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WATER CONDITIONS IN THE STRAIT OF CANSO

by

D. G. MacGregor

## Water Conditions in the Strait of Canso

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### Introduction

The Strait of Canso separates Cape Breton Island from the mainland of Nova Scotia. It is a narrow body of water some  $14\frac{1}{2}$  miles (27 km.) long and 0.45 miles (0.8 km.) wide at its narrowest between Balache Point and Cape Porcupine. The land is high on the sides of the Strait and the shores bold. In the deepest part, off Cape Porcupine, the depth of the channel reaches 30 fathoms (55 metres), and only in a few places is it less than 15 fathoms (27.5 metres). The currents are strongest off Point Tupper and Cape Porcupine where the velocity may be as high as 5 knots at spring tides (Tide Tables).

The tides at the ends of the Strait are of two distinct types. On the Atlantic side, the tide is synodic with a range of 6.0 ft. (1.8 metres) in Chedabucto Bay at times of spring tide. On the northern end, the tide is dominated by the moon's declination so that marked diurnal inequalities in the tidal oscillations are observed at times of maximum declination. The tidal range here is less than on the Atlantic end being 4.5 ft. (1.4 metres) at Cape Jack in Georges Bay. The times of high and low water at the ends of the Strait are not simultaneous. High water is later at the northern end than at the southern end by an amount which varies from zero to over two hours depending on the phase and declination of the moon. Differences in the times of low water are not so great.

As the flow through the Strait depends upon the difference of level of the two ends, the tidal streams are complicated. When the moon is on the equator, a semi-diurnal reversing flow is observed with only minor differences between the magnitude or duration of successive flows in opposite directions, or between successive flows in the same direction. However, at times of maximum declination, the two cycles of tidal flow in one day may differ greatly in magnitude and duration. In the extreme case, one period of flow may be completely suppressed and appear only as a long stand in the tidal stream. The tide tables report a net flow to the southward corresponding to an outflow from the Gulf of St. Lawrence. Even with the moon on the equator, there is a slight preponderance of southward flow. The non-periodic contributions of the meteorological factors of wind and barometric gradients also complicate the flow.

Observations of the tidal flow in the Strait of Canso have been carried out from time to time by the Canadian Hydrographic Service and are referred to in Tide Tables for the Atlantic Coast. Predictions of the times of slack water for the Strait are included. The early observations were made under the direction of Dr. W. Bell Dawson in 1915-16. A series of observations on the tidal currents in the central section of the Strait were made by the master and first officer of the car ferry "Scotia". In the tide tables of 1929, reference is found to harmonic analysis of four summer season's day and night observations of the time of turn of the current. These observations have formed the basis for the prediction of the times of slack water as published in the Tide Tables.

Construction has recently begun on a causeway which will link Cape Breton Island to the mainland, and which will close off the Strait of Canso. It is desirable that a fairly complete series of observations be made before and after the blocking of the Strait so that the effect upon the waters of the region may be assessed.

The present study of temperatures and salinities in the Strait, under various conditions, is a contribution to the knowledge of this hydrographic feature which is about to disappear.

Observations

During the period from May, 1952 to November, 1952, thirteen passages through the Strait were made by the oceanographic vessel, C.N.A.V. "Sackville", taking observations at seven stations of which the locations and depths are given in Table I.

TABLE I

			<u>Latitude</u>	<u>Longitude</u>	<u>Depth</u> <u>Metres</u>
			<sup>o</sup>	<sup>o</sup>	
Atlantic	-	Station I	45 25.7'N.	61 07.0'W.	62
		{ Station II	45 29.5	61 11.4	36
Strait		{ Station III	45 32.3	61 17.1	38
of		{ Station IV	45 35.5	61 22.2	32
		{ Station V	45 39.8	61 26.3	32
Canso		{ Station VI	45 43.5	61 31.0	32
Gulf	-	Station VII	45 46.5	61 36.5	32

These stations were spaced evenly at intervals of 5.0 miles (9.3 km.) along the axis of the Strait, and their locations are shown in figure 1. Bathythermograph observations were made at

all stations, and water samples were obtained usually at all odd numbered stations from depths of 0, 5, 10, 20, and 30 metres. Stations (I) and (VII) at the south and north ends of the Strait are situated in the approaches to the Strait proper.

Observations were made during periods when the ship was engaged in more extensive surveys. When possible, the times of passage were arranged to give observations during a variety of tidal conditions. Passages through the Strait were made in pairs within a short interval, except in the instance of passage V for which there is no related return passage. The time of slack water and the direction of the tidal current referred to frequently in the following descriptions have been obtained from the Tide Tables (1952).

#### Temperature and Salinity

The vertical distribution of temperature and salinity, as observed during the various passages, are shown in figures 2 to 19 inclusive.

##### (a) May 11, 12, 1952

Passage I, 23:40 G.M.T. May 11 to 02:50 G.M.T. May 12, 1952 (figure 2).

At this time the moon was at its maximum south declination and was three days past full. The tide tables predicted a marked diurnal inequality in tidal flow, with southward flow most of the day, and one-half cycle of northward flow degenerating into a condition of slack water. The passage was made during a period of northerly flow. Station 4 was occupied three hours after the current turned northward, in which direction it flowed for seven hours.

Temperatures ranged from 2.8 C. at the surface to 0 C. at 30

metres depth in the northern approaches, and showed approximately the same values in the southern approaches. In the central part of the Strait, the water was well mixed, varying in temperature by only 1 °C. from top to bottom.

The salinity varied in the northern end from 27.57 ‰ at the surface to 28.28 ‰ at 20 metres depth, and, in the southern end, from 29.36 ‰ at the surface to 30.62 ‰ at 45 metres depth. The downward slope of the isochalines from south to north pointed to the penetration of the denser Atlantic water far into the Strait near the bottom and the southward displacement of the lighter Gulf waters in the top layers.

Passage II, 10:45 to 14:37 G.M.T., May 12, 1952 (figure 3).

Prior to passage II, the current turned to the southward and had been flowing in that direction for seven hours, when the central stations was occupied (12:45 G.M.T.). The result of the southerly flow can be seen in the configuration of the isotherms and isochalines in figure 3. Water of low salinity, with temperature ranging from 4 °C. at the surface to 0 °C. at 30 metres, had entered the northern end of the Strait. A surface temperature in excess of 4.0 °C. was observed at station 6, and salinity lower than 27.0 ‰ was found at the surface at station 5. At the more southerly stations (2, 3, and 4) the water was found to be quite uniform in temperature. The higher salinity observed in the southern end of the Strait in passage I had retreated approximately two miles southward.

(b) May 19, 1952

Passage III, 12:05 to 16:05 G.M.T., May 19, 1952 (figure 4).

At this time, the moon was three days after the last quarter, and one day past its equatorial position so that little diurnal inequality in tidal flow was expected. The tide tables predicted a slight excess of southward flow in each cycle. The passage was made during a period of southward flow. Temperatures varied in the north end (station 6) from 6.0 C. at the surface to 1 C. at the bottom, while at station I in the south end, a smaller temperature range, from 4 C. at the surface to 0.5 C. at 40 metres, was observed. In the north the salinity ranged from 27.79 / $\text{oo}$  at the surface to 28.35 / $\text{oo}$  at 15 metres, and in the south from 29.43 / $\text{oo}$  to 31.85 / $\text{oo}$ . In the central section (station 4), the water was extremely uniform in temperature (3.1 C.) and in salinity (28.5 / $\text{oo}$ ). The isochalines sloped downward from the south to the north, showing the intrusion of the light Gulf water to the south in the upper layers and the trend of heavier Atlantic water in the reverse direction below.

Passage IV, 19:35 to 23:00 G.M.T., May 19, 1952 (figure 5).

This passage was made during the period of northerly flow following passage III. There was virtually no variation in the configuration of isotherms and isochalines between passage III and passage IV.

(c) July 28, 1952

Passage V, 20:30 to 23:40 G.M.T., July 28, 1952 (figure 6).

A single passage only was made on this occasion. Bathythermograph observations and water samples were taken at all stations. It was two days before the first quarter of the moon and two days after its crossing of the equator. Station 4 was reached an hour and a half after the current turned southward. At station I the

temperature range was from 14.5° C. at the surface to 2.0° C. at 40 metres while at the north end (station VII), the surface temperature was 19.3° C. and the temperature at the bottom 7° C. Isotherms and isochalines generally sloped downward from south to north. At this time the least temperature stratification was observed at station 5 where the range was from 17.0° C. to 14.5° C. This contrasted to the previous passages where the minimum stratification was observed at station 4. Temperature stratification had increased greatly throughout the Strait since the time of passage IV, showing the effect of summer warming of the surface layer. The salinity at the northern end varied from 28.03 ‰ at the surface to 29.16 ‰ at 30 metres, in contrast with the more saline southern (Atlantic) end which varied from 29.09 ‰ at the surface to 30.57 ‰ at 30 metres, and 31.49 ‰ at 50 metres.

(d) August 22, 1952

Passage VI, 11:56 to 15:08 G.M.T., August 22, 1952 (figure 7).

Station 4 was occupied at 13:40 G.M.T., less than two hours after a northerly flow had set in. This had been preceded by an eight-hour flow in a southerly direction. The moon was two days old and was on the equator. Temperatures at the northern end (station 7) ranged from 20.3° C. at the surface to 4.8° C. at 25 metres. The temperature gradient was very marked near the 25-metre level. At the southern end, the temperature range was from 16.5° C. at the surface to 5.0° C. at 40 metres with a less pronounced thermocline. At the centre (station 4), the temperature ranged from 16.0° C. at the surface to 10.0° C. at a depth of 30 metres. The isotherms again sloped downward from the south. At station 3 an upward displacement

of the isotherms was observed.

Salinities in the northern approaches (station 7) ranged from 27.56 ‰ at the surface to 30.0 ‰ at 30 metres depth. In the southern end the waters varied in salinity from 29.33 ‰ at the surface to 30.9 ‰ at 35 metres depth.

Passage VII, 17:00 to 20:30 G.M.T., August 22, 1952 (figure 8).

Passage VII was made with the ship occupying station 4 at 18:45 G.M.T., three hours after the current had turned to a southerly direction. The temperatures and salinities at the two approaches are seen to be almost identical with those recorded on passage VI. The isotherm of 16 °C. and the isochaline of 29.0 ‰ which cut the surface at station 4 in passage VI are observed to be displaced toward the north end of the Strait in passage VII, indicative of a net northward displacement of the waters in the Strait between passages.

(e) September 1, 1952

Passage VIII, 13:25 to 16:50 G.M.T., September 1, 1952 (figure 9).

This passage was made while the current was flowing southward, station 4 being occupied at 15:50 G.M.T., three hours after slack water. This was two days before the full of the moon and three days after the moon's maximum south declination. Surface temperature at the northern approaches (station 7) was 16.5 °C., while the 16.0 °C. isotherm was found slightly below 20 metres. Below this, the temperature dropped rapidly to 4.0 °C. at 30 metres in a gradient of 1.2 °C. per metre. Temperatures at the southern end were higher than at the northern end, a reversal of the regime

of earlier passages. At station I temperatures ranged from  $18.7^{\circ}$  C. at the surface to  $8.0^{\circ}$  C. at a depth of 58 metres. The warmest water in the section was found in the surface layer at station 6.

The salinity at station 7 in the northern end ranged from  $28.06^{\circ}$  / $\infty$  at the surface to  $29.75^{\circ}$  / $\infty$  at 30 metres depth, while the southern end showed a range from  $28.64^{\circ}$  / $\infty$  to  $30.6^{\circ}$  / $\infty$ .

Passage IX, 19:30 to 22:00 G.M.T., September 1, 1952 (figure 10).

A northerly current had been flowing for two hours at the time station 4 was occupied (20:55 G.M.T.), and the result of northerly flow could be seen in the displacement of the warm surface water previously observed at station 6, in the displacement of the region of least vertical stratification towards station 6, and in the northward shift of the  $28.5^{\circ}$  / $\infty$  isochaline. Water as cold as  $6.0^{\circ}$  C. had moved into the deep area at station 1 and the maximum salinity at this station had increased from  $30.6^{\circ}$  / $\infty$  to  $31.2^{\circ}$  / $\infty$ . Observations were not made to sufficient depth at station 7 to show if the pronounced thermocline observed during passage VIII had persisted.

(f) October 24, 1952

Passage X, 14:21 to 17:50 G.M.T., October 24, 1952 (figure 11).

These observations were taken when the moon had just passed through its maximum south declination and was within two days of the first quarter. Diurnal inequality in tidal flow was such that the northward flow which had been going on for four hours before passage X had been preceded by sixteen hours of southerly flow. At this time autumnal cooling had progressed to a point where temperatures throughout the Strait were almost uniform from top to bottom. The total range observed was from  $11.7^{\circ}$  C. at the northern

end to 10.0 °C. at the bottom in the centre of the section. No observations of temperature were made at station 1, however. Salinity gradients, too, were slight except in the southern approaches where the range was from 29.4 ‰ at the surface to 31.0 ‰ at fifty metres.

Passage XI, 20:02 to 23:13 G.M.T., October 24, 1952 (figure 12).

This passage followed passage X during the subsequent southward flow, and showed essentially similar water conditions with a slight southward displacement of isotherms and isochalines. Observations at station 1 showed a moderate temperature gradient below forty metres, with temperature as low as 8.5 °C. at 55 metres.

(g) November 12, 1952

Passage XII, 14:45 to 18:20 G.M.T., November 12, 1952 (figure 13).

This section was made during a period of southward flow when the moon was on the equator and three days past the last quarter. The water throughout the Strait was extremely uniform in temperature from top to bottom, with a slight positive gradient. The 8.5 °C. isotherm cut the surface at the northern end, and followed the length of the Strait at a depth of 6 to 16 metres with a wave-like profile. The highest temperature noted was 9.0 °C. (at the 25-metre level at station 1 in the southern approaches), and the lowest 8.3 °C.

The salinity at station 7 was extremely uniform, varying from 28.17 ‰ to 28.24 ‰. In the south end (station 1) the salinity increased from 29.22 ‰ at the surface to 31.00 ‰ at a depth of 50 metres. A marked hump in the isochalines of 29.00 ‰ and 29.50 ‰ appeared in the region of stations 3 and 4, but the

general tendency of these isochalines was downward toward the north.

Passage XIII, 19:05 to 22:35 G.M.T., November 12, 1952  
(figure 14).

This passage followed shortly on passage XII after the current had turned to the north. Except for the occurrence of colder water (as low as 7.7 C.) at station 2, the pattern of temperature and salinity distribution was similar to that of passage XII.

#### Density

The pattern of variations in density throughout the Strait was fairly consistent from one passage to another and is well represented by the mean densities for all thirteen passages. These mean values of  $\sigma_t$  are given in Table II. The mean  $\sigma_t$  for each of three depths 0, 15, and 30 metres has been calculated for each station, as has the mean  $\sigma_t$  for each station (column 5). In column 6 is given the mean density difference between the surface and the 30-metre level for each of the seven stations, in units of  $\sigma_t$ . The longitudinal distribution of the mean density at the surface and at 15 and 30 metres is shown graphically in figure 14.

TABLE II

Mean densities ( $\sigma_t$ ) of waters in the Strait of Canso during thirteen passages between May and November, 1952.

1	2	3	4	5	6
Station	$\sigma_t$ Surface	$\sigma_t$ 15 metres	$\sigma_t$ 30 metres	Mean $\sigma_t$	$\sigma_t 30 - \sigma_t 0$
1	22.2	22.7	23.6	22.5	1.4
2	22.1	22.7	23.5	22.8	1.4
3	22.0	22.5	23.2	22.6	1.2

(cont'd)

TABLE II

1	2	3	4	5	6
Station	$\sigma_t$ Surface	$\sigma_t$ 15 metres	$\sigma_t$ 30 metres	$\sigma_t$ Mean	$\sigma_t$ 30 - $\sigma_t$ 0
4	21.7	22.2	22.8	22.2	1.1
5	21.5	21.8	22.2	21.8	0.7
6	21.1	21.6	22.3	21.7	1.2
7	20.9	21.4	22.6	21.6	1.7

The following features are to be noted as applying to these mean values of  $\sigma_t$  .

- (1) the density at the surface and at a depth of 15 metres decreases from station 1 in the southern approaches to station 7 in the northern approaches. At the 30-metre level, the minimum density is reached at station 5 near the northern end of the Strait, slightly higher density being characteristic of the waters of the northern approaches at this depth.
- (2) the density increases with depth at all stations. This feature is less marked within the Strait proper, where, at station 5, the mean  $\sigma_t$  at 30 metres is 0.7 units greater than at the surface, in comparison with differences of 1.5 and 1.7 at the southern and northern approaches, respectively.

The greater density stratification was observed in the summer months (passage V to IX) and the least in the autumn (passage X to XIII). No passages were made in the winter season when the Strait is closed to navigation.

In the autumn passages, at station 7 in the northern approaches, the density was practically constant at all levels, while at the

other stations there was a  $\sigma_t$  difference from the surface to the 30-metre level, which reached a maximum value of 0.7 at the southern end of the Strait. This is consistent with the disappearance of the summer temperature stratification and the onset of autumnal cooling which are to be expected at an earlier date in the shallow water of Georges Bay than in the Atlantic approaches.

### Discussion

The thirteen passages from May, 1952 to November, 1952, show the seasonal variation of temperature and salinity in the waters of the Strait of Canso, for all but the winter season. At each end, conditions are those prevailing in the southern Gulf of St. Lawrence and in the northeastern sector of the Scotian Shelf, respectively. Tidal oscillation in the narrow Strait functions as a mixing mechanism which maintains a body of well mixed water slightly to the north of the centre of the Strait (stations 4 and 5). Although passages were not timed so as to show the maximum effect of tidal oscillation, the results demonstrate that the whole body of water moves back and forth in the Strait without a significant breakdown of temperature and salinity patterns during a single cycle.

From the mean configuration of density (Table II and figure 14), it can be seen that there is a dynamic tendency for the lighter waters of the north to flow south over the heavier waters at that end. This southward flowing water is modified somewhat by the mixing which takes place in the Strait, so that the outflowing surface waters are more saline and heavier than the surface waters of the northern approaches (station 7). The consistent slope of isotherms and isohalines downward from south to north in the

southern end of the Strait points to a flow of deeper waters towards the north. While such a two-way flow might not involve a net flow in either direction, it probably accounts partially for the dominant southward set of surface currents as reported in the Tide Tables.

#### Summary

1. Thirteen passages through the Strait of Canso in the period May-November, 1952, provided temperature and salinity values at seven stations in the length of the Strait and its approaches.
2. Paired passages at different stages of the tidal cycle show evidence of tidal displacement of the complete body of water in the Strait.
3. Vigorous mixing and consequent increased homogeneity is characteristic of the central portion of the Strait in all seasons.
4. A recurring feature of the sections is the downward sloping of the isotherms and the isohalines from south to north in the central and southern regions of the Strait. From this, residual surface transport to the south and a reverse flow at the bottom is inferred to exist, in addition to the oscillatory, tidal displacement of from 3 to 10 miles per tidal cycle.
5. Seasonal variations in conditions in the Strait exist, with marked temperature stratification accompanying the vernal warming. In later autumn, this stratification almost completely disappears.
6. Density decreases progressively from station 1 to station 7 at the surface and at 15 metres. At 30 metres depth, it decreases

from station 1 to station 5, and then increases slightly at station 6 and 7, which are in the northern approaches to the Strait.

References

Tide Tables for the Atlantic Coast of Canada.

Department of Mines and Technical Surveys, 132 pp. Ottawa, 1952.



Figure 1. Chart of the Strait of Canso showing stations (1 to 7) occupied during survey. Small scale inset shows location relative to Gulf of St. Lawrence and Atlantic Ocean.

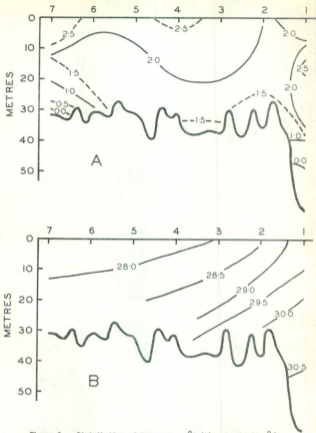


Figure 2. Distribution of temperature  $^{\circ}\text{C}$  (A) and salinity  $\text{‰}$  (B) in the Strait of Canco. May 11th (20:40 G.M.T.) to May 12th (02:50 G.M.T.), 1952.

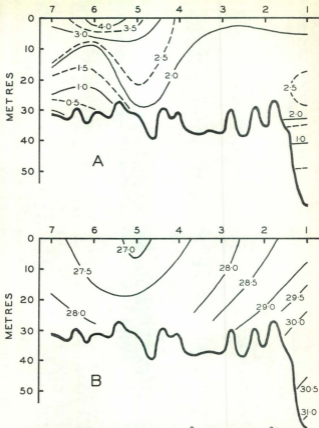


Figure 3. Distribution of temperature  $^{\circ}\text{C}$  (A) and salinity  $^{\circ}/\text{oo}$  (B) in the Strait of Canso. May 12th (10:00 to 14:37 G.M.T.), 1952.

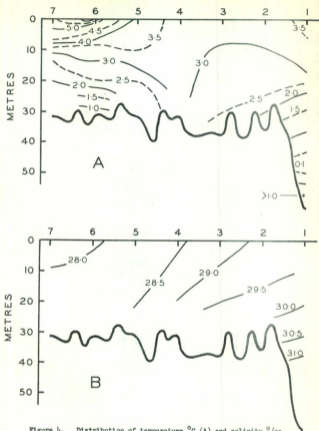


Figure 4. Distribution of temperature  $^{\circ}\text{C}$  (A) and salinity  $\text{‰}$  (B) in the Strait of Canso. May 19th (12:05 to 16:05 G.M.T.), 1952.

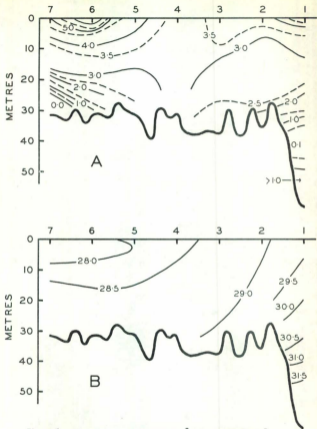


Figure 5. Distribution of temperature  $^{\circ}\text{C}$  (A) and salinity  $\text{‰}$  (B) in the Strait of Canso. May 19th (19:35 to 23:00 G.M.T.), 1952.

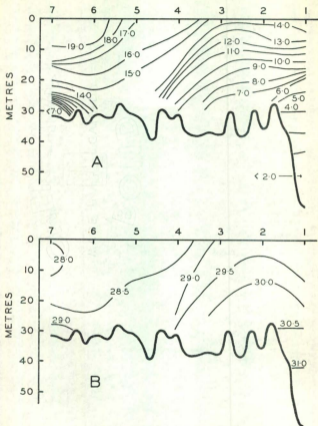


Figure 6. Distribution of temperature °C (A) and salinity ‰ (B) in the Strait of Canso. July 28th (20:30 to 23:40 G.M.T.), 1952.

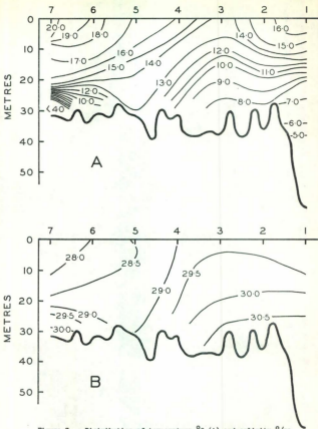


Figure 7. Distribution of temperature  $^{\circ}\text{C}$  (A) and salinity  $\text{‰}$  (B) in the Strait of Canso. August 22nd (11:56 to 15:03 O.M.T.), 1952.

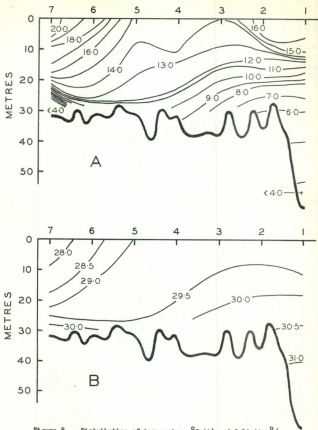


Figure 8. Distribution of temperature  $^{\circ}\text{C}$  (A) and Salinity  $\text{‰}$  (B) in the Strait of Canso. August 22nd (17:00 to 20:30 G.M.T.), 1952.

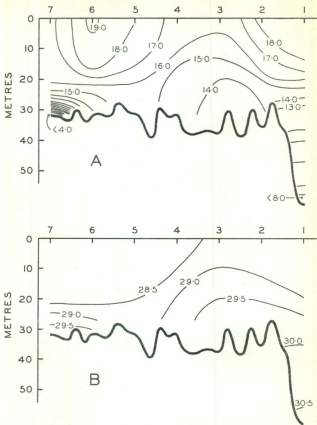


Figure 9. Distribution of temperature  $^{\circ}\text{C}$  (A) and salinity  $\text{‰}$  (B) in the Strait of Canoa. September 1st (13:25 to 16:50 G.M.T.), 1952.

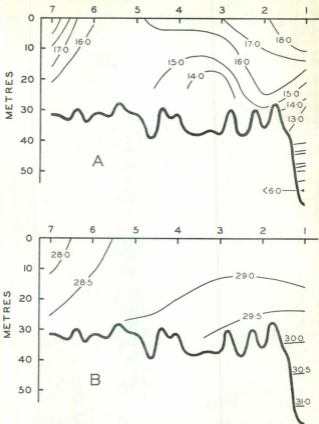


Figure 10. Distribution of temperature  $^{\circ}\text{C}$  (A) and salinity  $^{\circ}/\text{oo}$  (B) in the Strait of Canso, September 1st (19:30 to 22:00 G.M.T.), 1952.

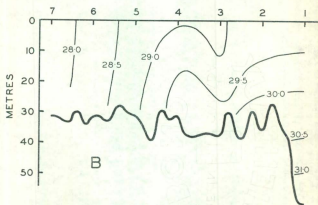
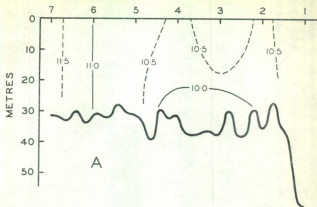


Figure 11. Distribution of temperature  $^{\circ}\text{C}$  (A) and salinity  $\text{‰}$  (B) in the Strait of Canso. October 24th (11:20 to 17:50 G.M.T.), 1952.

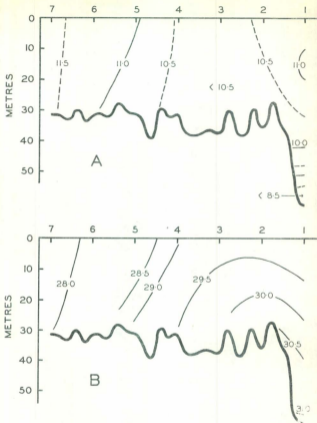


Figure 12. Distribution of temperature  $^{\circ}\text{C}$  (A) and salinity  $\text{‰}$  (B) in the Strait of Canso, October 24th (20:00 to 23:15 G.M.T. ), 1952.

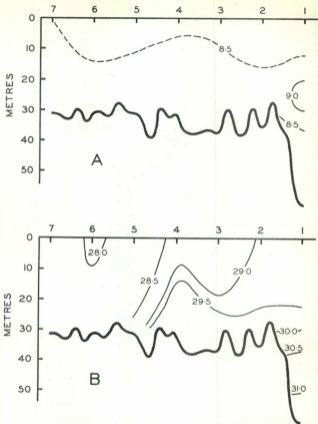


Figure 13. Distribution of temperature  $^{\circ}\text{C}$  (A) and salinity  $^{\circ}/_{\infty}$  (B) in the Strait of Canso. November 12th (11:45 to 18:25 G.M.T.), 1952.

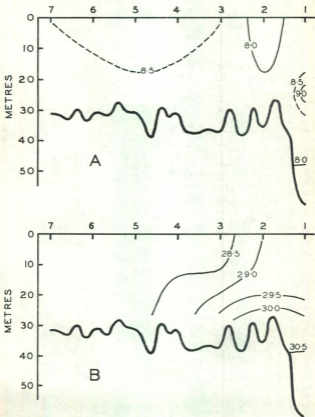


Figure 14. Distribution of temperature  $^{\circ}\text{C}$  (A) and salinity  $\text{‰}$  (B) in the Strait of Canso. November 12th (19:05 to 22:45 G.M.T.), 1952.

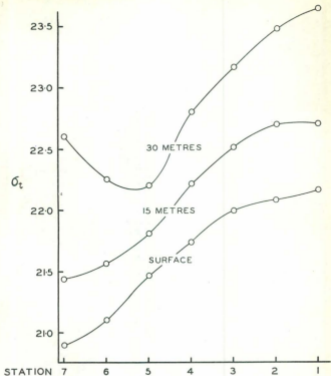


Figure 15. Mean distribution of density ( $\sigma_t$ ) at three levels in the Strait of Canso. From observations taken during thirteen passages between May 11th and November 12th, 1952.

