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SOME ASPECTS OF OCEANOGRAPHIC CONDITIONS IN THE
GULF OF ST. LAWRENCE
FROM AUTUMN 1956 TO SPRING 1957

AUTHORSHIP

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Some Aspects of Oceanographic Conditions

in the Gulf of St. Lawrence

from Autumn 1956 to Spring 1957

by

L. M. Lauzier

INTRODUCTION

For the second consecutive winter, oceanographic observations were carried out in the Gulf of St. Lawrence in February-March, 1957, on H.M.C.S. "Labrador". During the first survey, in 1956, the ice coverage was light with young and very young ice of an average thickness of less than twelve inches (Lauzier, 1957). From meteorological and oceanographic conditions in the autumn 1956, it was expected that the formation of ice in 1957 would be much more extensive throughout the Gulf of St. Lawrence. The purpose of the survey was to observe, under conditions different from those prevailing in 1956: (a) the horizontal and vertical distribution of temperature and salinity throughout the Gulf, (b) the nature and extent of ice cover, and (c) the disposition and volume transport of the Gaspe Current and Cape Breton Current. Observations in winter are necessary to understand the process of formation of the cold-water layer that remains over the deep channels throughout the following summer and to determine what proportion of this cold-water layer is formed "in situ" or comes from outside the Gulf. A knowledge of winter conditions coupled with that of previous autumn and following spring, is related to the study of the heat budget of the Gulf, and an understanding of the problems of winter ice, as well as the formation

of the cold-water layer.

AUTUMN OBSERVATIONS

Temperatures and Salinities in 1956

In order to study the oceanographic conditions before the freezing, the regular autumn seasonal survey of C.N.A.V. "Sackville" was extended to the northwestern Gulf in November 1956. The locations of the stations by sections are indicated in Figure 1. The plotted data for the autumn survey are given in Figures 2-9 (S-35).

Observations in the autumn show that the three-layer stratification was featured in all the sections. The surface layer had a thickness varying between 20 and 50 metres with an average thickness of 35 metres, which was 15 metres shallower than in 1955 at approximately the same time of the year. The intermediate temperature layer, during the autumn survey in 1956, had a minimum temperature of -0.1°C . in Esquiman Channel. This was the only case of sub-zero temperatures. In other sections, the minimum temperature varied between 0.3° and 0.8°C . In 1956, the salinity stratification in the upper layers was greater than in the previous year. Examples of steep vertical gradients of salinity are shown in Figures 5 and 7. The salinity at the minimum temperature varied between 32.50 and $33.00^{\circ}/\text{oo}$. The deep water layer in the Laurentian Channel had a smaller volume in 1956 than in 1955, but temperatures were higher than in 1955, with a maximum temperature of 6.0°C . and 5.3°C . respectively, in Cabot Strait. In the

northwestern Gulf, the maximum temperature was 4.9°C . in 1956 as compared to 4.8°C . in 1955.

Seasonal changes in the volume of the different layers is of great importance in considering the exchange of water types. In 1956-57, the volume of the deep layer and of the layer of salinities between $33.00^{\circ}/\text{oo}$ and $34.00^{\circ}/\text{oo}$ had increased from autumn to winter. In 1955-56, the volume of these same layers had decreased during a similar period. It seems then that a greater inflow of warm saline waters occurred from autumn to winter 1956-57, in contrast to the season of 1955-56.

Ice Potentials

Using data collected during the autumn cruise of C.N.A.V. "Sackville", the heat loss necessary for the formation of ice was calculated as well as the depth of convective mixing. The calculations were made for each station.

As for the autumn 1955, the minimum values of heat loss in 1956 were found at stations nearest to the Gaspé Coast. In the Gaspé Passage, relatively high values were found for the water columns in the middle of the Laurentian Channel. Values of heat loss over the Magdalen Shallows were higher than in the Gaspé Passage. The patterns of variation of heat loss necessary for ice formation, from one area to the other, were approximately the same in 1955 and in 1956. However, the values in 1956 were generally lower than in 1955, indicating an earlier formation of ice under the same atmospheric conditions. A detailed study of heat loss in the Gaspé Passage and the northwestern Gulf, and of

the heat budget in the same area has been carried out (Lauzier and Graham, MS, 1958).

WINTER OBSERVATIONS

General

In February and March 1957, observations were made at 44 stations located along sections across the main channels and passages. As shown in Figure 10, special attention was given to the Laurentian Channel with five sections, from Cabot Strait up to the mouth of the Saguenay River. Observations were also made west of the Saguenay River, in Jacques Cartier Passage, and in Esquiman Channel as far as Bay of Islands, Newfoundland. Only one station was occupied over the Magdalen Shallows.

Ice

Ice observations were made regularly from the ship during the whole survey. These were supplemented by aerial surveys conducted by the Geographical Branch of the Department of Mines and Technical Surveys and the Maritime Squadron of the Royal Canadian Air Force (Black, 1957). Ice samples were collected for a preliminary study of a brown deposit in the lower layer of the ice.

At the time H.M.C.S. "Labrador" was cruising in the Gulf, only two aerial surveys were completed. Other surveys were made just before and after the cruise, February 19th to March 5th. The data of 5 aerial flights were thus available for completing the picture of ice conditions as observed from the ship during the cruise.

In the Cabot Strait area and the Esquiman Channel, the ice

coverage observed during the flights of February 19 and 20 varied between 3/10 to 10/10, but mostly over 8/10. The winter ice comprised between 60 to 100% of the coverage. From the ship cruising in these areas, between February 22 to 25, the observed coverage corresponded to that of the aerial observations made previously. Pressure ridges were encountered by the ship off the Cape Breton Coast, south of St. Paul Island, and in the Esquiman Channel between Bay of Islands, Newfoundland, and the North Shore, where the pressure ridges were more numerous. In these areas, the ice thickness varied from 1 to 3 feet in Cabot Strait, and from 3 to 5 feet in Esquiman Channel. At approximately 25 miles from the North Shore in Esquiman Channel, the thickness of ice in ridges amounted to more than 10 feet.

Along the North Shore and through Jacques Cartier Passage, from longitude 62°W. to 66°W., 9/10 to 10/10 coverage was reported from the aerial surveys. East to west this ice varied from young ice to a mixture of winter and young ice. From the ship, some pancake ice was reported in the eastern sector of Jacques Cartier Passage. The pancake ice had increasing diameter and thickness from the northern half of the Passage to the southern half, with a maximum thickness of one foot.

In the northwestern Gulf mostly young ice was observed, with a maximum thickness of about one foot. Some hummocked ice was observed at times. During the crossing, from the North Shore to the Gaspé Peninsula, as much as 10/10 young ice was observed. Along the Gaspé Peninsula young flat ice was encountered. In the middle of the estuary, west of Pointe des Monts, medium size

fields of hummocked ice were observed in the midst of very young ice. West of longitude 69°W., no ice was encountered with the exception of bands of broken ice or newly formed ice in the vicinity of the Saguenay River. West of the Saguenay River, ice concentration varied from 3/10 to 8/10 consisting mostly of young ice. Some river ice was drifting in this sector and the amount of thicker winter ice did not exceed 2/10. There were also a few patches of hummocked ice.

In the Gaspé Passage, between Anticosti Island and the Peninsula, the ice coverage varied from 3/10 to 9/10 of young and winter ice of an average maximum thickness of one foot. In the Laurentian Channel, towards Cabot Strait, the ship sailed through young and winter ice of a maximum thickness of one and a half feet. At that time, March 3rd, there were large openings on the Newfoundland side of Cabot Strait, while on the Cape Breton side, 10/10 coverage was experienced. The most recent aerial observations in the area, on March 1st, showed an ice edge, having open water on the Newfoundland side.

As compared to the conditions in 1956, those of 1957 were of the other extreme. In 1956, a large area of open water surrounded Anticosti Island and extended to the Newfoundland coast from Cabot Strait to the western end of Belle Isle Strait. In 1957, only small areas of open water were observed at times on the lee-side of land masses. Moreover, in 1956 most of the ice was young and very young, while in 1957, more than half of the ice was winter ice. In 1956, the thickness of ice was generally less than a foot, while in 1957, ice thickness of 3 to 5 feet

was very common. Pressure ridges were frequent in Cabot Strait and Esquiman Channel during the 1957 survey.

Ice formation and growth was a slow process in 1956 but it seems that in 1957, the ice either started to form early or grew very fast during the winter season. Along the North Shore, the number of degree-days of frost by the end of February 1957 was more than double the value obtained at the same time in 1956. In the southwestern Gulf, the 1957 value was slightly less than double the 1956 value. In 1956, the freezing season was between three and six weeks late, while in 1957, it was between three and four weeks early.

In November and December, the winds over the Gulf were stronger in 1955 than in 1956. In January 1956, the prevailing winds were from the N and NE, while in January 1957, they were westerly. In February and March 1956, the prevailing winds were from the W., while during the same months in 1957, they varied from W. to NE.

When ice was turned over with the passage of the ship, a brown colouration on the underside of the ice floes was observed. Soon after the "Labrador" entered the ice field around the east coast of Cape Breton, the occurrence of this brown material became very frequent. Ice samples were collected from a large ice floe off the east coast of Cape Breton. The ice was 12-15 inches thick with a snow cover of 4-6 inches. The brown material was present on the underside of the ice, adjacent to or incorporated with a thin layer of ice which had a different structure from that of the ice above. Two samples of the brown material were collected, the

first one (Sample I) by scraping the thin layer of ice mentioned above, and the other (Sample II) from crushed ice between floes "in situ". The melted ice containing the brown material was preserved and analysed by Mr. A. Bursa of the Arctic Unit of the Fisheries Research Board of Canada. The results of Mr. Bursa's analysis are given in Appendix I, listing thirty-five species of diatoms present in the samples.

A remarkable feature of the distribution of the brown material, under the ice, is that it was found in comparably large quantities only in the areas where the ice was covered with snow. The occurrence of the visible brown material under the ice was general over the Gulf, from Cabot Strait to Esquiman Channel, the North Shore, and the Gaspé Passage.

Surface Temperatures and Salinities

As shown in Figure 11, the surface temperatures during the cruise, ranged from -0.5° to -1.8°C . with a steep gradient in the Estuary, just east of the Saguenay River, and also on the Newfoundland side of Cabot Strait. In the central Gulf, the maximum surface temperatures were observed along the south coast of Anticosti Island. The overall minimum temperature was observed along the North Shore. It is assumed that, on the Magdalen Shallows, the surface temperatures would be -1.6°C . or lower. The higher temperature waters produced in the Estuary, at the head of the Laurentian Channel, seemed to be responsible for the comparatively small amount of ice in the area during the 1957 survey. This was not the case during the 1956 survey. However, the surface temperature distributions during the two surveys, were similar in

that relatively maximum temperatures were found along the south coast of Anticosti Island, and warmer waters were located on the Newfoundland side of Cabot Strait.

The horizontal gradient of salinity in the Gaspé Passage and in Cabot Strait is indicative of the circulation, delineating the Gaspé Current as well as the Cape Breton Current (Figure 12). The bodies of relatively high salinity are located along the Newfoundland coast, the North Shore, and along the south coast of Anticosti. Along the south coast of Anticosti Island, the higher salinity waters had a somewhat higher temperature than the surrounding waters, and a tendency to be free of ice. This is indicative of a renewal of surface waters, by water from below along the slopes due to the action of the wind. Probabilities of ice formation and growth are less in such an area than, for instance, along the Gaspé Coast. A maximum surface salinity was observed during the two surveys along the North Shore, but it was higher in 1957 than in 1956, $32.61^{\circ}/\text{oo}$ as compared to $32.38^{\circ}/\text{oo}$.

In the Estuary, east of the Saguenay River, the surface salinity increased seaward from less than 28.00 to $30.50^{\circ}/\text{oo}$ in a similar fashion during the two winter surveys. West of the Saguenay, where observations were made only in 1957, the surface salinity decreased very rapidly. A value of $18.50^{\circ}/\text{oo}$ was recorded 45 miles west of the Saguenay, and 10 miles further upstream the surface salinity had a value of $12.30^{\circ}/\text{oo}$.

Thickness of the Mixed Layer

The thickening of the surface layer in the autumn is a

fundamental process, related to the heat loss at the surface and to the vertical distribution of temperature and salinity of the water mass. With the progress of the seasons, the surface layer deepens down to the level of the intermediate temperature layer so that, in the winter, the stratification is of two layers, the mixed layer and the deep warm layer. The mixed layer is isothermal but not necessarily isohaline. As shown in Figure 13, the mixed layer with respect to temperature, was fairly shallow in the north-western Gulf, between 40 and 60 metres. From Gaspe Passage to Cabot Strait, the thickness in the Laurentian Channel seemed to increase from the southwest to the northeast. Along the North Shore, east of Anticosti Island, the thickness of the mixed layer was at a maximum, 160 metres. In the Estuary, east of the Saguenay River, the thickness of the mixed layer varied laterally with a minimum along the Gaspe Peninsula.

Comparing the two years of winter observations, the thickness of the mixed layer in 1957 was generally equal to or less than that of 1956 in the western sector of the Gulf, and equal to or greater than that of 1956 in the eastern sector. The year-to-year variations in the thickness of the mixed layer are important in relation to ice studies, as well as to the formation of the intermediate cold-water layer which persists in the area during the following spring and summer. Too few data are now available to make it possible to define all the factors responsible for such variations. However, a few pertinent facts should be pointed out.

The surface layer in the autumn was generally thinner in

1956 than in 1955 by an average value of 15 metres, with a maximum difference in Cabot Strait and a minimum in the northwestern Gulf. During November and December, the prevailing winds, generally from the westerly quadrant all over the Gulf, were much stronger in 1955 than in 1956. Due to the action of the wind, the thickening of the surface layer was a faster process in the autumn of 1955 than in 1956. Even with more cooling at the surface, and more degree-days of frost in the winter of 1957 as compared to 1956, the thickening of the mixed layer was less in most of the Gulf, with the exception of Esquiman Channel and part of Cabot Strait. Warmer and higher salinity waters along the Newfoundland coast during the 1956 winter survey, as compared to that of 1957, indicate a stronger inflow of outside water into the Gulf in 1956 through the northeastern half of Cabot Strait. In a similar manner, colder and lower salinity waters along Cape Breton during the 1957 survey indicate a stronger outflow of Gulf water in 1957 through the southwestern half of Cabot Strait. Such variations in the circulation through Cabot Strait are partly responsible for the variations in the thickness of the mixed layer in the eastern Gulf.

Vertical Distribution of Temperature and Salinity

The two-layer system described in the report of the 1956 winter survey (Lauzier, MS 1957) was again featured in all the sections studied in the winter of 1957. The thickness of the mixed layer has been discussed previously. The lower boundary of the mixed layer with respect to temperature, is roughly the depth of the -1.0 degree isotherm. The 1957 data are presented

in Figures 2-9 (LAB-5) and 14-20 (LAB-5). Additional data for 1956, are also shown in Figures 16, 17, 21 and 22 (LAB-3). Within a given section the depth variations of the -1.0 degree isotherm might be large, but in general, the depth of this isotherm was slightly greater in 1956 than in 1957. The average salinity at the lower boundary of the mixed layer was approximately $32.00^{\circ}/\text{oo}$ in 1956 and $32.30^{\circ}/\text{oo}$ in 1957. In general, the isohaline $32.50^{\circ}/\text{oo}$ was shallower in 1957 than in 1956. The salinity stratification within the mixed layer was featured in the Estuary during the two surveys in the northwestern Gulf and the Gaspé Passage in 1957 only.

The deep warm layer formed by waters of salinity greater than $34.00^{\circ}/\text{oo}$ (Lauzier and Trites, MS 1957) was present in the Laurentian Channel as well as in the Esquiman Channel. It was thicker and warmer in 1957 than in 1956. In 1956, waters warmer than 5.0°C . were restricted only to the Newfoundland side of Cabot Strait, and to the Esquiman Channel over a relatively short distance. In 1957, these waters penetrated into the Laurentian Channel as far as Anticosti Island but not in the Gaspé Passage. They also penetrated into Esquiman Channel as far as Bay of Islands. In Cabot Strait, the maximum temperature in the deep layer was 6.1°C . in 1957, and 5.1°C . in 1956. The boundary zone (Lauzier and Trites, MS 1957) between the mixed layer and the deep warm layer, with salinity between $33.00^{\circ}/\text{oo}$ and $34.00^{\circ}/\text{oo}$, had an average thickness of 75 metres in 1957 as compared to 60 metres in 1956. The $33.00^{\circ}/\text{oo}$ isohaline was shallower in 1957 than in 1956, but the average temperature at this isohaline was the same during the two surveys.

SPRING OBSERVATIONS

General

In order to assess the volume of the cold-water layer in the spring and to evaluate the relationship between the volume of this layer and the amount of cooling during the winter, an extended seasonal spring cruise was made on C.N.A.V. "Sackville" from June 14 to June 21, 1957. The locations of the stations by sections are shown in Figure 1.

Stratification

Vertical distributions of temperature and salinity during the 1957 spring cruise are shown in Figures 2-9 (S-36) and 14-20 (S-36). Some data from the 1956 spring cruise are presented in Figures 16, 17, 21 and 22 (S-31).

Following the winter, due to vernal warming, the three-layer temperature stratification reappears. The three-layer system is illustrated in all sections. The surface layer was well defined by a sharp thermocline in the eastern sector of the Gulf, but not in the western half of the Gulf. Figure 9 (S-36) illustrates the former case, and the latter is illustrated in Figure 4. The salinity stratification in the upper 50 metres was very intense in the western sector.

The cold-water layer (Lauzier and Bailey, 1957) was present in all the sections. This layer of sub-zero water had an average thickness of 75 metres in the eastern half of the Gulf, and about 40 metres in the western half. In the Laurentian Channel, the thickness of the cold-water layer decreases from north of the

Magdalen Shallows to the Estuary. The average salinity in the cold-water layer was $32.50^{\circ}/\text{oo}$. In general, the volume of the cold-water layer in the spring was greater in 1957 than in 1956. This feature was less marked in the estuary, the northwestern Gulf, and the Gaspé Passage than in the rest of the Gulf. In Cabot Strait, the volume of sub-zero water was exceptional. Generally such water is not present in the Strait from late May until the next winter.

In general, the boundary of the deep water layer, of salinity greater than $34.00^{\circ}/\text{oo}$, as well as the boundary zone, had deepened from the winter to the spring 1957, and the maximum temperature within this deep layer had decreased somewhat since the winter.

The Cold-Water Layer

Considering the winter season as a whole, the winter cooling was much more intense in 1957 than in 1956. The surplus of cooling in 1957 occurred in January but there was a deficit in March 1957 as compared to March 1956. On the average, the thickness of the mixed layer, as observed at the end of February and the beginning of March, was slightly less in 1957 as compared to 1956. More ice was formed in the area in 1957 than in 1956. The fact that the mixed layer was deeper in 1956 than in 1957 indicates that the heat loss has been distributed over a deeper column of water in 1956 than in 1957.

The year-to-year variations of the heat loss to the atmosphere and the heat loss required locally to cool the water, Q_0 , need consideration (Lauzier and Graham, MS 1958). These two losses do

not balance in 1957 but in 1956 they approximately do. The increase in volume of the water layers of salinity greater than $33.00^{\circ}/\text{oo}$ from autumn 1956 to winter 1957 indicates the movement of more saline and warmer waters into the area. Mixing of these waters with those of the upper layers, of salinity less than $33.00^{\circ}/\text{oo}$, interferes with the cooling process. Effectively, the waters in the lower zones of the mixed layer and immediately underneath were cooled from the surface and warmed from the bottom by mixing. The quantity Q_0 is therefore less than it should have been in 1957. However, the cooling from the surface was so intense in 1957 that the waters of salinity between 32.50 and $33.00^{\circ}/\text{oo}$ were colder in 1957 than in 1956.

The cold-water layer is considered to be in part, a by-product of the winter mixed-layer. According to the winter observations, the cold-water layer should have been deeper and thicker in 1956 than in 1957. This was not the case. Hence the greater thickness of the cold-water layer in 1957, as compared to 1956, might be attributed to the decrease in volume of the deeper layers during the late winter and the spring of 1957.

The formation of the cold-water layer is related to the cooling of the upper layers and to the production of the mixed layer in winter. In turn the production of the mixed layer is greatly influenced by the amount of heat brought into or away from the region by deep currents, or the processes of mixing. The influence of the deep waters is also noticeable in the late winter or in the spring. Hence, atmospheric conditions remaining

constant, the amount of cooling in the upper layers, and the volume of the cold-water layer in the following spring, will vary from year to year depending on the dynamics of the Gulf.

SUMMARY

1. A winter oceanographic survey of the Gulf of St. Lawrence was carried out in February and March 1957 for the second consecutive winter on H.M.C.S. "Labrador".
2. Ice observations were made from the air and from the ship. Ice coverage was much greater in 1957 than in 1956. In 1957, a large proportion of winter ice was encountered, while in 1956, the ice was mostly young and very young. Atmospheric conditions were of two extremes during the two winters, abnormally cold in 1957 and abnormally warm in 1956.
3. The surface temperature and salinity distributions were somewhat different in winter 1957 as compared to those of winter 1956. The waters of the upper layer were stratified, salinity-wise, in the Estuary, the northwestern Gulf, and the Gaspé Passage. The waters of the deep layer were warmer and occupied a greater volume in 1957 than in 1956.
4. A preliminary study of the brown colouration on the underside of the ice floe in the Gulf was undertaken.
5. Oceanographic observations were made in the autumn 1956 and in the spring 1957 in order to study the conditions before freezing in the Gulf, and the relation between the cold-water layer and the cooling.
6. The oceanographic conditions in the autumn 1956 as compared to those in 1955 indicate that the ice would form earlier during

the winter 1957 than during the winter 1956.

7. The cold-water layer had a larger volume in the spring 1957 than in the spring 1956. The variation in the volume of the cold-water layer in the spring during the two years is associated, in part, with the variation in severity of ice conditions during the previous winters. Both processes are related to the cooling of the upper layers during the winter, and the oceanographic conditions of the deeper layers.

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LIST OF DIATOMS TAKEN FROM UNDER THE ICE IN THE
GULF OF ST. LAWRENCE IN FEBRUARY 1957

by A. S. Bursa

Two plankton samples, Nos. I and II, show typical ice-floe flora. Sample No. 1 is more pelagic in its composition, while Sample No. II contains more neritic diatoms, not contained in the first. Apart from diatoms, various flagellated groups of species were observed, which were however unidentifiable because of deformation caused by the preservative. It is of general biological interest to study growth and taxonomic composition of green-brown films of diatoms and associated protozoa, which are of particular importance as a source of food for planktonic crustaceans. The studies have to be carried out in the field, and special tools for collecting samples are required.

- List:
- * Achnantes taeniata
 - * Asterionella japonica
 - * Amphiprora hyperborea
 - * Biddulphia aurita
 - Chaetoceros debilis
 - Chaetoceros wighamii
 - Chaetoceros sp.
 - Chaetoceros laciosus
 - * Coscinodiscus concinnus
 - * Coscinodiscus sp.
 - * Coscinosira polychorda
 - * Distephanus speculum var. regularis (silicoflagellata)

- ✱ Gyrosigma spenceri
- ✱ Gyrosigma sp.
- ✱ Fragillaria crotonensis
- ✱ Fragillaria cylindrus
- ✱ Fragillaria oceanica
- ✱ Lauderia borealis
- ✱ Melosira arctica
- ✱ Navicula grani
- ✱ Navicula septentrionalis
- ✱ Navicula vanhoffeni
- ✱ Navicula sp.
- ✱ Nitzchia closterium
- ✱ Nitzchia longissima
- ✱ Nitzchia seriata
- ✱ Nitzchia pungens
- ✱ Nitzchia frigida
- ✱ Nitzchia sp.
- ✱ Pleurosigma elongatum
- ✱ Pleurosigma sp.
- ✱ Skeletonema costatum
- ✱ Synedra sp.
- ✱ Thalassiosira gravida
- ✱ Thalassiosira nordenskjoldi
- ✱ Gymnodinium sp. (Dinoflagellatae)
- ✱ Bodo sp.
- ✱ Fungi imperfecti
- ✱ Ceratium longipes

Resume:

Thirty-five plankton diatoms, characteristic of arctic ice-floes, were identified. Species marked with an asterisk occurred in both samples. Not marked, only in one sample. Three species of Gymnodinidae and some amorphous flagellated forms were also observed.

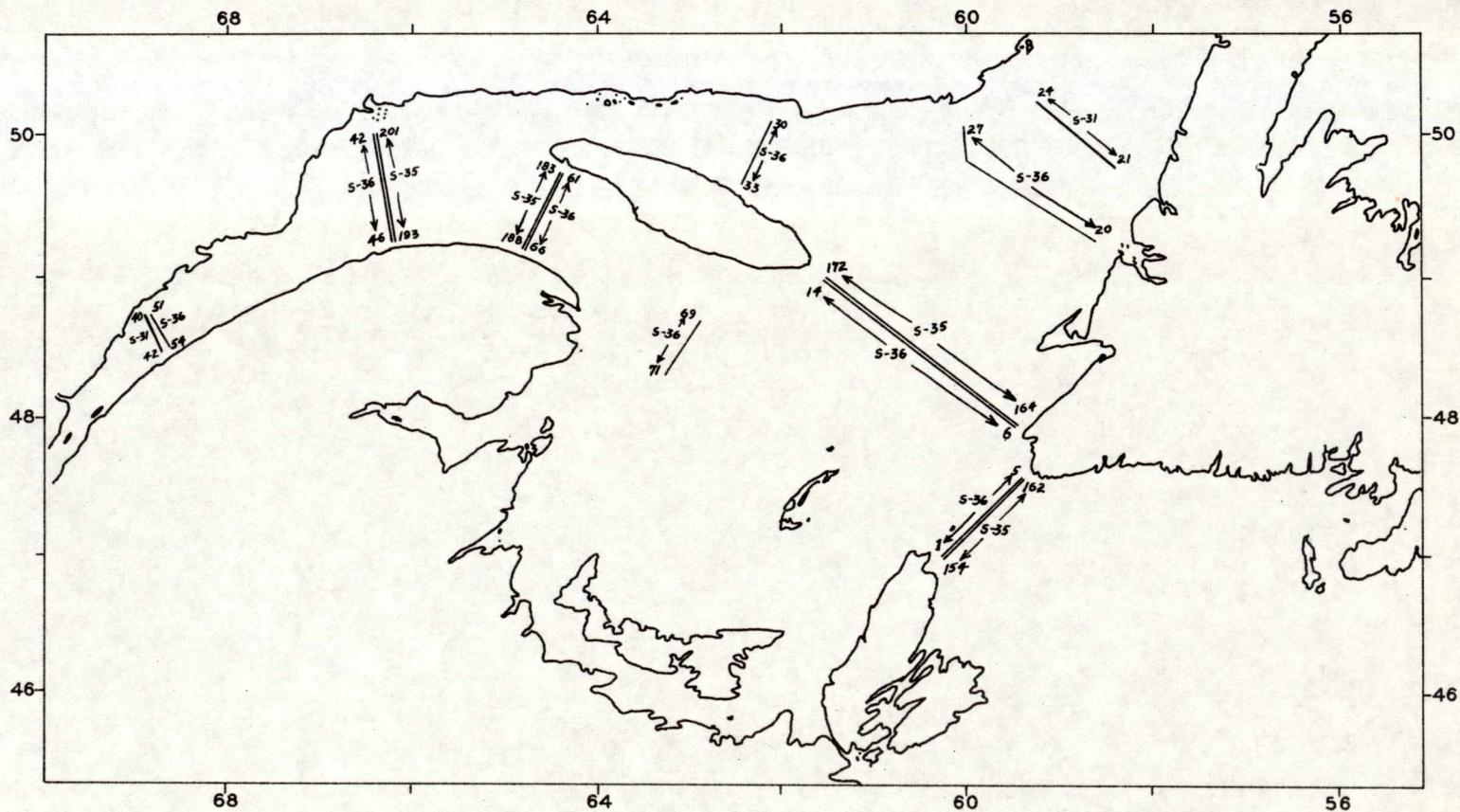


Figure 1. Location of hydrographic sections in the Gulf of St. Lawrence and the eastern sector of the Estuary occupied by C.N.A.V. "Sackville" during the autumn 1956 (cruise S-35), the spring 1957 (cruise S-36).

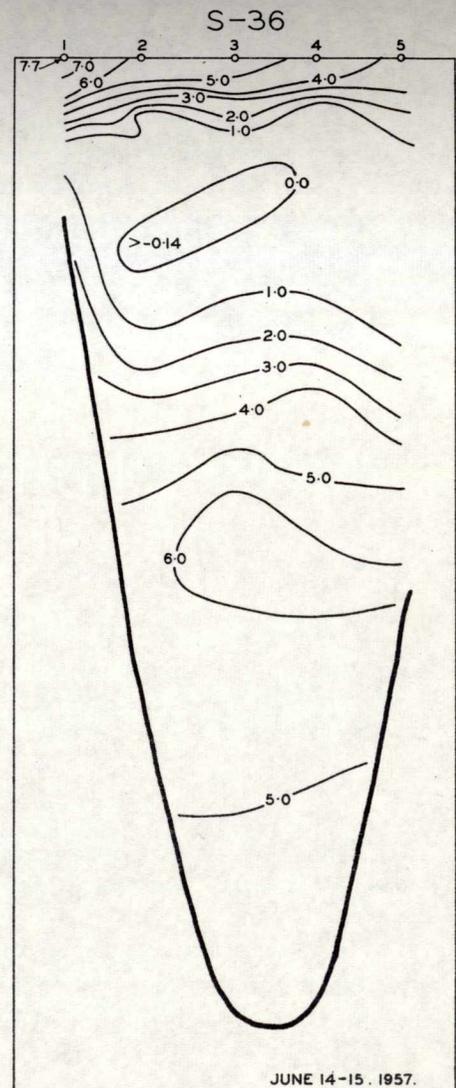
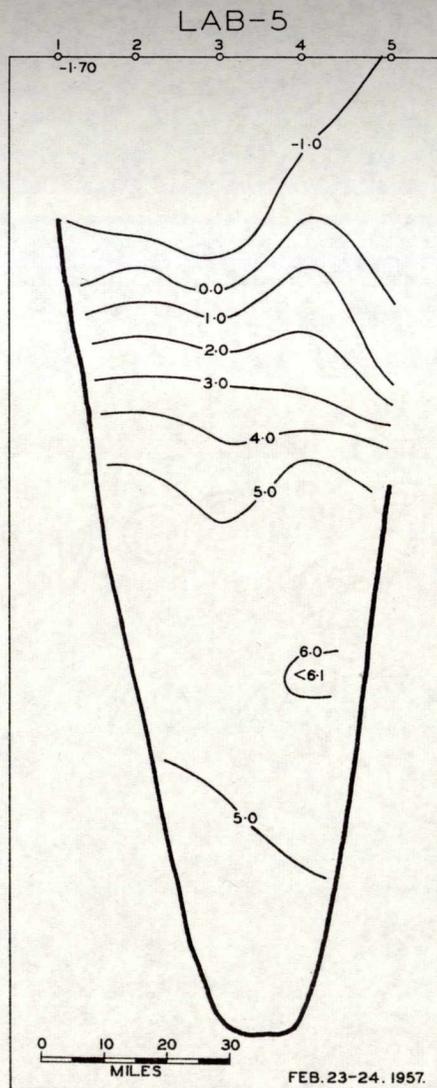
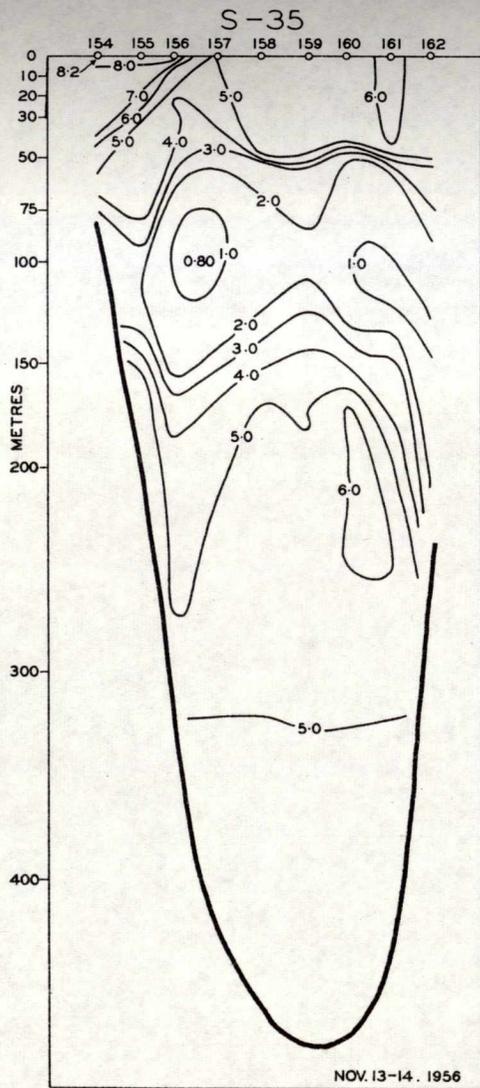


Figure 2. Distribution of temperature ($^{\circ}\text{C}$) in Cabot Strait in the autumn, winter and spring.

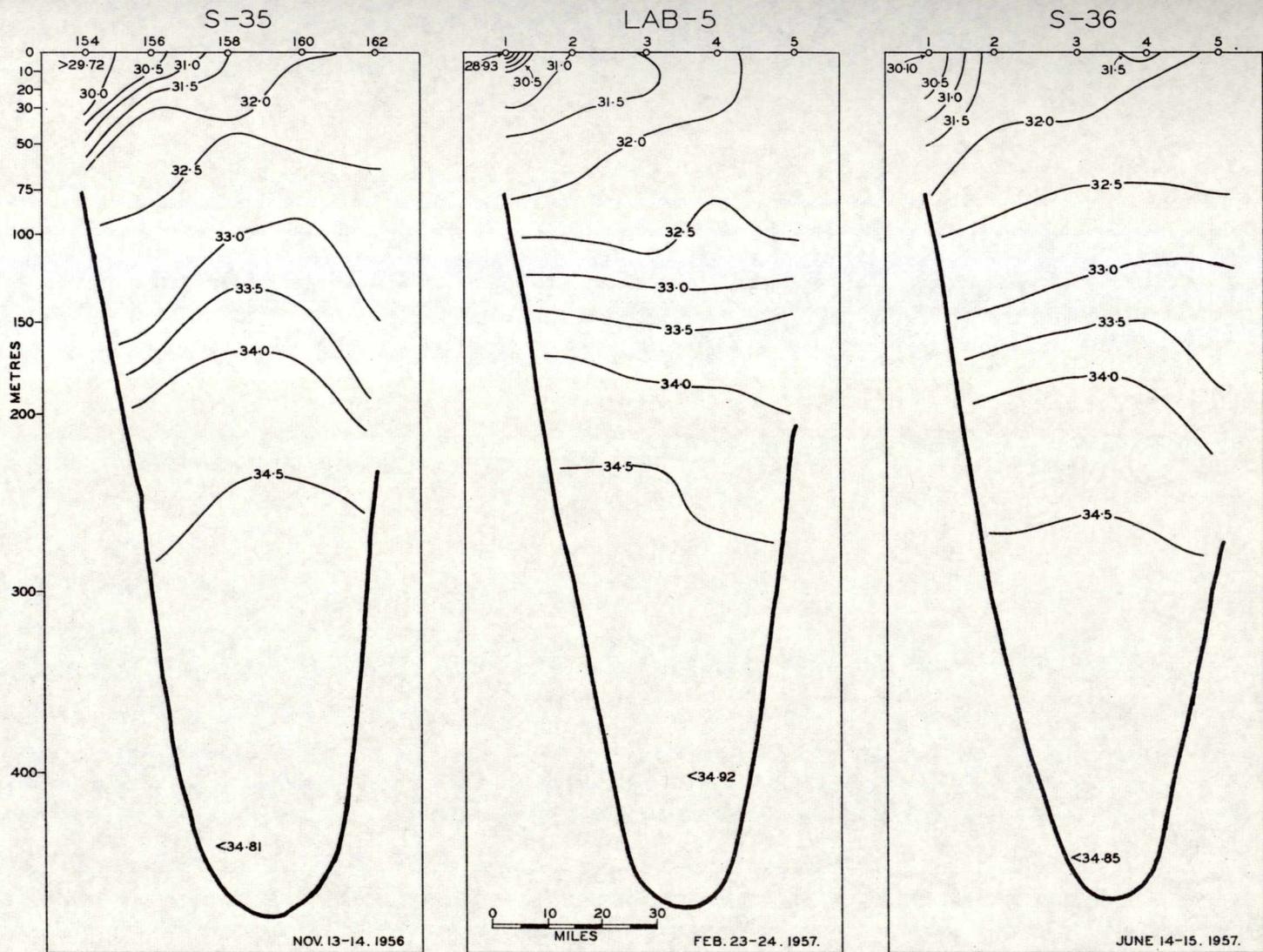


Figure 3. Distribution of salinity (‰) in Cabot Strait in the autumn, winter and spring.

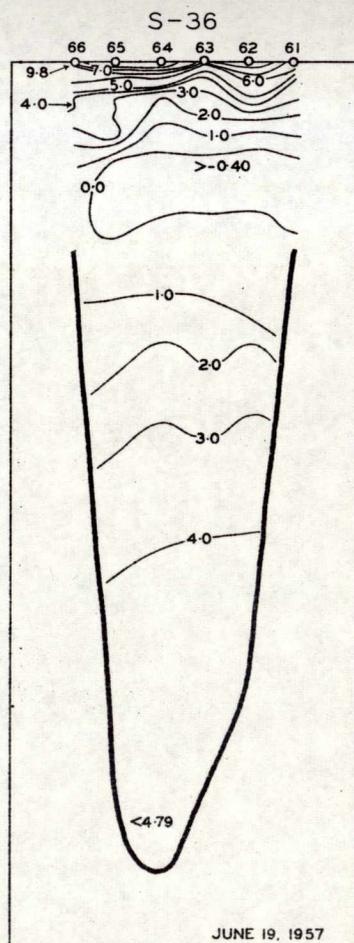
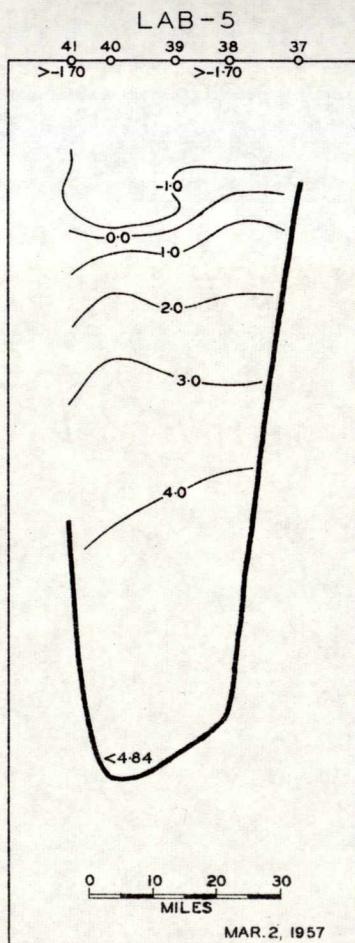
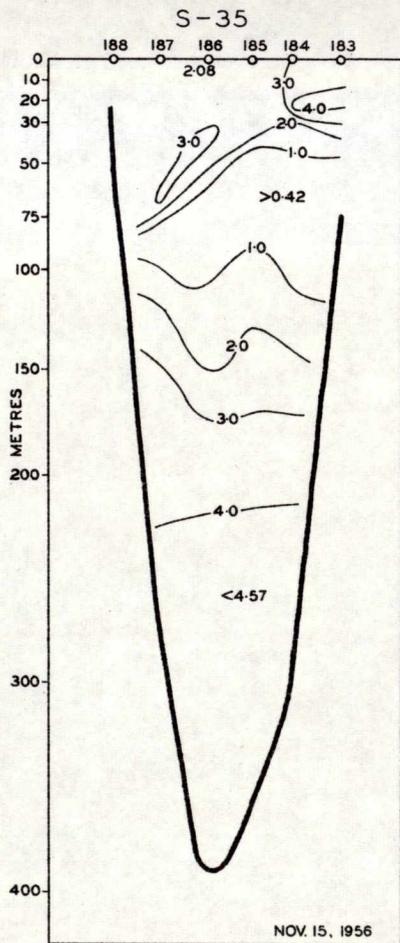


Figure 4. Distribution of temperature ($^{\circ}\text{C}$) in a section of Gaspe Passage in the autumn, winter and spring.

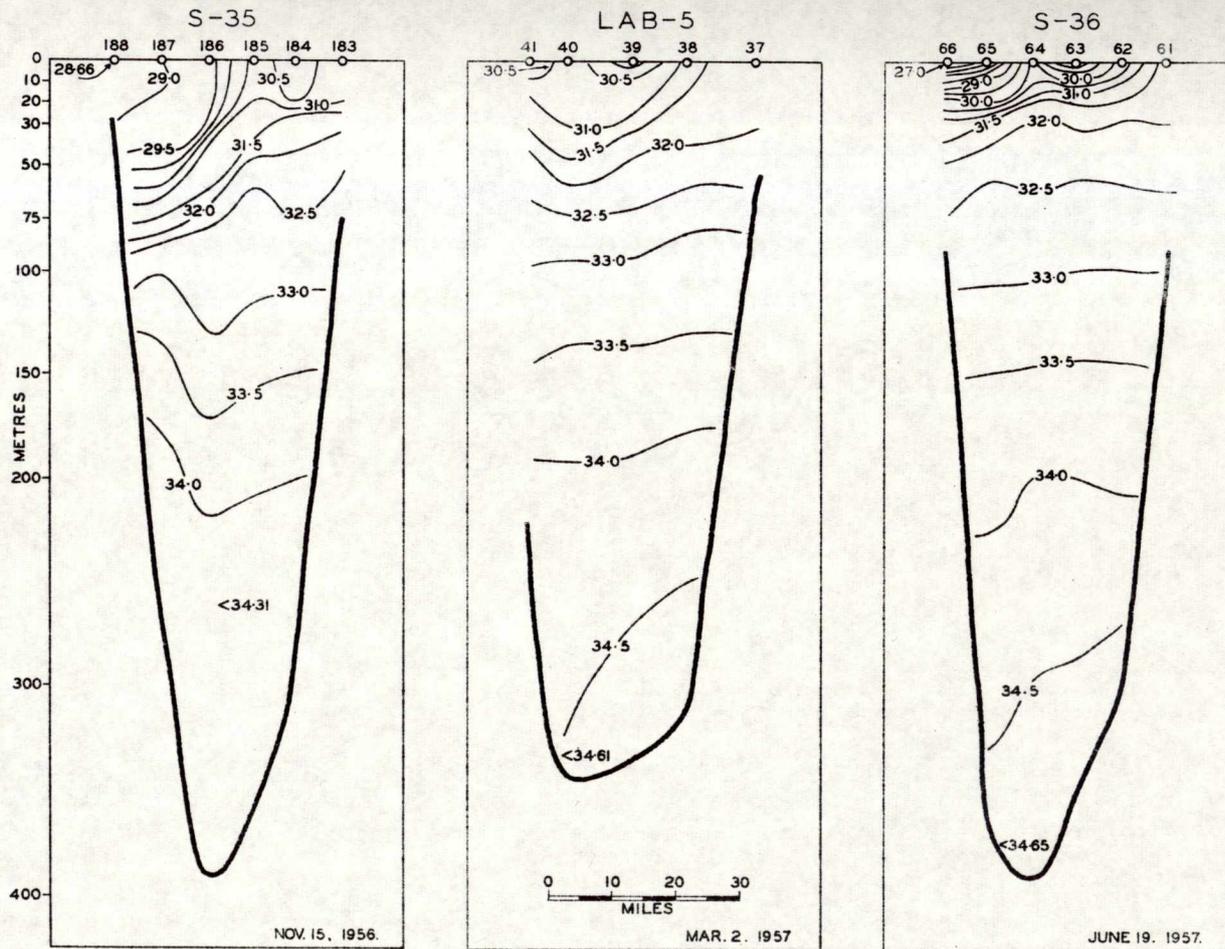


Figure 5. Distribution of salinity (‰) in a section of Gaspé Passage in the autumn, winter and spring.

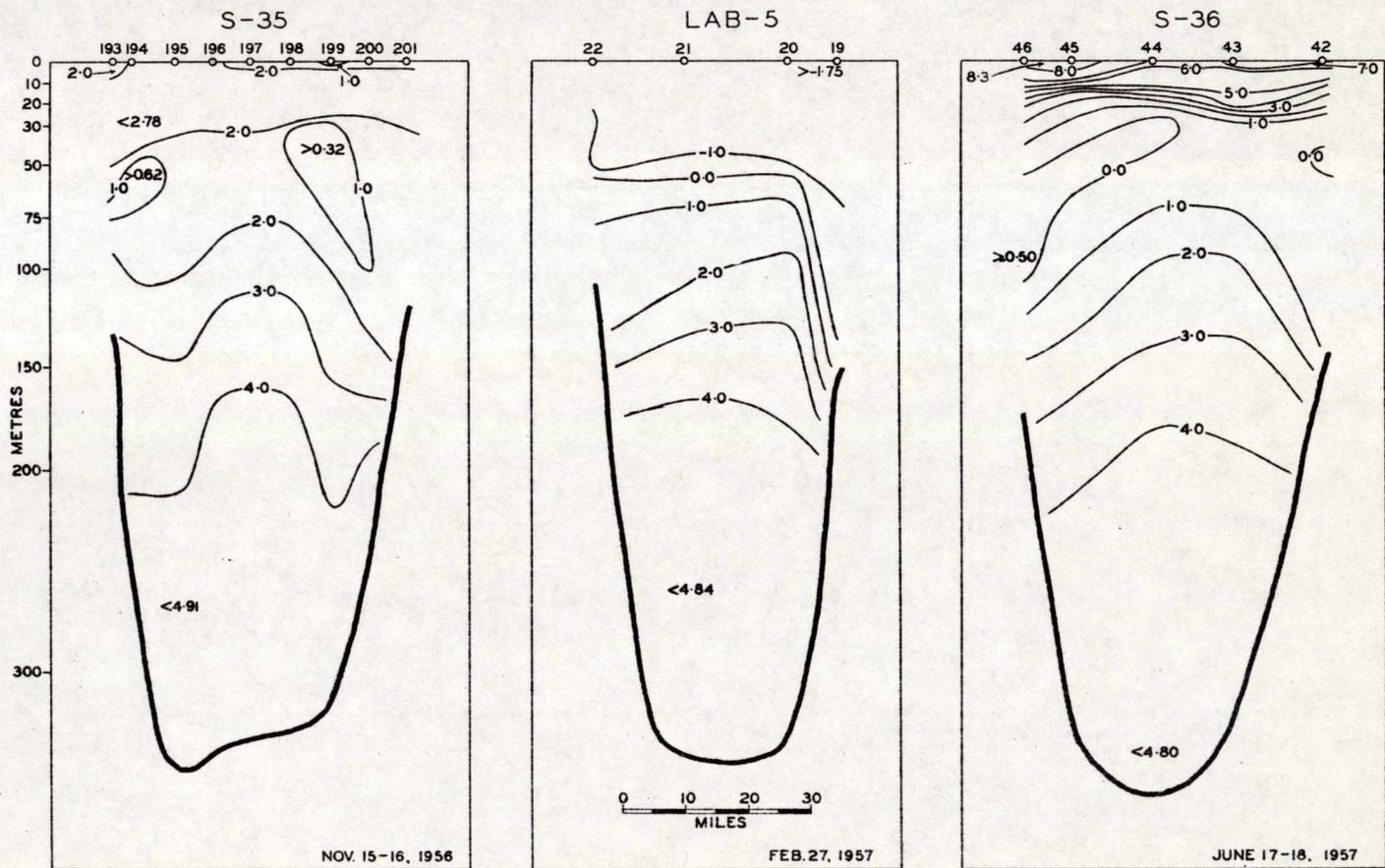


Figure 6. Distribution of temperature ($^{\circ}\text{C}$) in a section of the north-western Gulf in the autumn, winter and spring.

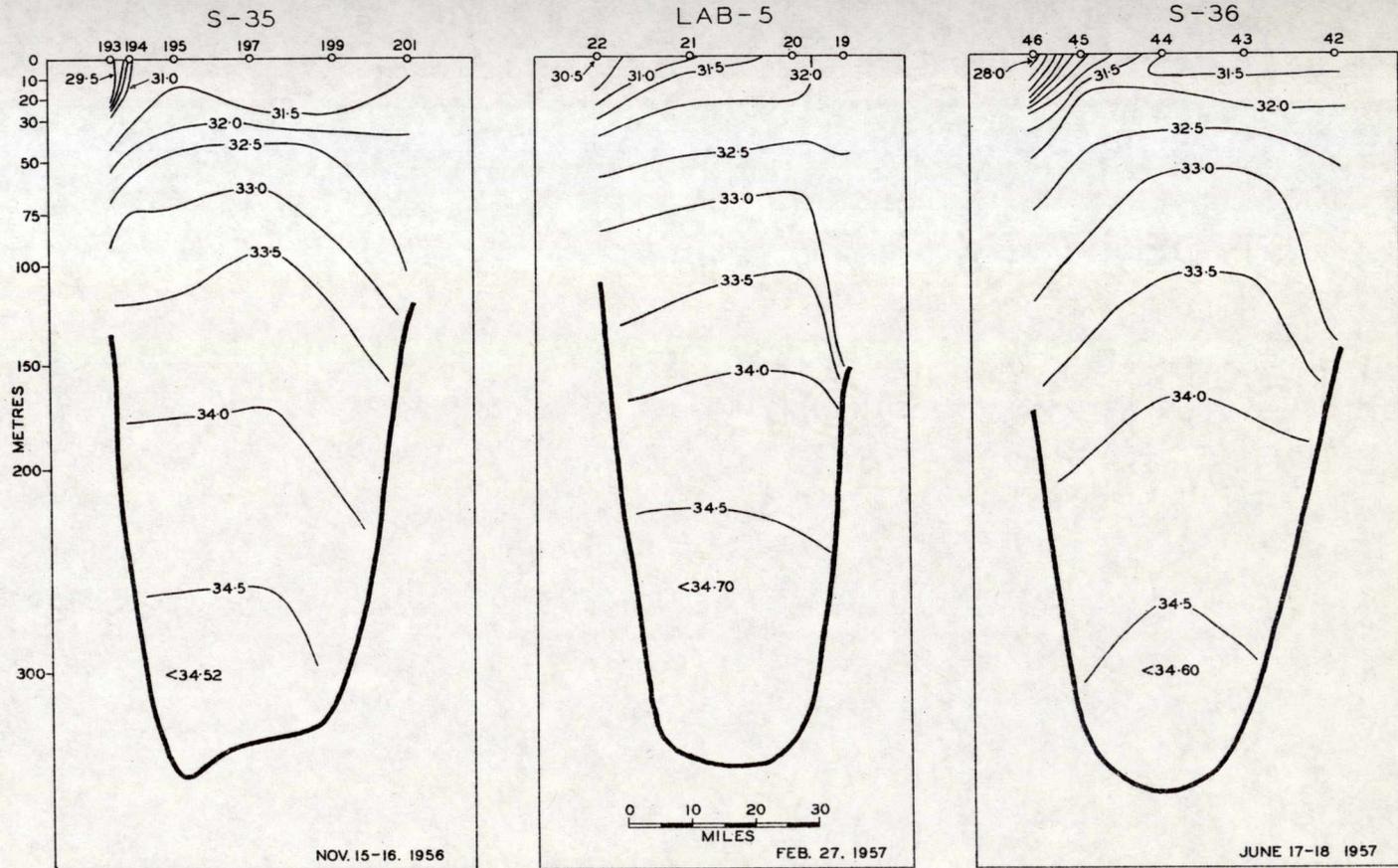


Figure 7. Distribution of salinity (‰) in a section of the northwestern Gulf in the autumn, winter and spring.

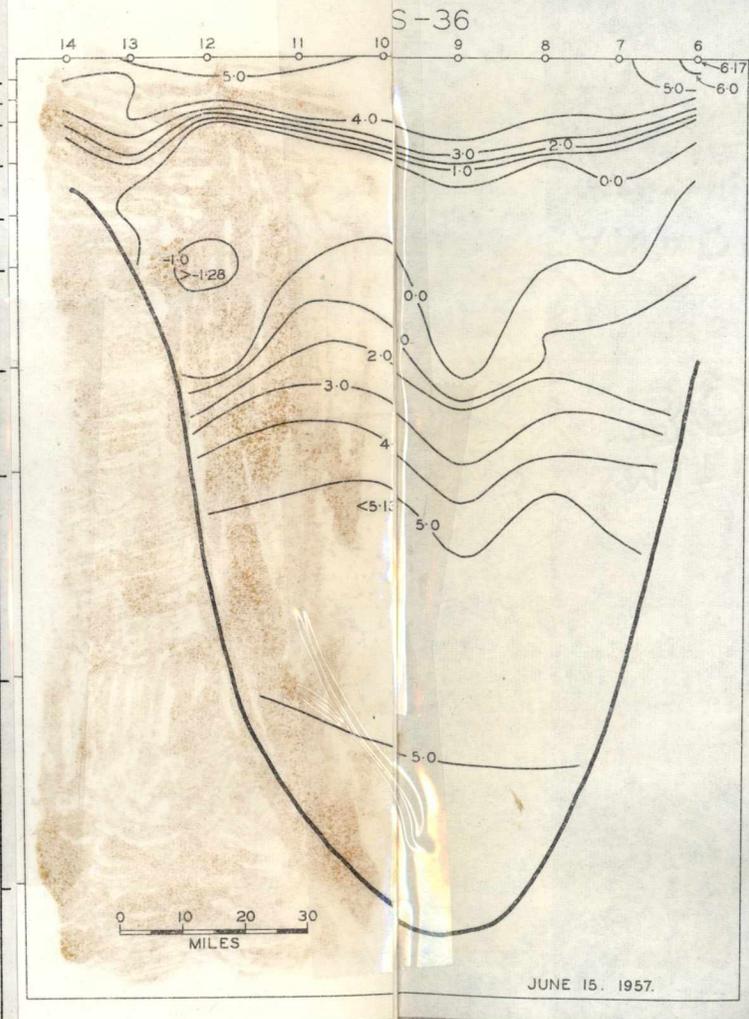
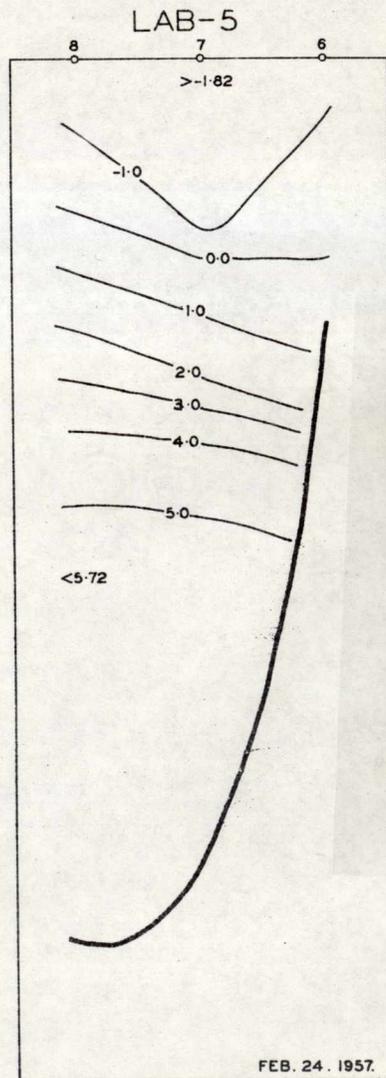
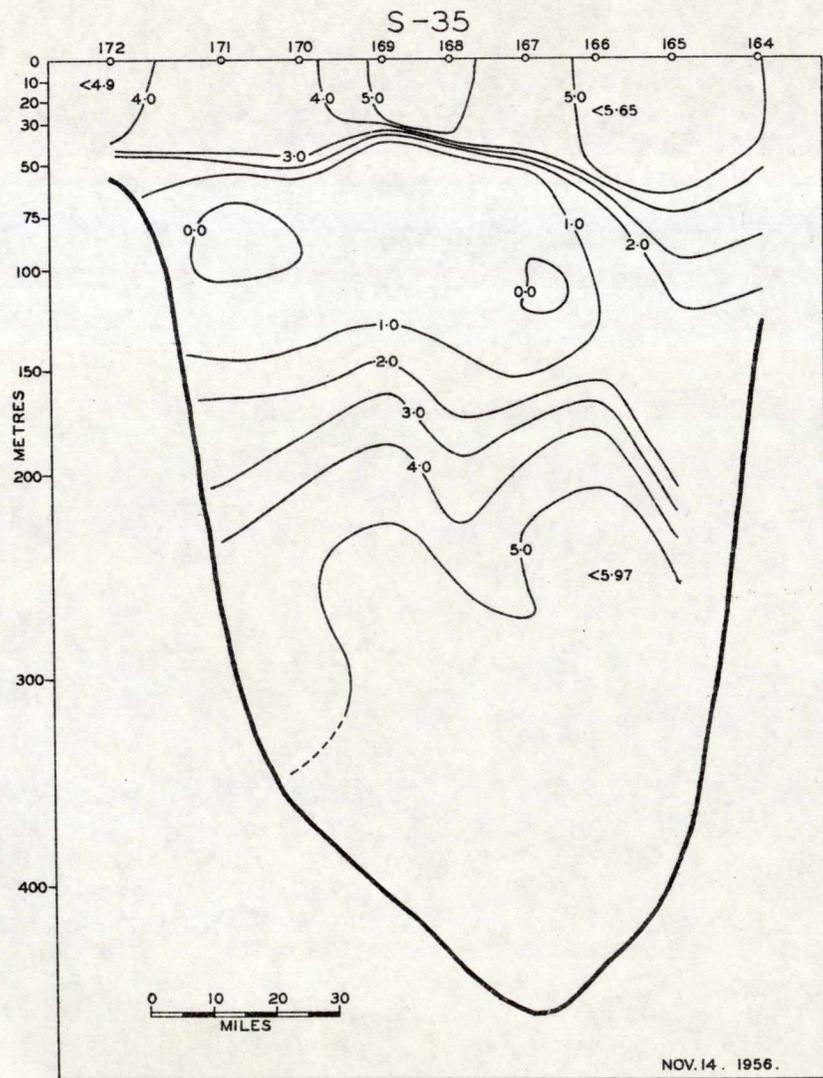


Figure 8. Distribution of temperature ($^{\circ}\text{C}$) in a section of Esquiman Channel, between Newfoundland and Anticosti Island.

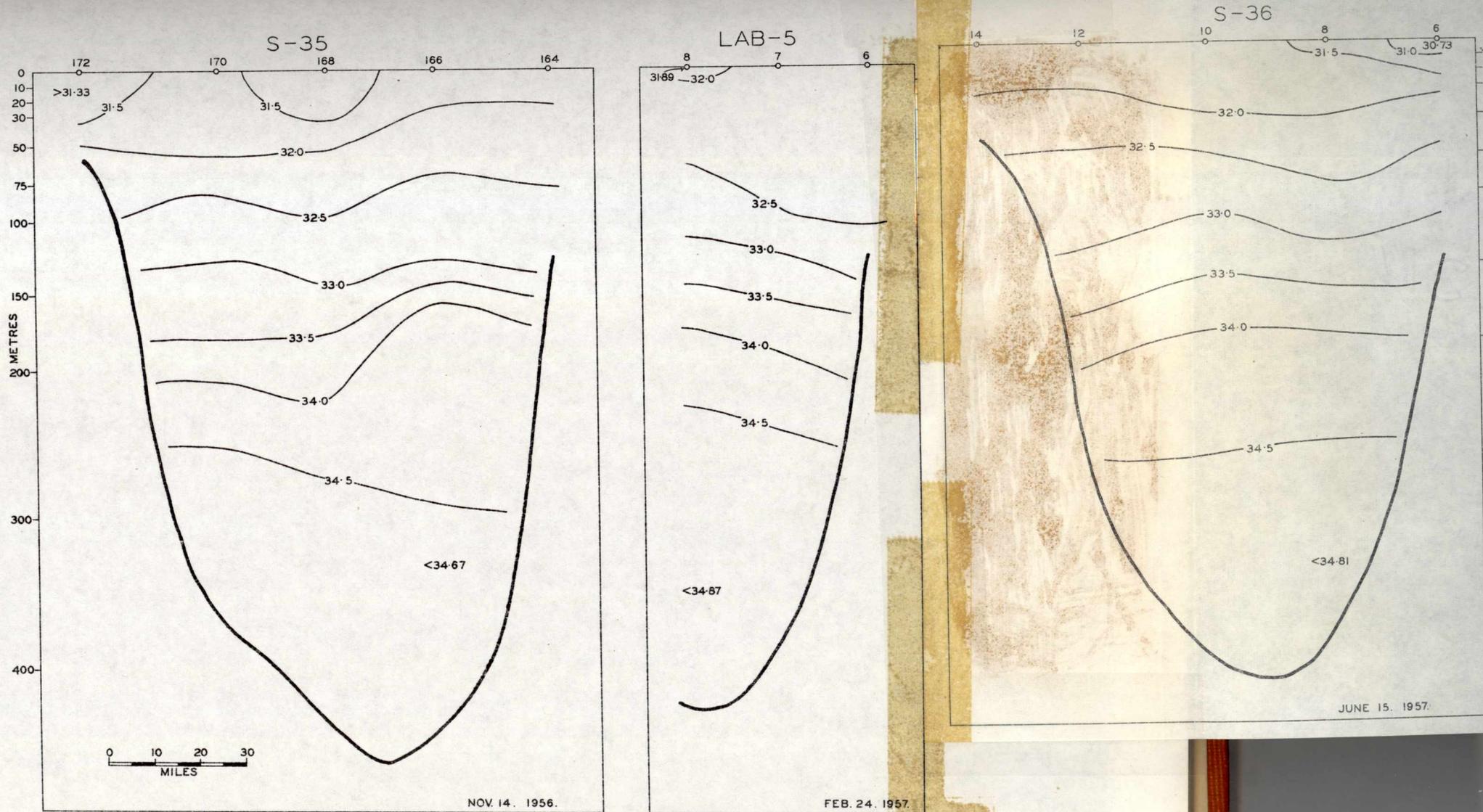


Figure 9. Distribution of salinity (‰) in a section of Esquiman Channel between Newfoundland and Anticosti Island.

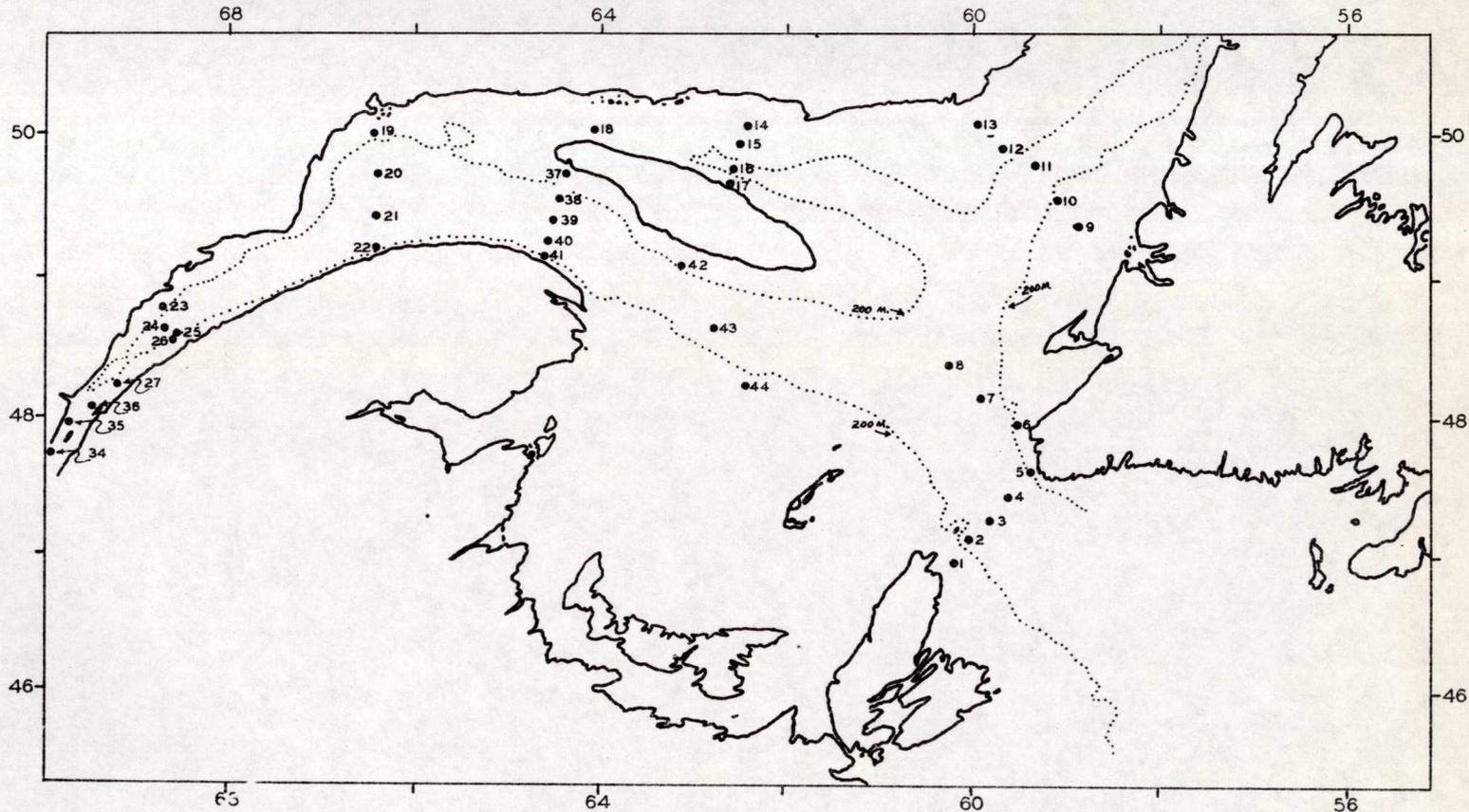


Figure 10. Location of hydrographic stations in the Gulf of St. Lawrence and the Estuary during the winter cruise of 1957 by H.M.C.S. "Labrador" (cruise LAB-5).

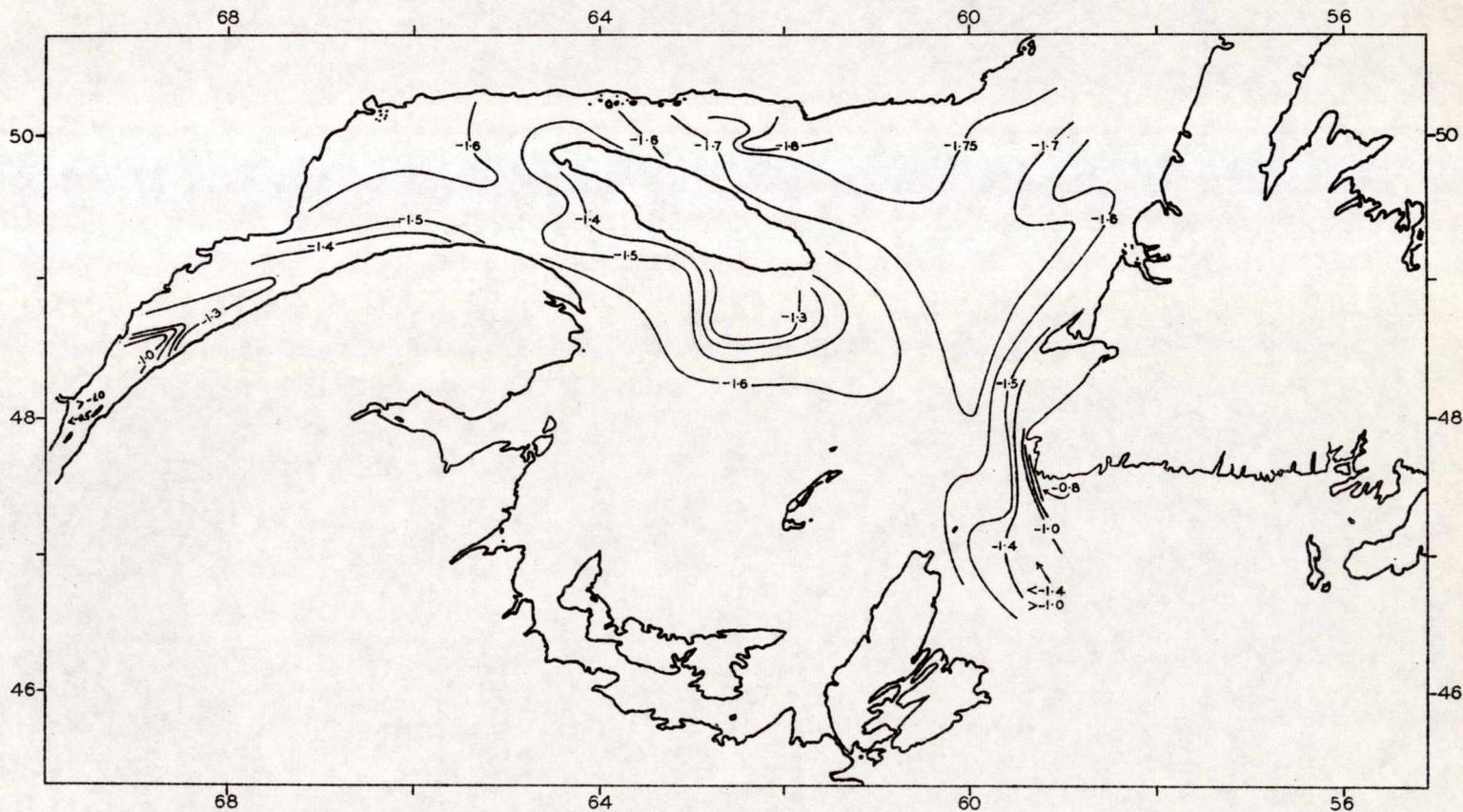


Figure 11. Surface distribution of temperature ($^{\circ}\text{C}$) in the Gulf of St. Lawrence and the eastern sector of the Estuary, February 23rd. to March 3rd. 1957.

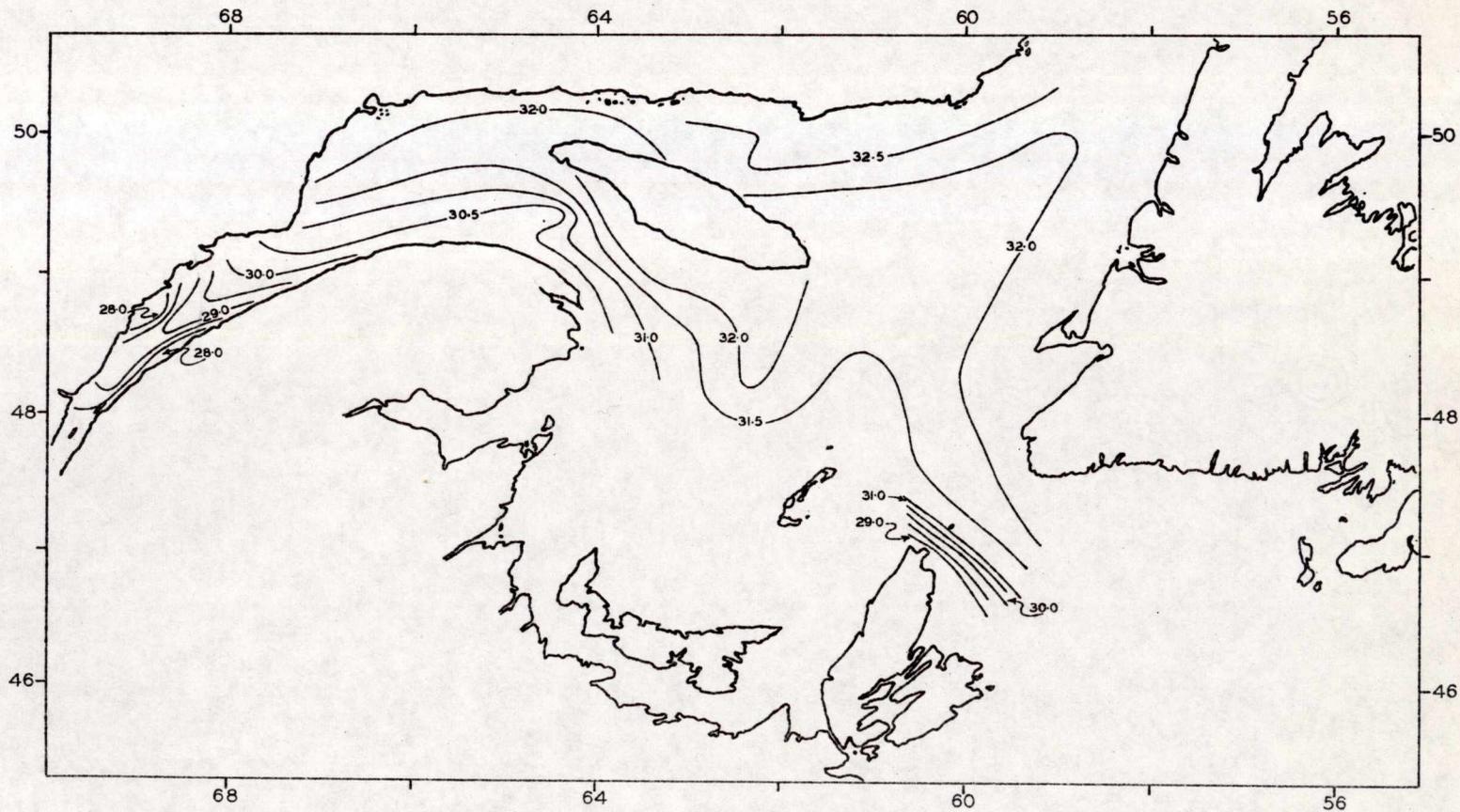


Figure 12. Surface distribution of salinity (‰) in the Gulf of St. Lawrence and the eastern sector of the Estuary, February 23rd. to March 3rd. 1957.

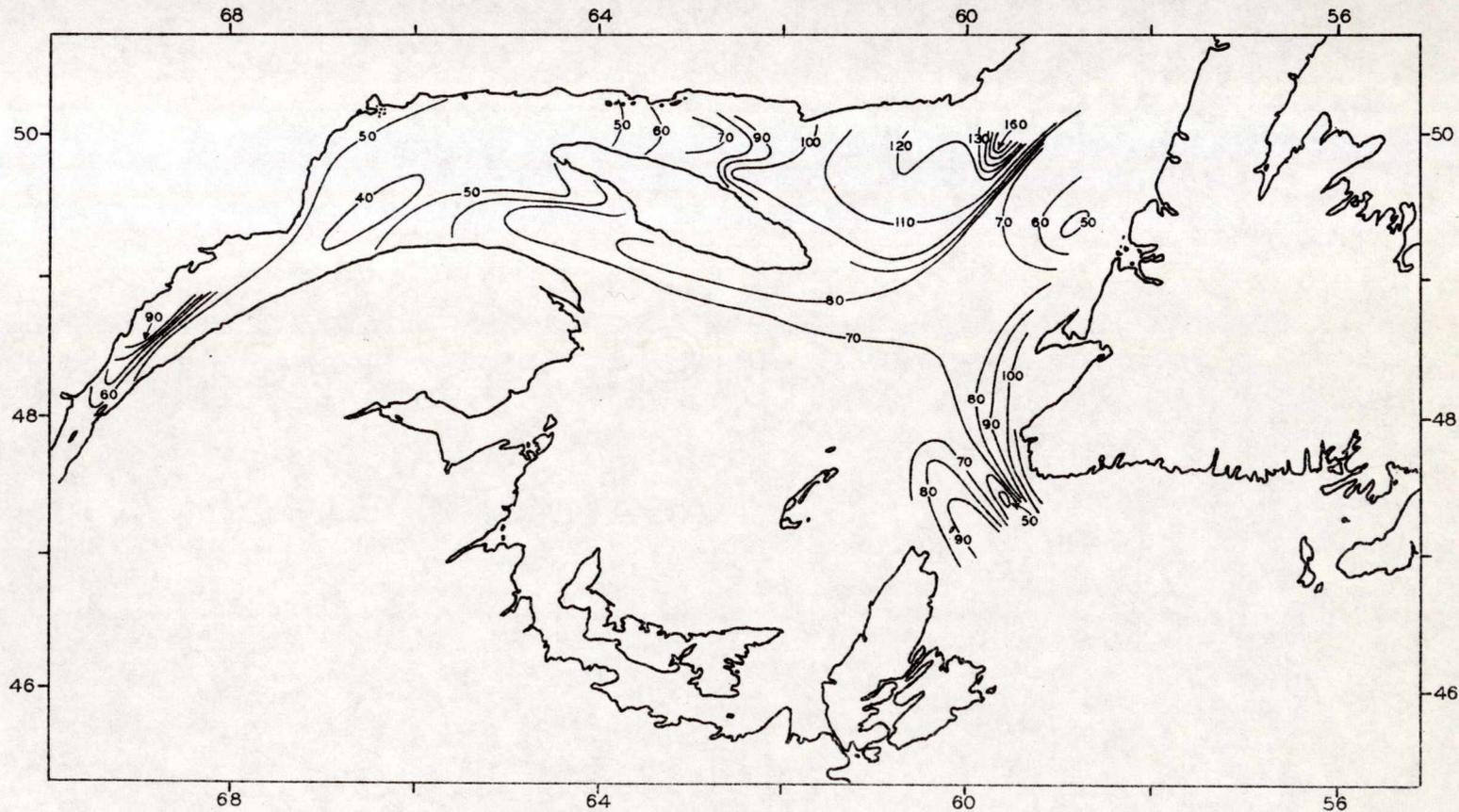


Figure 13. Thickness of the mixed layer, in metres, in the Gulf of St. Lawrence and the eastern sector of the Estuary, February 23rd. to March 3rd. 1957.

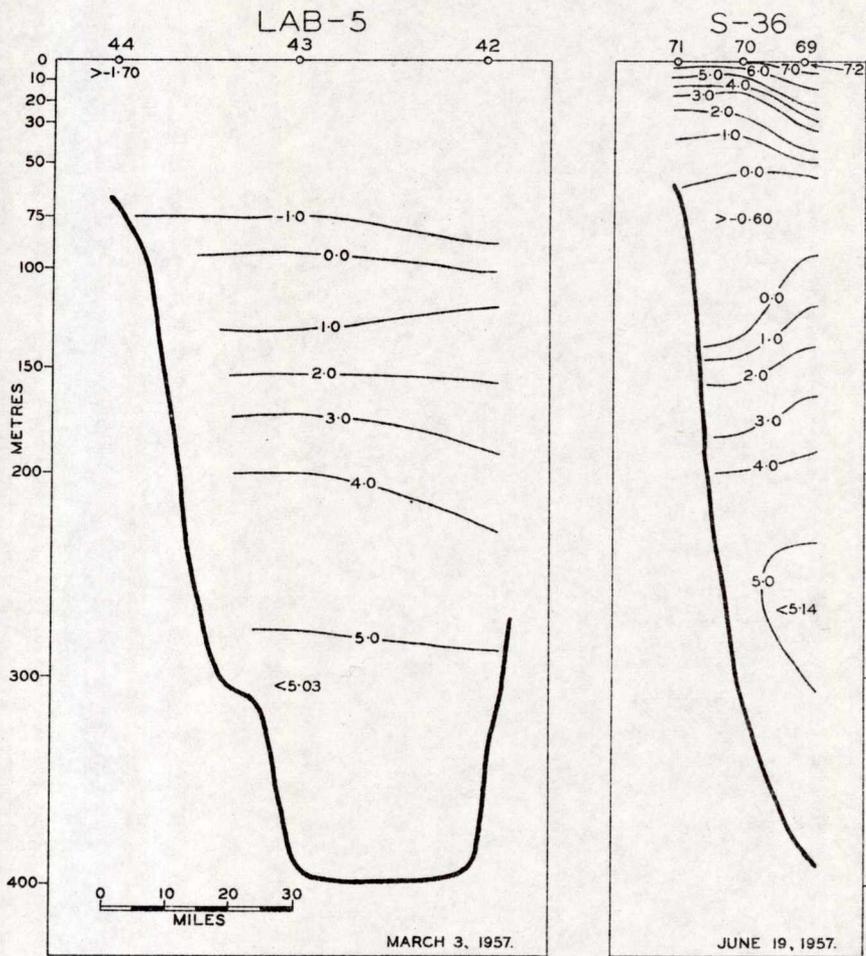


Figure 14. Distribution of temperature ($^{\circ}\text{C}$) in a section north of the Magdalen Shallows in the winter and spring.

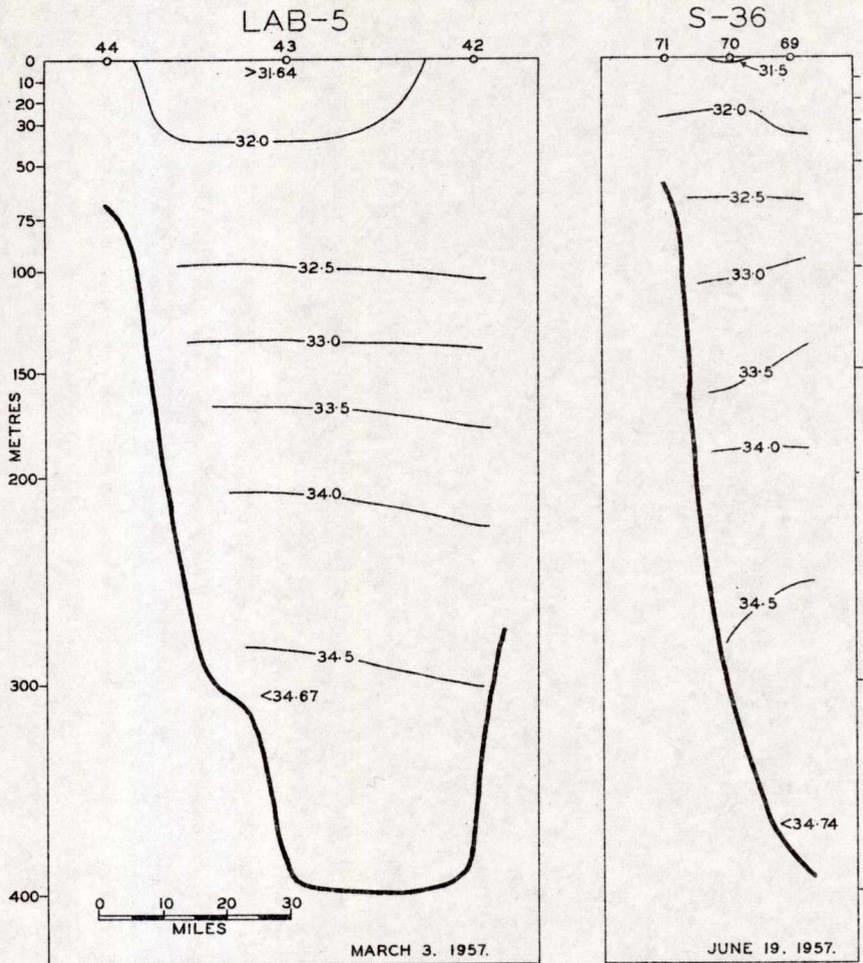


Figure 15. Distribution of salinity (‰) in a section north of the Magdalen Shallows in the winter and spring.

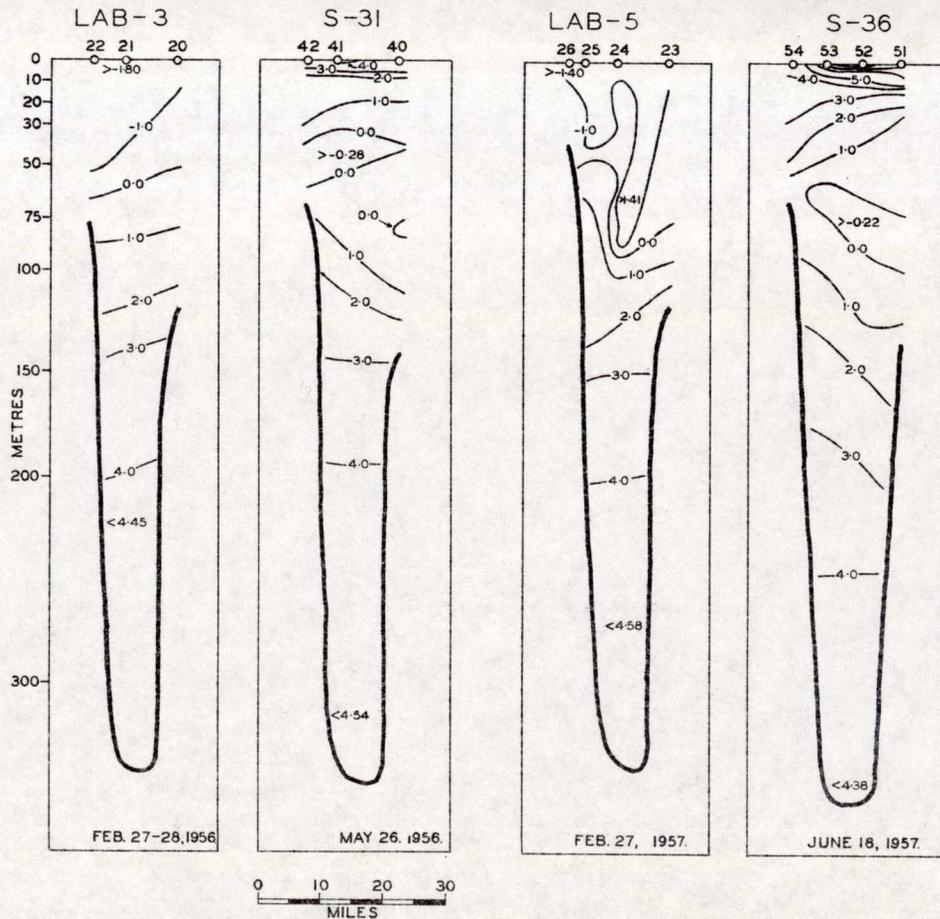


Figure 16. Distribution of temperature ($^{\circ}\text{C}$) in a section of the Estuary, east of the Saguenay river, in the winter and spring, 1956 and 1957.

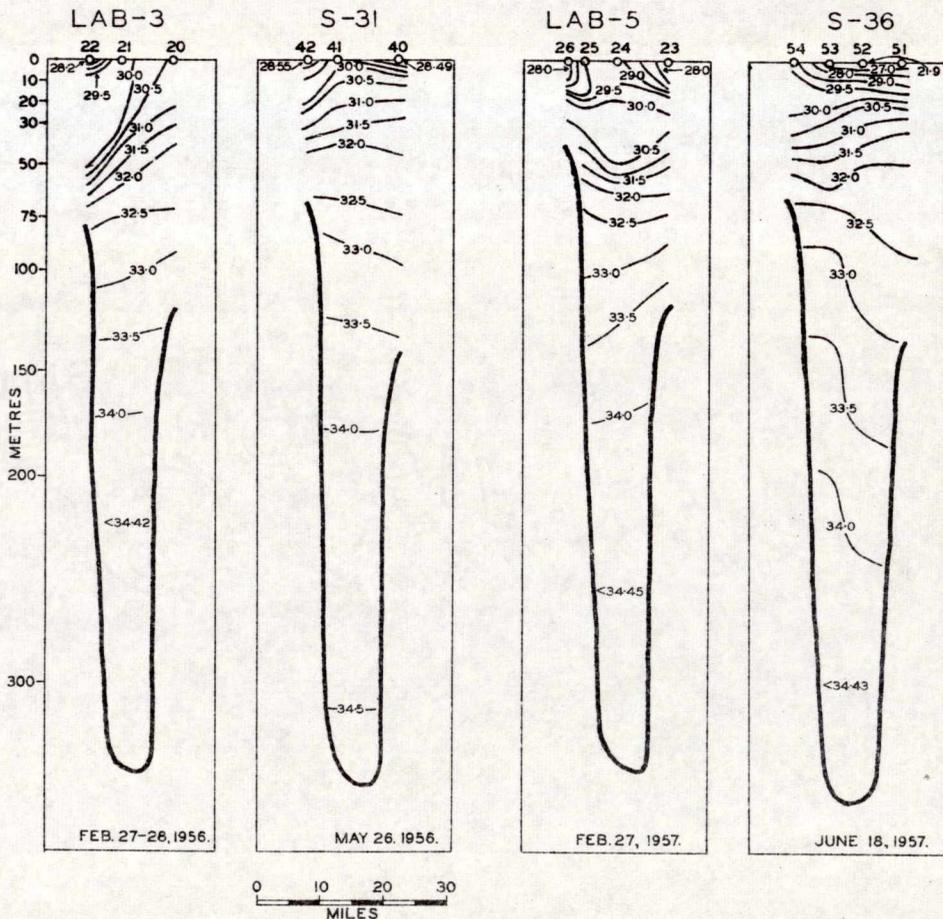


Figure 17. Distribution of salinity (‰) in a section of the Estuary, east of the Saguenay river, in the winter and spring, 1956 and 1957.

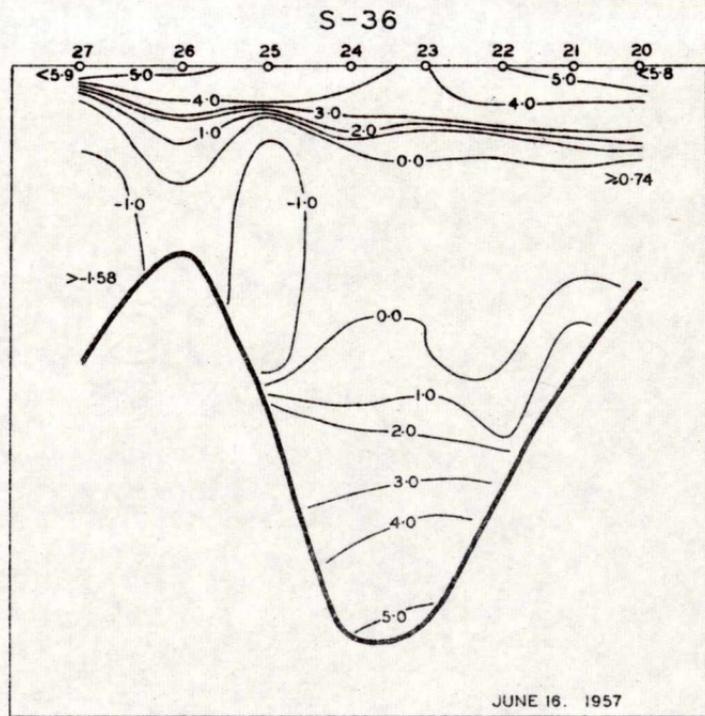
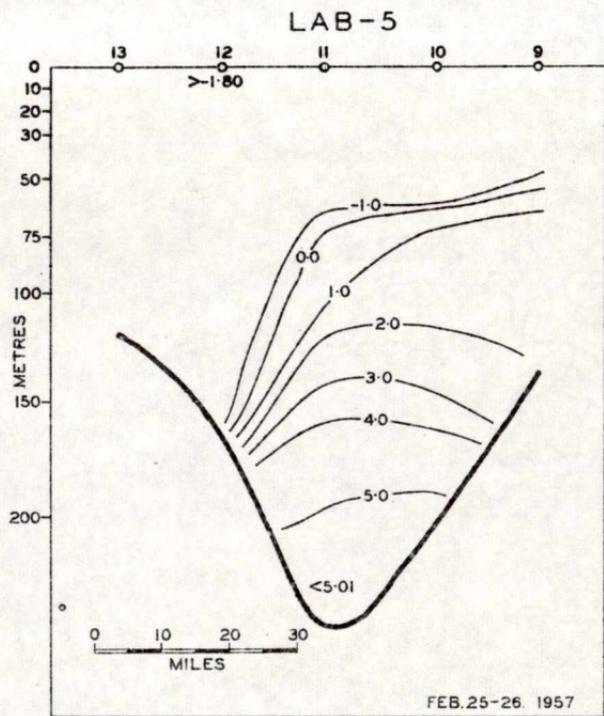


Figure 18. Distribution of temperature ($^{\circ}\text{C}$) in a section of Esquiman Channel, between Newfoundland and the North Shore, in the winter, and spring, 1957.

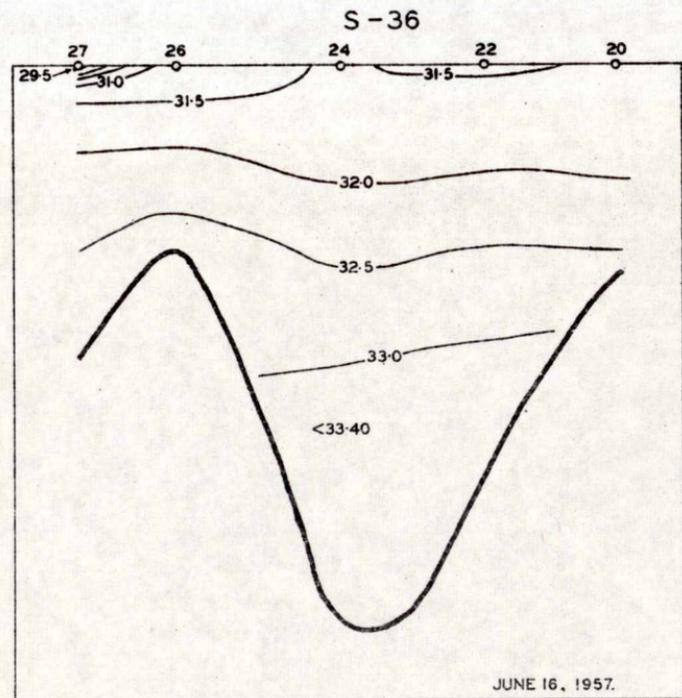
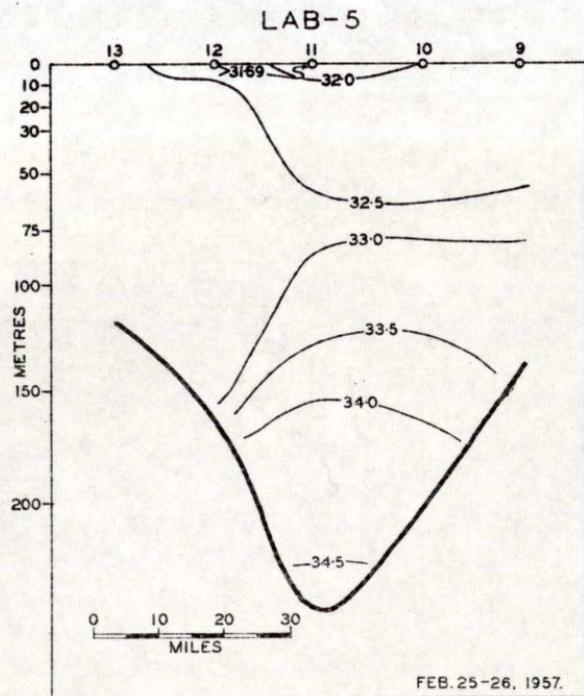


Figure 19. Distribution of salinity (‰) in a section of Esquiman Channel, between Newfoundland and the North Shore in the winter and spring, 1957.

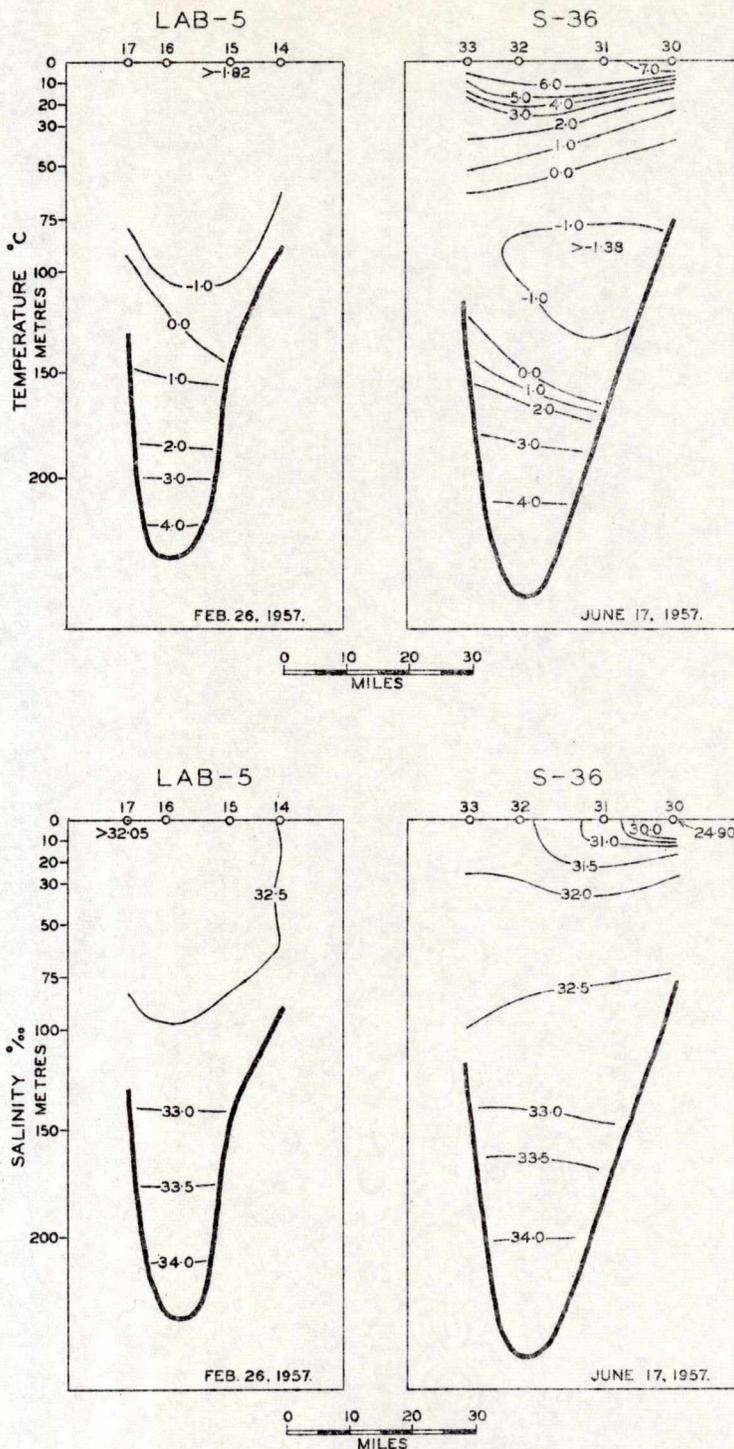


Figure 20. Distribution of temperature ($^{\circ}\text{C}$), upper graphs, and of salinity (‰), lower graphs, in a section of Jacques Cartier Passage in the winter and spring.

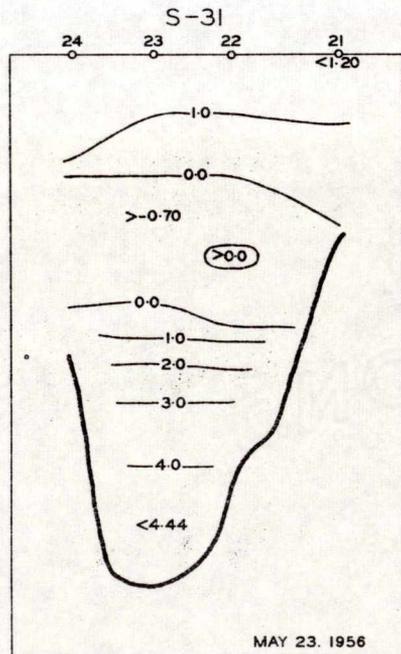
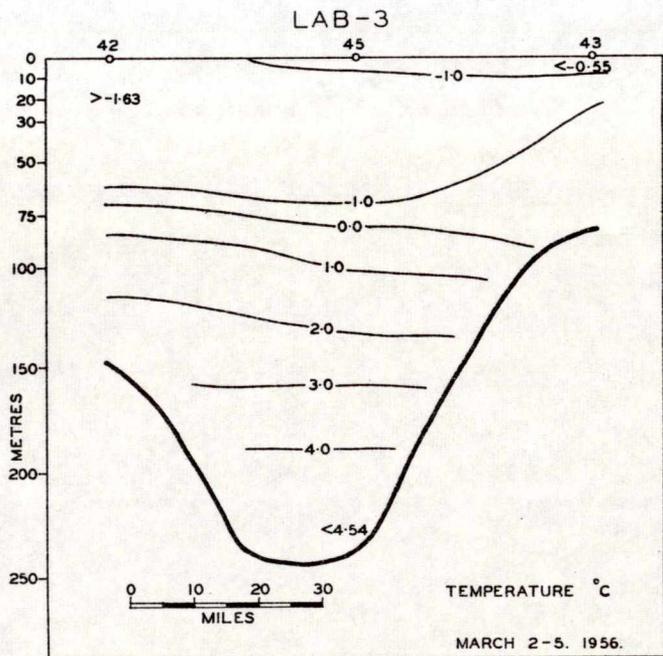


Figure 21. Distribution of temperature ($^{\circ}\text{C}$) in a section of Esquiman Channel, between Newfoundland and the North Shore, in the winter, and spring, 1956.

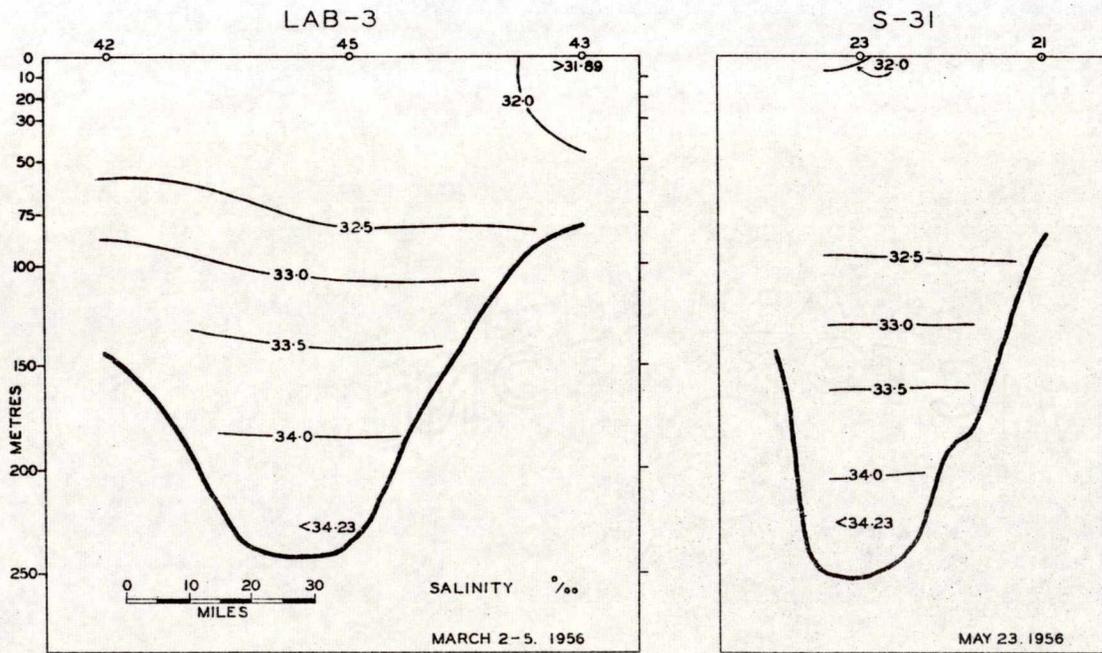


Figure 22. Distribution of salinity (‰) in a section of Esquiman Channel, between Newfoundland and the North Shore, in the winter, and spring, 1956.