10	31.76		3.10
			25	31.91		3.10
			50	32.14		2.70
			75	32.41		3.15
			100	32.63		3.70
988	April 29	1.03 p.m.	0	31.79		4.25
			10	31.83		3.20
			25	31.91		3.10
			50	32.20		3.00
			75	32.34		3.20
989	April 29	1.44 p.m.	0	31.83		3.45
			10	31.83		3.10
			25	31.98		3.25
			50	32.34		3.35
			75	32.39		3.65
990	May 6	3.04 p.m.	0	31.04		6.53
			10	31.53		4.33
			25	32.43		4.67
			50	32.68		4.62
			75	33.04		4.33
			100	33.04		4.43
991	May 8	2.06 p.m.	0	31.60		6.63
			10	31.91		5.85
			25	32.34		5.28
			50	32.97		5.00
			75	33.12		4.86
			100	33.22		4.90

Table III (continued)

<u>Station</u> <u>No.</u>	<u>Date</u> <u>1930</u>	<u>Time</u>	<u>Depth</u> <u>M.</u>	<u>Salinity</u>	<u>Density</u>	<u>Temperature</u> <u>°C.</u>
992	May 8	12.59 p.m.	0	32.61		6.53
			10	32.72		5.68
			25	32.77		5.47
			50	32.95		5.10
			75	33.06		5.00
			100	33.10		4.81
993	May 8	11.54 p.m.	0	32.61		6.24
			10	32.59		5.90
			25	32.74		5.47
			50	32.79		5.19
			75	33.01		5.05
			100	33.15		4.60
994	May 1	4.36 p.m.	0	31.99		4.25
			10	32.01		4.00
			25	32.09		3.95
			50	32.16		3.85
			75	32.32		3.59
995	May 1	3.56 p.m.	0	31.92		4.15
			10	31.96		3.95
			25	32.05		3.90
			50	32.10		3.85
			75	32.32		3.75
996	May 1	3.20 p.m.	0	31.92		4.55
			10	32.00		4.35
			25	32.07		4.00
			50	32.18		3.70
997	April 28	1.30 p.m.	0	32.01		3.75
			10	31.96		3.80
			25	32.00		3.44
			50	32.23		3.71
			75	32.32		3.40
			90	32.41		3.45
998	April 28	11.41 a.m.	0	31.83		3.85
			10	31.80		3.60
			15	31.91		3.44
999	May 7	9.09 a.m.	0	32.30		4.45
1000	May 7	9.27 a.m.	0	32.29		4.15

Table IV.

Line No. A.

<u>Point No.</u>	<u>Date</u>	<u>Place Found</u>	<u>Period of Drift</u>	<u>Rate of Drift</u>
1	May 8/30	Old Proprietor, G. Manan, N. B.	1 day	
	July 23/30	Black River, St. John Co., N. B.	76 days	
	June 15/30	Off Frenchman's Bay, Me.	38 days	
2	June 22/30	Pemaquid Pt. Maine	45 days	
3	Aug. 25/30	Kennebunk, Maine	109 days	
	July 3/30	Gr. Wass Is., Maine	56 days	
	Aug. 5/30	Parker's Cove, N. S.	89 days	
	Sept. 27/30	Duck Is., G. Manan, N. B.	142 days	
4	Sept. 1/30	Cundy's Harbour, Maine	116 days	
	June 9/30	Cases Cove, N. S.	32 days	
5	Oct. 7/30	Bishop Brook, N. S.	152 days	
6	Sept. 23/30	Nash Is., Maine	138 days	
7	Aug. 5/30	15 west of Digby, N.S.	89 days	
	Aug. 12/30	5 miles from Metegan, N.S.	96 days	
	Aug. 12/30	West Advocate, N. S.	96 days	
8	Sept. 20/30	Welche's Cove, N. B.	135 days	
	Oct. 26/30	Highland Light, Mass.	171 days	
	June 16/30	Port Lorne, N. S.	39 days	
9	Sept. 2/30	Near Machais, Maine	117 days	
	May 19/30	Off Parker's Cove, N.S.	11 days	4 miles per day
11	July 22/30	West Advocate, N. S.	45 days	
	Aug. 7/30	6 mi. south Isle Haute, N.S.	91 days	
12	July 22/30	Parker's Cove, N. S.	45 days	
13	July 28/30	Spruce Is., Char. Co., N.B.	51 days	
15	Aug. 5/30	West apple River, N. S.	89 days	
	Oct. 5/30	Dodge Brook, N. S.	150 days	
	Oct. 5/30	Young's Cove, N. S.	150 days	

No. of bottles put out60
 Percentage returned45

Table V.

Line No. B.

<u>Point No.</u>	<u>Date</u>	<u>Place Found</u>	<u>Period of Drift</u>	<u>Rate of Drift</u>
1	May 5/30	North Hd. G. Manan, N.B.	1 day	2 mi. per day
	May 5/30	North Hd. G. Manan, N.B.	1 day	
	May 5/30	Castalia, G. Manan, N.B.	1 day	
2	Sept. 24/30	Ogilvie Wharf, N. S.	132 days	
	May 24/30	S. of Petit Manan, Maine	19 days	
3	Oct. 26/30	N. of Nauset Lt. Mass.	174 days	
4	June 6/30	Sandy Cove, N. S.	32 days	
	Dec. 21/30	Darmis Co., Ha. R. Me.	230 days	
	May 23/30	Freeport, N. S.	18 days	
5	July 10/30	Barnes Is., N. B.	36 days	
6	July 23/30	Hampton, N. S.	79 days	
	Aug. 9/30	Cape Small Pt., Maine	96 days	
7	June 9/30	Seal Cove, G. Manan, N.B.	35 days	
	Aug. 21/30	Cutler, Maine	108 days	
8	Oct. 2/30	White Is.	150 days	
	May 12/30	Head Harbour, N. B.	7 days	
	May 19/30	Pocologan Is., Char. Co. N.B.	14 days	
9	May 13/30	Barnes Is., N. B.	8 days	
	May 12/30	Mait's Is., N. B.	7 days	
	May 19/30	Carlow's Is., N. B.	14 days	
10	May 16/30	Head Harbour, N. B.	11 days	
	May 15/30	Pt. Lepreau, N. B.	10 days	
11	May 18/30	St. Andrews, Is., N. B.	13 days	
	July 18/30	The Wolves, N. B.	74 days	
	May 13/30	Barnes Is., N. B.	8 days	
12	July 5/30	Jonesport, Maine	61 days	
	Oct. 8/30	Cape Cod, Mass.	156 days	
13	May 19/30	Deer Is. Pt., N. B.	14 days	
		Corea Harbour, Maine	177 days	
14	July 17/30	9 mi. W. of Brier Is., N.S.	73 days	
15	May 16/30	Deer Is. N. B.	11 days	
	May 15/30	Eastern Wolves, N. B.	10 days	

Table V. (continued)

Line No. B.

<u>Point No.</u>	<u>Date</u>	<u>Place Found</u>	<u>Period of Drift</u>	<u>Rate of Drift</u>
16	July 16/30	Adams Is., N. B.	72 days	
	Sept. 23/30	Leonardville, N. B.	131 days	
	May 12/30	Simpson's Is., N. B.	7 days	
17	May 16/30	Leonardville, N. B.	11 days	
	May 12/30	Head Harbour, N. B.	7 days	
18	Sept. 14/30	Port Lorne, N. S.	122 days	
19	May 12/30	Mill Cove, Cher. Co. N.B.	7 days	
	May 12/30	Head Harbour, N. B.	7 days	
	May 13/30	Barnes Is., N. B.	8 days	
	May 12/30	Maits Is., N. B.	7 days	
20	May 25/30	Pee Pt., N. B.	20 days	
	May 15/30	Wolves Is., N. B.	10 days	
	May 13/30	Barnes Is., N. B.	8 days	
21	May 13/30	Barnes Is., N. B.	8 days	
	June 2/30	Bliss Is., N. B.	28 days	
22	May 12/30	Maits Is., N. B.	7 days	
	May 15/30	Passamaquoddy Bay, N.B.	10 days	1½ mi. per day

No. of bottles put out84
 Percentage returned54

Table VI

Line No. C.

<u>Point No.</u>	<u>Date</u>	<u>Place Found</u>	<u>Period of Drift</u>	<u>Rate of Drift</u>
1	Aug. 18/30	Westport, N. B.	103 days	
2	June 1/30	Gott's Is., Maine	25 days	
	Apr. 26/31	Frenchman's Bay, Maine	354 days	
	Sept. 11/30	Petite Passage, N. S.	127 days	
3	May 19/30	Moose Peak Lt., Maine	12 days	
	May 24/30	Petit Menan Lt., Maine	17 days	
4	June 22/30	Boishubert Is., Maine	46 days	
5	May 12/30	Bredford Cove, G. Menan, N.B.	5 days	1 mi. per day
6	Sept. 19/30	Provincetown, Mass.	135 days	
	May 20/30	Little Dark Harbour, G. Menan, N. B.	13 days	
7	June 21/30	Watimous Is., Maine	45 days	
	May 31/30	Outer Long Is. Maine	24 days	
9	May 13/30	White Head, G. Menan, N.B.	6 days	5 mi. per day
	May 12/30	Kent's Is., G. Menan, N.B.	5 days	6 mi. per day

No. of bottles put out36
 Percentage returned39

Table VII.

Line No. D.

<u>Point No.</u>	<u>Date</u>	<u>Place Found</u>	<u>Period of Drift</u>	<u>Rate of Drift</u>
1	June 9/30	Swallow Tail Lt., G.Menan, N.B.	34 days	
3	Oct. 16/30 May 12/30	Nantucket Is., Mass. Barnes Is. Char.Co. N.B.	164 days 7 days	
4	Nov. 26/30 May 19/30 May 22/31 May 15/30	Off Pt. Lepreau Lt., N.B. Deer Is., Char. Co. N.B. Herring Cove, Char.Co. N.B. N. E. Cutler Lt., Maine	205 days 14 days 382 days 10 days	
5	May 12/30 May 16/30 May 13/30 June 30/30	Mill Cove Char.Co. N. B. Mill Cove, Char.Co. N. B. Barnes Is., Char.Co. N. B. Adams Is., Char.Co. N. B.	7 days 11 days 8 days 56 days	
6	Oct. 9/30 May 22/30 June 22/30	Cape Cod, Mass. Indian Is., Char.Co., N.B. Fairhaven, N. B.	157 days 17 days 48 days	
7	May 18/30 June 3/30	Deer Island, N.B. Bains Is., N. B.	13 days 29 days	
8	Oct. 13/30 May 18/30 May 12/30 May 22/30	Wolves Is., Char.Co., N.B. Mill Cove, Maine. Head Harbour, Campobello, N.B. St.Helena Is., Char.Co. N.B.	161 days 13 days 7 days 17 days	
9	Aug. 26/30 Dec. 26/30	Swan's Is. Maine Mechais Bay, Maine	113 days 235 days	
10	July 10/30 May 13/30	Barnes Is. Char.Co., N.B. Barnes Is. Char.Co., N.B.	66 days 8 days	
11	May 12/30	Head Harbour Is., Char.Co. N.B.	7 days	
12	May 12/30 May 12/30	Head Harbour Is., Char.Co. N.B. Mill Cove, Char.Co., N.B.	7 days 7 days	
13	May 25/30 June 30/30	Indian Is. Char.Co., N.B. Woodward's Cove, G.Menan, N.B.	20 days 56 days	
14	Aug. 24/30 May 8/30	Ogunquill, Maine Long Pt. G.Menan, N. B.	111 days 3 days	3 mi. per day

Table VII (continued)

Line No. D.

<u>Point No.</u>	<u>Date</u>	<u>Place Found</u>	<u>Period of Drift</u>	<u>Rate of Drift</u>
16	Aug. 20/30	Centreville, N. S.	107 days	
17	June 22/30	New River Beach, N.B.	48 days	120 miles in 48 days
18	May 14/30	4 mi. west of Quoddy Head, Me.	9 days	
	Nov. 20/30	Minturn, Maine	199 days	
19	Aug. 23/30	Whale Cove, G. Menan, N.B.	110 days	
	July 26/30	W. of Bear's Head, N.S.	82 days	
	June 14/30	Sandy Cove, Maine	40 days	

No. of bottles put out76
 Percentage returned50

Table VIII.

Line No. E.

<u>Point No.</u>	<u>Date</u>	<u>Place Found</u>	<u>Period of Drift</u>	<u>Rate of Drift</u>
1	May 16/30	Cape Split Har., Maine	21 days	
	May 10/30	Bailey's Mistake, Maine	5 days	
2	May 19/30	N.E. Moosebec Lt., Maine	14 days	
	May 14/30	Boat Head, Maine	9 days	
	May 14/30	W. of Quoddy Hd., Maine	9 days	
3	June 21/30	10 mi. N.W. Pt. Lepreau, N.B.	47 days	
	Aug. 2/30	Cape Small, Maine	89 days	
4	June 26/30	Old Orchard, Maine	52 days	
	May 16/30	Indian Is., N. B.	11 days	
	Aug. 9/30	East Ferry, N.S.	96 days	
5	June 16/30	Spruce Is., N. B.	42 days	
6	May 9/30	Campobello Is., N. B.	4 days	2½ mi. per day
	Sept. 3/30	G. Duck Is., Maine	121 days	
	May 16/30	Mill Cove, Char.Co., N.B.	11 days	
7	May 23/30	E. of Petit Manan Is., Maine	18 days	
	May 14/30	Morton's Rock, Maine	9 days	
	Aug. 8/30	Bocabec, N. B.	95 days	
	May 12/30	Simpson's, N. B.	7 days	

No. of bottles put out 28
 Percentage returned 64

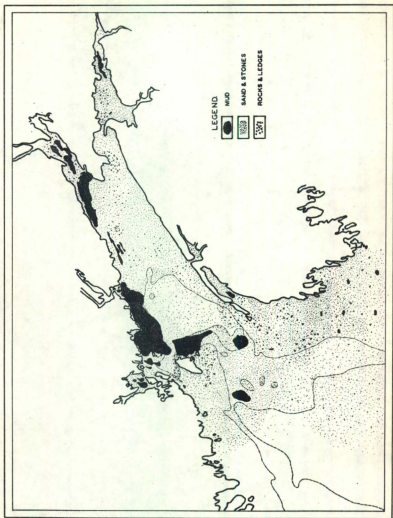


Fig. 1 Chart of the Bay of Fundy showing the distribution of bottom types.

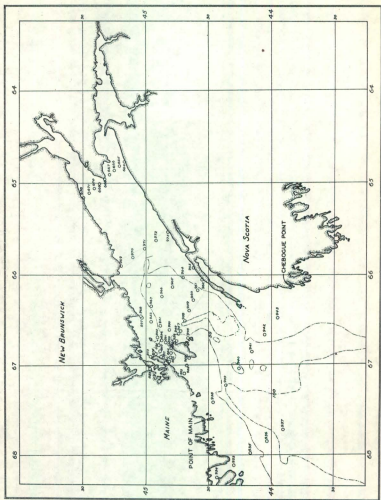


Fig. 2 Chart of the Bay of Fundy showing the location of hydrographic stations.

7
8
9
10

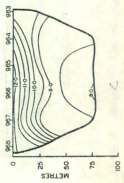
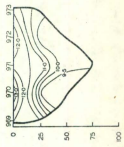
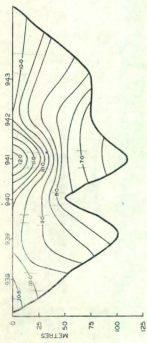
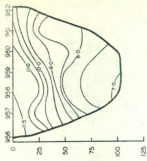


Fig. 3 Vertical distribution of temperature in the Bay of Fundy (Aug. 25 - Sept. 19, 1929).

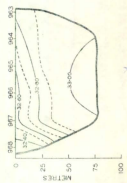
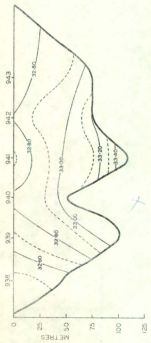
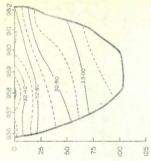


Fig. 4 Vertical distribution of salinity in the Bay of Fundy (Aug. 25 - Sept. 19, 1959).

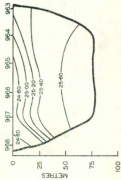
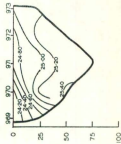
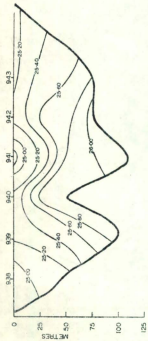
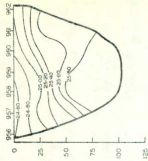


Fig. 5 Vertical distribution of density in the Bay of Pundy (Aug. 25 - Sept. 19, 1929).

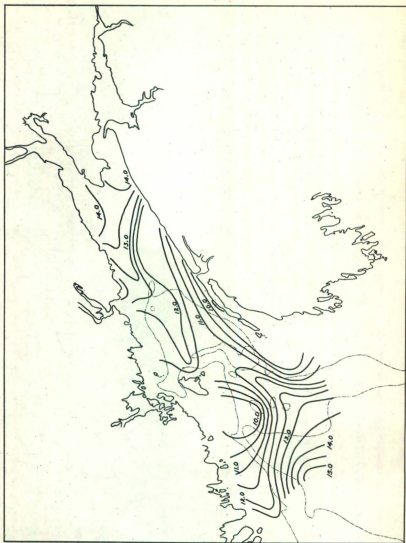


Fig. 6 Horizontal distribution of temperature at 1 metre (Aug. 25 - Sept. 19, 1929).

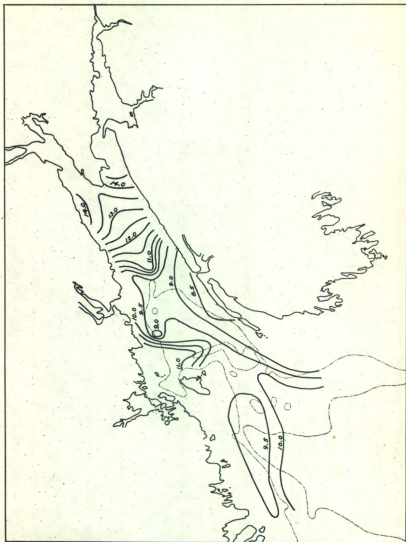


Fig. 7 Horizontal distribution of temperature at 25 metres (Aug. 25 - Sept. 19, 1929).

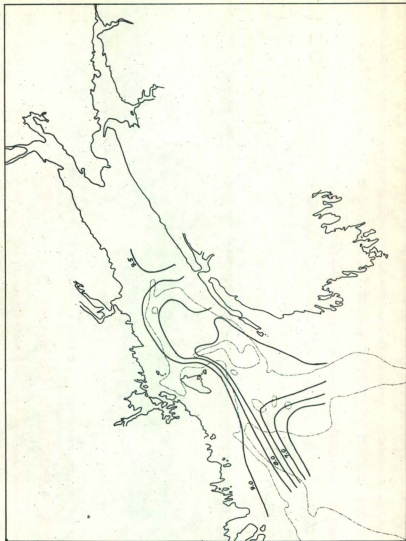


Fig. 8 Horizontal distribution of temperature at 50 metres (Aug. 25 - Sept. 19, 1929).

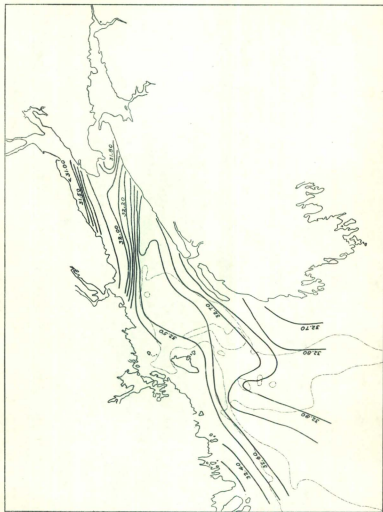


Fig. 9 Horizontal distribution of salinity at 1 metre (Aug. 25 - Sept. 19, 1929).

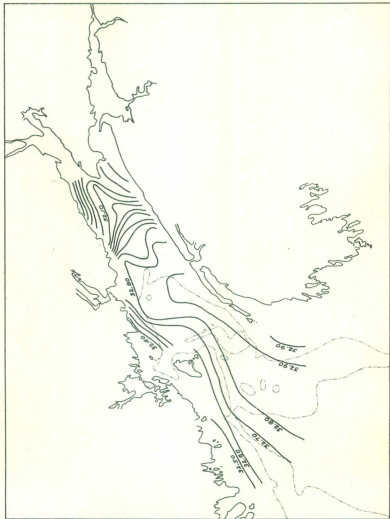


Fig. 10 Horizontal distribution of salinity at 25 metres (Aug. 25 - Sept. 19, 1929).

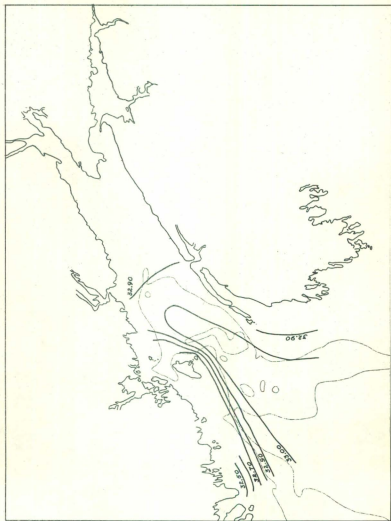


Fig. 11 Horizontal distribution of salinity at 50 metres (Aug. 25 - Sept. 19, 1929).

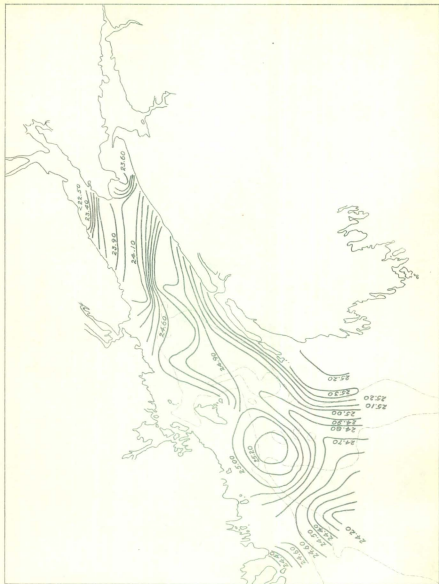


Fig. 12 Horizontal distribution of density at 1 metre (Aug. 25 - Sept. 19, 1979).

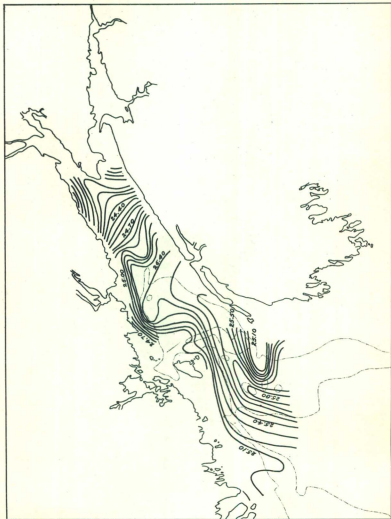


Fig. 13 Horizontal distribution of density at 25 metres (Aug. 25 - Sept. 19, 1929).

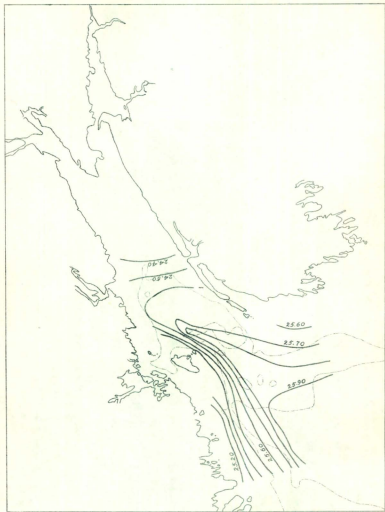


FIG. 11. Horizontal distribution of density at 50 metres (Aug. 25 - Sept. 19, 1967).

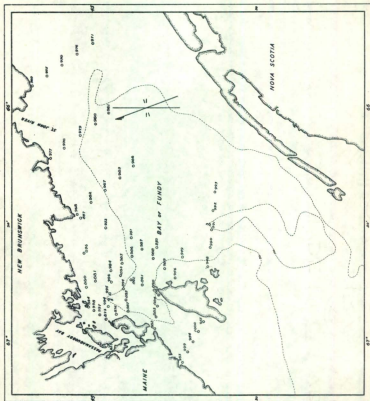


Fig. 15 Location of stations occupied in September, 1929 and April-May, 1930.

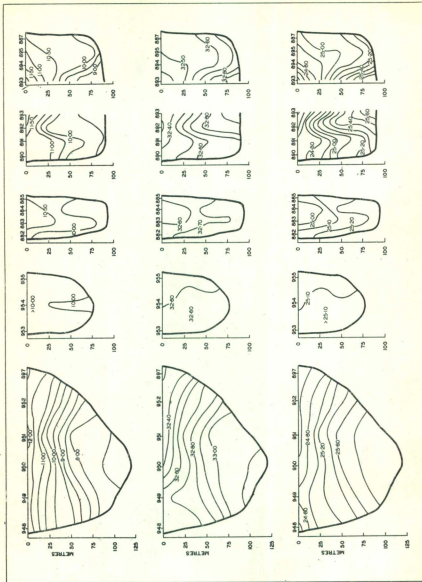


Fig. 16 Vertical distribution of temperature, salinity and density in the Passamaquoddy area (Sept. 5-7, 1969).

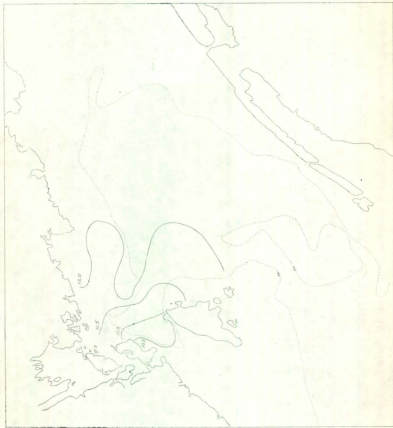


Fig. 17 Horizontal distribution of temperature in the Passamaquoddy area at 1 metre.

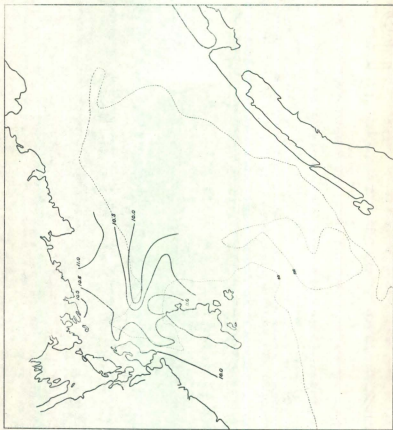


FIG. 13 Horizontal distribution of temperature in the Passamaquoddy area at 25 metres.

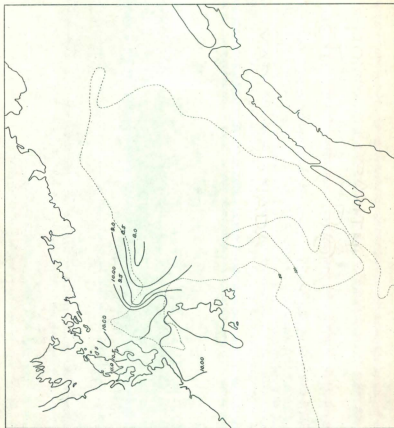


Fig. 19. Horizontal distribution of temperature in the
* Passamaquoddy area at 50 metres.

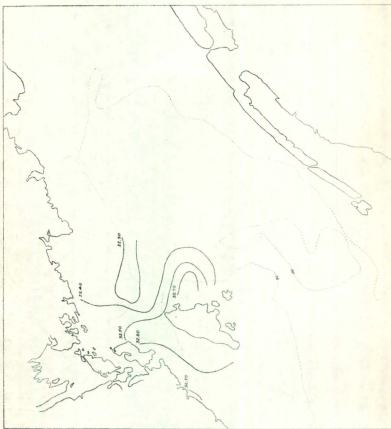


Fig. 20 Horizontal distribution of salinity in the Passamaquoddy area at 1 metre.

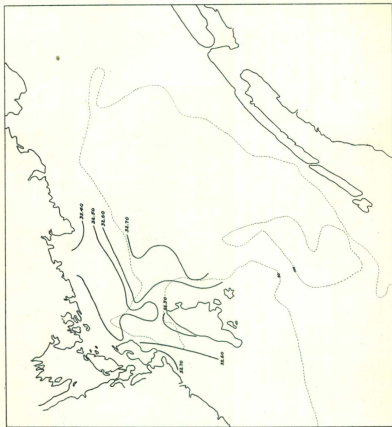


Fig. 21 Horizontal distribution of salinity in the Passamaquoddy area at 25 metres.

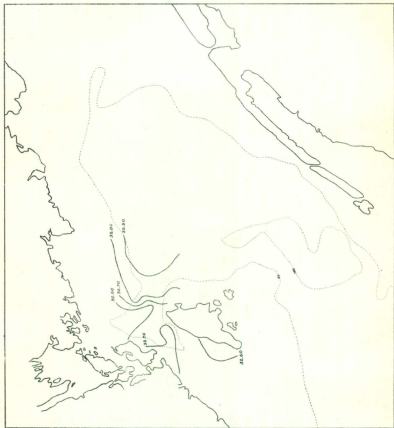


Fig. 22 Horizontal distribution of salinity in the Puntanquedy area at 50 metres.

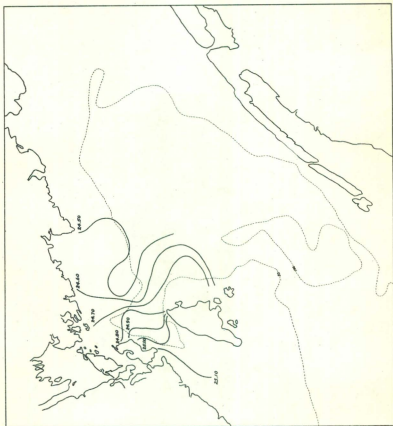


Fig. 23 Horizontal distribution of density in the Passamaquoddy area at 1 metre.

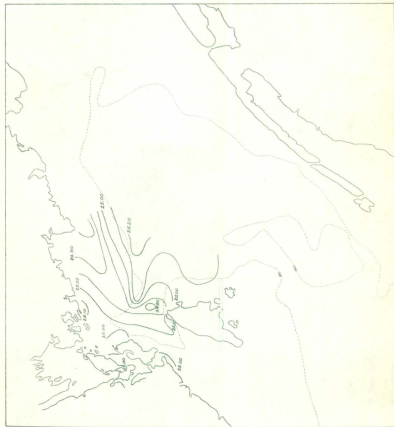


Fig. 24 Horizontal distribution of density in the Pausaniquoddy area at 25 metres.

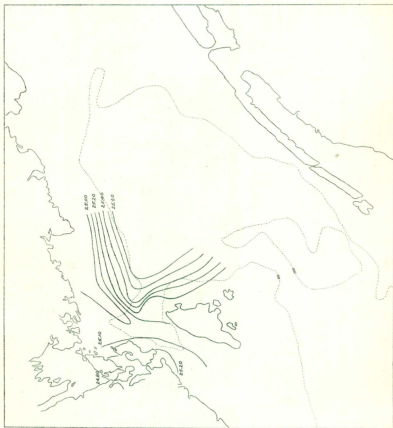


Fig. 25 Horizontal distribution of density in the Passamaquoddy area at 50 metres.

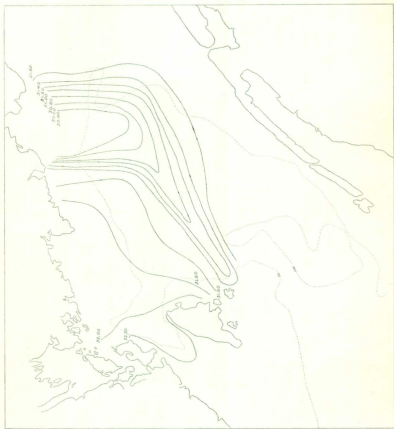


Fig. 26 Horizontal distribution of salinity at the surface - Spring Fresnet (April 17-May 8, 1930).

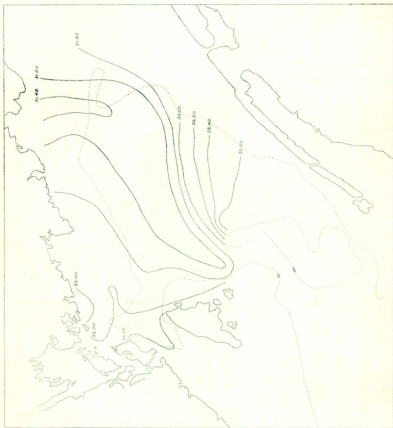


Fig. 27 Horizontal distribution of salinity at 10 metres -
Spring Freshet (April 17 - May 8, 1930).

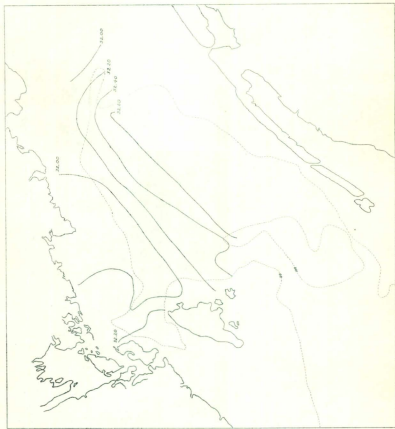


Fig. 26 Horizontal distribution of salinity at 25 metres -
Spring Freshet (April 17 - May 8, 1930).

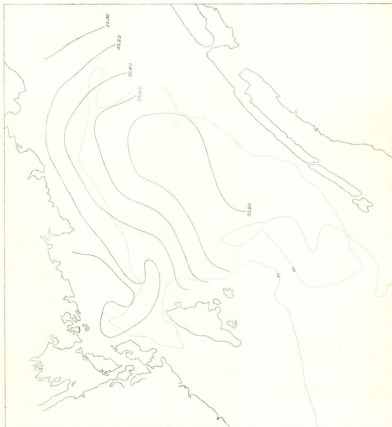


FIG. 29 Horizontal distribution of salinity at 50 metres -
Spring Freshet (April 17 - May 8, 1930).

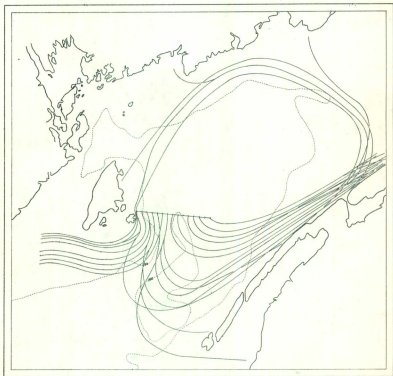


Fig. 30 Drift Bottle Results - Series A.

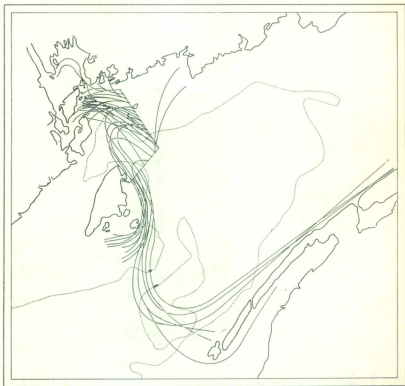


Fig. 31 Drift Bottle Results - Series B.



Fig. 32 Drift Bottle Results - Series C.



Fig. 33 Drift Bottle Results - Series D.

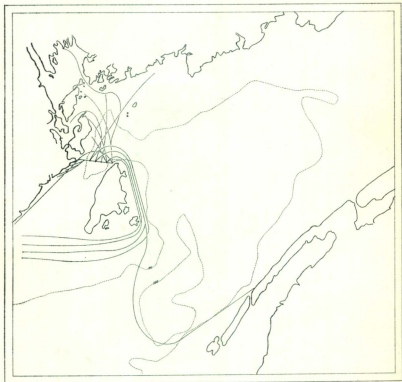


Fig. 34 Drift Bottle Results - Series E.

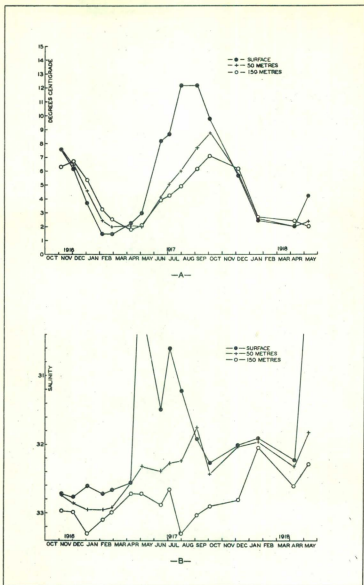


Fig. 35 Temperatures(A) and Salinities(B) for Station 3 - November 1916 to May 1918.

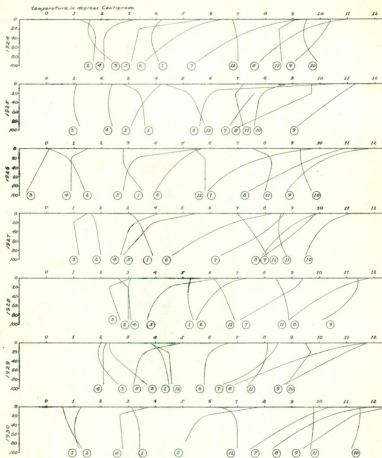


Fig. 36 Typical temperature-depth curves at Station 5, for each month of the period 1924-30.

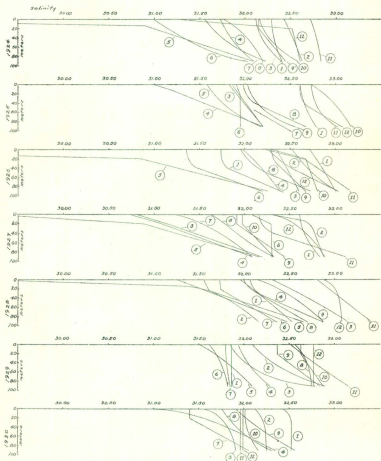


Fig. 37 Typical salinity-depth curves at Station 5, for each month of the period 1924-30.

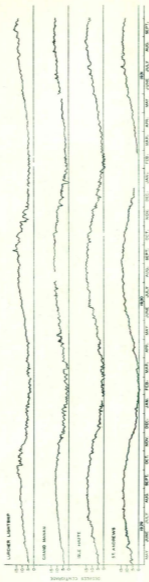


FIG. 38 Surface temperature at Lurcher Lightship, Grand Manan, Isle Haute, and St. Andrews - May 1929 to September 1930.

