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No. 500

Title

Variations of Temperature and Salinity in Shallow
Waters of the Southwestern Gulf of St. Lawrence.

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St. Andrews, N. B.

VARIATIONS OF TEMPERATURE AND SALINITY
IN SHALLOW WATERS OF THE SOUTHWESTERN GULF OF ST. LAWRENCE

by

L. Lauzier.

Variations of Temperature and Salinity
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INTRODUCTION

The temperature variations of surface waters of the Canadian Atlantic coast have been studied (Hachey 1939), as well as certain trends and cycles (Hachey and McLellan, 1948). In 1945, a full scale study of the Gulf of St. Lawrence was initiated by the Atlantic Herring Investigation Committee. The main features of the surface layer (Lauzier and others, 1951) and of the deeper layers (Lauzier and Bailey, 1952), have now been described. Some aspects of the study dealing with the shallow waters of the southwestern sector of the Gulf have also been reported; the effect of storms on the water conditions in the Magdalen Shallows (Lauzier 1952a), and also the relationship between the spring run-off of the St. Lawrence system and the summer minimum salinity in the southwestern Gulf (Lauzier 1952b).

The data in the present paper were collected from continued weekly or bi-weekly observations at three selected points, Cheticamp, N. S., North Rustico, P.E.I., and Grand River, Quebec, between 1945 and 1949. In the later part of this period, data have also been collected from a station in the Northumberland Strait, off Richibucto, N.B. Along the Gaspé Coast, observations on American Bank were taken in 1947. The locations of stations are shown in figure 1.

The data are used in describing seasonal and geographical variations of temperature and salinity of the waters of the western Gulf of St. Lawrence, as well as the variations that occurred from year to year. Tentative explanation of short-term variations are given.

SEASONAL AND ANNUAL VARIATIONS

Temperature Changes

1947. The seasonal temperature variations for three stations, North Rustico, P.E.I., Cheticamp, N.S., and Grand River, Quebec, are illustrated in figure 2, using data from the surface and the 30-metre level.

The temperature variations at the surface show a maximum in mid-summer, from July to August, depending on the location. The rate of vernal warming from May to July was approximately the same for the three stations. By the middle of July, the Grand River waters had reached their summer maximum temperature (18.0 °C.); the corresponding maximum was reached about two weeks later at North Rustico (19.9 °C.), and three weeks later at Cheticamp (22.3 °C.). The maximum temperature, at North Rustico was greater than at Grand River, while at Cheticamp still higher temperatures were attained. From the end of August, the rates of cooling at the three stations differed slightly from one another, the temperatures converging towards the temperatures of the freezing point.

The 30-metre level, chosen for comparison, is the bottom layer at North Rustico, and a mid-water layer at Grand River and

Cheticamp where the total depth exceeds 50 metres. The seasonal temperature variations at 30 metres show some variability as well as different rates of warming and cooling. At Grand River the temperature slowly increased from an average of 1.0 to 4.0^o C. from May to August, while a rapid increase was recorded at the beginning of September which seems to indicate that the thermocline was then deeper than 30 metres. During the autumn, the rates of cooling at the surface and at 30 metres were approximately the same. At North Rustico, the 30-metre waters reached a maximum at the beginning of July (5.5^o C.), and in October (9.0^o C.), with a minimum at the beginning of August (3.0^o C.). At Cheticamp, the 30-metre waters also showed two maxima, one in July (13.0^o C.), and one in October (11.0^o C.), with a minimum at the end of August (5.0^o C.). At Grand River, as well as at Cheticamp, the water temperatures varied over a comparatively wide range, as compared to the North Rustico waters.

1945-1949. The variations from one year to another are best represented by the North Rustico data for the period 1945-1949. The results are shown graphically on figure 3 for four different levels.

At the surface, the differences in temperature from year-to-year are small. It may be seen that, on the average, from June to August, the temperatures were low in 1946 and high in 1949, and from September to November, high in 1945 and low in 1947. During this five-year period, the maximum variation of temperature at a given time, was approximately 3^o C. At 10 metres, the difference from year-to-year was greater than at the surface, and the

temperatures showed some tendency of being subjected to local variations. At 20 metres, the wide range of variations in temperatures was due to the year-to-year variations, and also to the short-term erratic variations that are related to upwelling and subsidence (Lauxier 1952a). With the exception of 1949, when erratic variations masked any such trend, the data show a semi-annual cycle of temperature at 20 as well as 30 metres. It is to be noted that from October at 20 metres and from November at 30 metres, the rates of cooling were very similar to those of the surface and that there was a very small vertical temperature gradient. This indicates vertical interchange to a depth of at least 30 metres. On the average, the overturn occurred about the middle of November, when temperatures tended to uniformity throughout the water column.

Salinity Changes

1947. The cyclic variations of salinity are represented by time-salinity graphs in figure 2, for the surface and the 30-metre depth. At the surface, the variations show a marked minimum salinity from early to mid-summer depending on the location of the stations. Off the southern Gaspé coast (Grand River) the minimum of 22.1 ‰ occurred at the beginning of July; off North Rustico the minimum of 25.2 ‰ was recorded at the beginning of August, and at Cheticamp the corresponding minimum of 26.7 ‰, was reached at the end of the month. There was approximately a four week interval between the time of occurrence of the minimum salinity at Grand River and at North Rustico, and almost two weeks' interval between North Rustico and Cheticamp. This lag, as well as the varying intensity of the minimum, indicates the slow progression of the

continental drainage effects on salinity in spring and early summer, from the Gaspé area southward.

At 30 metres, a decrease in salinity corresponds to an increase in temperature and vice-versa. However, the salinity variations seem to be more erratic. Such correlations are expected on the basis of a seiche-like phenomena previously described (Lauzier, 1952a).

1945-1949. The most striking feature of the year to year variations of salinity off North Rustico is the wide range of variations within the upper layers from the middle of July to October (figure 4). The observed minimum salinity at the surface varied between 25.2 ‰ in 1947 and 27.7 ‰ in 1949. The minimum salinities for 1945, 1946, 1948 and 1949 were in the vicinity of 26.9 ‰. The minimum salinity reached in 1947 was much lower than during the two preceding and following years. The run-off of the St. Lawrence basin in 1947, was the greatest during the period 1945-1949. The correlation between the salinity and the run-off has been discussed in an earlier publication (Lauzier 1952b).

The salinity at 20 and 30 metres shows a semi-annual cycle inversely corresponding to the temperature variation. At the 20 and 30-metre levels, the year-to-year variations do not seem to be as large as at the surface, but erratic variations are more frequent.

Northumberland Strait and Gulf of St. Lawrence

A comparison of data from stations on both sides of Prince Edward Island, Richibucto in the Northumberland Strait, and North

Rustico in the Gulf of St. Lawrence, was made in 1948 and 1949 only. The temperature and salinity regimes in the two areas are fairly similar. However, some differences are shown in the surface salinities which are lower in the Northumberland Strait (figure 5), and also in the 10 metre temperature which is lower in the Strait than in the Gulf during the mid-summer.

Southwestern Gulf versus Atlantic Coast

The temperature data from North Rustico and Cheticamp have been compared with other data collected during the same period at other points in the Gulf of St. Lawrence and on the Canadian Atlantic coast. Such data are available from daily observations of surface temperatures at Grand River (Tremblay), and observations taken twice daily at Entry Island, Magdalen Islands, St. Andrews, and at Sambre, L.V.

Of the six stations, Cheticamp shows the largest annual range and St. Andrews the smallest (see Table I). However, along the Gaspé coast, the monthly maximum temperature is only slightly higher than at St. Andrews, 14.5 C. as compared to 13.9 C. It has been pointed out (Lauzier, 1952b), that the general trend towards higher temperatures was very pronounced during the period 1941-1951 along the Canadian Atlantic coast. It is suspected that our sampling in the Gulf of St. Lawrence was carried out during a period somewhat warmer than normal.

The deviations of the May to December average temperature from the normal are listed in Table II. Sambre L.V. and St. Andrews have been combined to represent the Atlantic coast as against Entry Island in the Gulf of St. Lawrence. The data in

Table II show that the variations are generally of the same sign in the two areas, but with a greater amplitude outside the Gulf.

TABLE I
Surface Temperature, 1945-1949

Month	Cheticamp		North Rustico (1)	Entry Is. (3)	Grand River (4)	St. Andrews (3)	Sambro L.V. (3)
	(1)	(2)					
May	4.9		3.7	4.5	3.7	7.3	5.4
June	10.9		10.1	9.1	8.4	9.6	8.9
July	17.2		16.3	15.0	13.4	12.7	13.7
August	18.9		18.7	17.6	14.5	13.9	16.2
September	16.5		16.2	15.0	11.6	13.1	16.5
October	13.2		12.0	10.4	7.3(5)	11.5	13.8
November	9.4		7.5	5.4		8.5	9.7
December			2.5	0.9		4.8	6.3

(1) from weekly observations
 (2) from 1947-1949
 (3) from twice daily observations
 (4) from daily observations
 (5) 1945

TABLE II
May-December temperature deviations from normal

Station	1945	1946	1947	1948	1949
Sambro L.V.}					
St. Andrews}	0.1	0.4	0.6	-0.4	1.2
Entry Island	0.1	0.1	0.4	-0.2	0.3

During the summer months only, July, August and September, the deviations from the 1945-1949 average are fairly similar

along the Atlantic coast and around Entry Island, but not uniform in the western Gulf of St. Lawrence (see Table III). Summer temperature deviations at North Rustico and Grand River are somewhat similar but they differ from those at Entry Island. Such a difference from place to place in the summer might be due to the variations in ice cover during the previous winter, in the lagging effects of the spring run-off, and in the resulting mixing processes due to prevailing winds. It seems then, that the waters near Entry Island are not similarly effected by factors which disturb the normal trend of water conditions in the areas of the Gaspé coast, Prince Edward Island, and Cape Breton Island.

TABLE III

Summer temperature deviations from 1945-1949 average

Station	1945	1946	1947	1948	1949
Sambre L. V. } St. Andrews }					
Entry Island	0.4	-0.1	0.4	-0.1	1.0
North Rustico	0.5	-0.1	0.8	-0.9	-0.4
Grand River	0.6	-0.4	0.0	0.1	0.2
	0.0	-0.4	-0.1	0.7	-0.2

Temperature-Salinity Relationship

The cycles of temperature and salinity as illustrated by figures 2, 3, 4 and 5 and discussed above, have shown that, in the shallow waters of the southwestern Gulf, increasing temperatures are generally associated with decreasing salinities and vice-versa. The amplitudes of variations are different from one station to another. The T-S curves are consistently distinct at least during

spring and summer, for each of the stations: Grand River, North Rustico, and Cheticamp. Individual T-S curves are furnished in figure 6, and envelopes of all the T-S curves, from May to November, for each of the three stations are furnished in figure 7. For comparison, a T-S envelope is furnished for stations in the middle of the Laurentian Channel near Cabot Strait. It is shown in figure 6 that the water masses at the three stations are the result of mixtures in various proportions of two water types: "A" cold water of temperature less than -1.0°C . and a salinity of $32.00^{\circ}/\text{oo}$, and "B" brackish water from St. Lawrence System, of variable temperature and salinity, depending on the season and location.

The process of mixing of the two water types, "A" and "B" is different for each of the stations. The waters that reach Grand River during the spring and summer were mixed with low salinity waters at a faster rate than the waters off the Cape Breton coast. In the region of Prince Edward Island, the waters have an intermediate regime, more closely related to that of the Cape Breton than of the Gaspé area. The rate of vernal warming was almost identical at the three stations. During the late summer and early autumn, the water masses of the three areas have somewhat similar T-S relationships.

Semi-Annual Cycle of Temperature and Salinity

As mentioned earlier in this paper, the bottom waters of the North Rustico area undergo a semi-annual cycle of temperature and salinity variations. This is indicated in figures 3 and 4 at the 20 and 30-metre levels, but the year-to-year variations and abrupt local changes seem to mask the general trend. In figure 8, 15-day

averages for the period 1945-1948, have been plotted for the 0-10 and 20-30 metre levels, and the annual and semi-annual cycles of variations are thus shown for the surface and bottom waters respectively.

In figure 8, it is seen that the surface salinity decreases fairly rapidly from May to July, reaching a minimum at the end of July. From August to December, the surface salinity increases slowly. The bottom salinity reaches a first minimum in the middle of July, increases to an August maximum, decreases again towards a second minimum in September. Within the period of September to December, the salinity increases slowly. The temperature variations are of the opposite sign to the salinity variations, maxima of the first corresponding roughly in time, with the minima of the second and vice-versa.

In the spring and early summer, the salinity of the waters at North Rustico and to a depth of 30 metres gradually decreases, a process which reflects the effects of the continental drainage. This decrease in salinity continues until the middle of July. Throughout this period another process goes on apace - the development of a thermocline and a layer of density discontinuity. In July, the surface layer has been clearly defined and waters at depths of approximately 30 metres are effectively separated from the surface layer by a layer of very high stability. During the month of August, the deeper waters are no longer effected by continental drainage and are influenced either by deeper and more saline waters or by adjacent intermediate layers. Increasing salinities have been observed during the summer months at the deeper levels of North Rustico from the end of July to the end

of August. During the month of September, the salinities in the 20-30 metre level again decrease and reach a lower level than in July, thus reacting to delayed effects of continental drainage. During the progress of the seasons, the surface layer becomes thicker and the thermocline deepens. Eventually by the end of September the surface layer has a thickness of 20 metres, and most of the water column at North Rustico reacts to a tendency for increasing salinities as the continental drainage tends to a minimum.

The temperatures at depths of 0 and 30 metres reflect this same phenomena. Increasing temperatures at all depths are recorded, on the average, until mid-July. The surface temperatures continue through the regular seasonal cycle, while the temperatures at 20-30 metres are depressed through the influence of adjacent layers of deeper and colder waters. By October, the temperatures tend to uniformity throughout the column. By then, the 20-30 metre waters had reached their highest maximum temperature and the thermocline had deepened to this level.

This semi-annual cycle of temperature and salinity is thus a phenomena to be observed at moderate depths, where the waters at times have the characteristics of the surface layer and at other times are separated from the surface layer by a strong thermocline and a layer of density discontinuity.

The semi-annual cycle of temperature and salinity was observed off the coast of Prince Edward Island throughout the period 1945 to 1949. In the Cheticamp area, off the Cape Breton coast, a similar semi-annual cycle at 20 and 30 metres was observed only in 1947. As the phenomena is associated with the formation and development of a surface layer and a thermocline, and as the

characteristics of the surface layer are determined in part by the continental drainage, variations in the phenomena are to be expected on the basis of geographical position and depth. It has been noted that the minimum salinity in 1947 was 27.10^o /oo as compared to 28.80 and 28.40^o /oo in 1948 and 1949 respectively.

SHORT-TERM VARIATIONS

Non Periodic Variations

A close examination of figures 3 and 4 will show abrupt variations of temperature and salinity in the North Rustico area during the summer months at the depths of 20 and 30 metres. Such variations have been observed along the west coast of Cape Breton Island, along the north shore of Prince Edward Island, and, in at least two instances, in the northern sector of Northumberland Strait, during the period 1948-1949.

These variations, resulting from the phenomena of upwelling and subsidence in stratified waters, are indications of oscillations of the thermocline due to external forces. They may be correlated with wind force and direction, controlling factors of internal adjustments of water layers, according to Ekman's theory of wind driven currents.

A detailed account of the effect of storms on the water conditions in the Magdalen Shallows has been given by the author at an earlier date (Lausier 1952).

were estimated from depth-temperature and depth-density graphs. The average depth and the range of variations of the thermocline are summarized in Table IV.

TABLE IV

Depth of the thermocline near Grand River from May 23 to August 6, 1946.

Tide	Number of cases	Depth (Metres)		
		Average	Min.	Max.
Flooding	8	22	8	30
Ebbing	8	48	40	52

The data listed in the above table show that the range of variations is 44 metres with a minimum depth of 8 metres on July 1st with flooding tide and maximum depth of 52 metres on June 21st and July 16th with ebbing tide. Observations made during the same tidal cycle revealed an oscillation of the thermocline with an amplitude of 11 metres.

The density stratification is shown in Table V where interpolated depths are given for different dates and stages of the tide.

The table shows that the layer of density discontinuity was located between $\sigma_t = 23.00$ and 24.00 . Examples given in Table V are representative of the data from May 23rd to August 6th, 1946. Oscillations of the layer of discontinuity corresponds very closely with the oscillations of the thermocline. Such oscillations seem to be the effect of internal adjustment of water masses. After August 10th, 1946, there was no correlation between the stage of the tide

Periodic Variations

The waters in the Grand River area are illustrative of short-term fluctuations which are not the effect of storms. The data used for these examples derive from two groups of observations, one taken during a whole season, and one during one tidal cycle. In 1946, observations were made off Grand River from May to September. The data, shown in figure 9 are from eighteen series of observations from the surface to the bottom. Erratic variations in both temperature and salinity at 20, and mainly at 50 metres, almost mask the seasonal variations. The sampling has been done whenever possible, regardless of the stage of the tide. Some observations have been repeated within 36 hours but they have been omitted in figure 9, in order to avoid confusion.

T-S relationships for each series of observations show that the water mass is a mixture of two types as described earlier in this paper. The proportions in this mixture change without essentially changing the T-S relationship. The T-S method of plotting the data, in series of observations, masks the erratic variations shown in figure 9. In figure 10, the temperature-salinity characteristics of the waters at 30 metres off Grand River are shown in relation to the tide. All data up to August 10th have been included. From the diagram, it is evident that the data for ebbing tides (E) are in the low density group, and all those, but one, for flooding tides (F) are in the high density group. The density fluctuations reflect variations in the level of the thermocline of the discontinuity layer between the light and the heavy water layers. Levels of the thermocline and of the discontinuity layer

and the density group or the depth of the thermocline.

TABLE V

Estimated density distribution in relation with the tide off Grand River.

Density (σ_t)	Date: July 9 Tide: $\frac{1}{2}$ HW	July 9 $\frac{1}{2}$ LW	July 16 LW	July 23 $\frac{3}{4}$ HW
21.00	10 m.	18 m.	--	--
22.00	26	32	--	12 m.
23.00	29	41	48 m.	26
24.00	30	43	51	30
25.00	33	46	53	33
26.00	64	--	--	--

In 1947, the observations were made as in 1946. The data, however, failed to show the same type of relationship as in 1946, between the density group and the stage of the tide. There were differences in the vertical distribution of temperature, salinity and density during the two consecutive years. Table VI gives examples of density stratification in 1946 and 1947. In 1947, there was no layer of discontinuity as in 1946, except for a few weeks in July in the subsurface waters. Low density waters with very steep gradient were present in the subsurface, while in 1946 a low density gradient was a feature between the surface and the discontinuity layer.

In 1947 repeated observations were made during one tidal cycle at two adjacent stations (25 miles apart), off Grand River and on the American Bank. The data have been plotted in figure 11

to show the fluctuations in temperature and salinity at different depths for the two stations.

TABLE VI

Estimated density distribution off Grand River in 1946 as compared to 1947.

Density (σ_t)	1946		1947	
	Date: June 18 Tide: $\frac{1}{2}$ HW	July 16 LW	June 14 HW	July 16 LW
16.00	--	--	--	0
16-20.00	--	--	--	2-8 m.
21.00	--	--	--	18
22.00	17 m.	--	4 m.	23
23.00	29	48 m.	21	26
24.00	30	51	35	29
25.00	44	53	50	40

It is interesting to note that at intermediate depths from 10 to 30 metres, the isotherms and isohalines were consistently deeper off Grand River than on the American Bank. The tidal oscillations of the thermocline were about fifteen metres in both cases. The thermocline, however, was deeper at Grand River than on the American Bank. In both cases, the T-S relationship was the same.

The fluctuations, seemingly, are the result of an internal wave of the tidal period. Nevertheless, the density stratification was fairly uniform from the surface to the bottom at both stations, except that on the American Bank very low density gradients were

observed from 25 metres to the bottom.

DISCUSSION

Time lags and differences in minimum salinities between the three stations dealt with in the foregoing are indications of the controlling effects of the Gaspé Current in the Grand River area. The waters reaching the Grand River area are chiefly those of the Gaspé Current. The effect of continental drainage of the St. Lawrence River System is most marked at Grand River by the end of June and the beginning of July by the very low salinity minimum. This body of low salinity water spreads progressively southward, while mixing both vertically and horizontally with adjacent water masses. This is indicated by the progressive increase in salinity between Grand River, North Rustico and Cheticamp, and with time lags in the minima of from four to six weeks. These differences in salinity and the delayed action of the continental drainage may be observed throughout the months of May, June and July.

The summer maximum temperature is lower at Grand River than at Cheticamp or North Rustico. This is apparently due to vertical mixing extending down to the intermediate cold layer, presumably in the estuary of the St. Lawrence. These waters, as they are carried along the Gaspé coast, are somewhat modified but they still retain the characteristic small annual range of temperature. From Grand River to the southwestern Gulf, the waters spread out and mix horizontally and vertically involving an intermediate layer which is then not as cold as in the estuary. Hence, the summer maximum is much higher off Cheticamp than off the Gaspé

coast. The time of occurrence of the summer maximum was different at the three stations concerned, but the rate of vernal surface warming was almost identical. In other words, the period of effective vernal warming was short in the estuary as compared to the southwestern Gulf. Mixing in the estuary, involving a comparatively cold intermediate layer, was more intense in the summer than in the spring. In the spring, the increased stability within the top layers, due to the run-off of the St. Lawrence system, would hamper vertical mixing as compared with that in summer when the stability has decreased.

The semi-annual cycle of temperature and salinity at moderate depths (20-30 metres), observed in the North Rustico area is associated with the formation and development of the surface layer, its lower boundary determined by a thermocline and layer of density discontinuity. Increasing salinities and decreasing temperatures during August at depths of 20-30 metres indicate effective replacement of the deeper waters as the surface layer develops. It seems evident that this replacement, if it could be measured, would be an indication of the scale of mixing that takes place.

The data collected off Grand River in 1946 show a correlation between the stage of the tide and the depth of the thermocline, or the layer of density discontinuity. Such oscillations as are shown to take place reflect the internal adjustment of the water masses. There is reason for believing that oscillations of the Gaspe Current with tidal phases would be a possible explanation. On the ebbing tide, the Gaspe Current would be of maximum strength, with a consequent deepening of the layer of density discontinuity towards the Gaspe peninsula. On the flooding tide, with the Gaspe

Current at minimum value, the layer of density discontinuity would be comparatively shallow. Such oscillations on a tidal-time basis would mask those having the characteristics of an internal wave, of shorter period and possibly smaller amplitude.

SUMMARY

1. The variations of temperature and salinity at fixed stations and at different depths in the southwestern Gulf of St. Lawrence have been described for the period, May to December, 1945-1949.
2. The surface temperature at all stations showed a maximum between the middle of July and the middle of August.
3. The temperature maximum at the surface was higher along the Cape Breton coast than along the Gaspé coast. It occurred earlier in the Grand River area than in the Cape Breton area.
4. The maximum temperature below the surface usually occurs at a later date than at the surface. The 20-30 metre waters off the North Rustico area generally show a semi-annual variation of temperature as well as of salinity. The highest maximum temperature occurs after the thermocline had reached this layer.
5. The year-to-year variations of temperature are rather small and inconsistent. During the five-year period, the range of temperature variations at the surface was approximately 3 C. in the North Rustico area. Below the surface, erratic variations seem to mask year-to-year variations.
6. The annual variations of salinity at the surface shows a minimum from early to mid-summer depending on the location. The

minimum occurs first off the southern Gaspé coast, in July, and then at North Rustico, and finally at Cheticamp in August.

7. The minimum salinity is lowest at Grand River and highest at Cheticamp.
8. A minimum salinity could also be detected below the surface at a date later than that for the surface. Erratic variations seemed to be more pronounced in the lower layers than at the surface.
9. The year to year variations of surface salinities are correlated with the variations in the run-off of the St. Lawrence. Both salinity and the run-off undergo a very wide range of variations.
10. The temperature and salinity regimes in the Northumberland Strait and along the north side of Prince Edward Island are fairly similar, although, the surface salinities are somewhat lower in the Strait.
11. Comparison of data from Grand River, North Rustico and Cheticamp with data from long established stations like Entry Island, St. Andrews and Sambro L.V. shows that during the period 1945-1949:
 - (a) the temperature at Entry Island generally follows the long term variations observed along the Atlantic coast, but that the variations are somewhat damped in the Gulf of St. Lawrence.
 - (b) the temperature variations at Grand River and North Rustico differ from those at Entry Island, presumably because of some local variable factors.
12. The temperature-salinity relationship is such that increasing temperatures are associated with decreasing salinities and

vice-versa.

13. The water masses at the three stations: Grand River, North Rustico and Cheticamp, are the results of mixtures in various proportions of two water types:
"A" cold water of temperature less than -1.0°C . and salinity $32.00^{\circ}/\text{oo}$,
"B" brackish water from the St. Lawrence River System of variable temperature and salinity depending upon the season and location.
14. Semi-annual cycles of temperature and salinity for the bottom waters in the North Rustico area are shown by a secondary minimum of temperature and a secondary maximum of salinity during the summer. This summer occurrence of high salinity and low temperature water along the bottom might be the result of advection of water from the greater depths or of mixing.
15. In 1946, the waters off Grand River showed erratic variations of temperature and salinity from 20 to 30 metres. These variations are the results of oscillations of the thermocline as well as the level of the layer of density discontinuity. Such oscillations in level might be due to an oscillatory incursion of the Gaspé current along the southern Gaspé coast, an incursion related to the tide.
16. Repeated observations during a tidal cycle, at two adjacent stations in the vicinity of Grand River, have shown oscillations of temperature and salinity at depths which indicate an internal wave of tidal period.

ACKNOWLEDGMENT

The writer wishes to extend his thanks and appreciation to H. B. Hachey and A. H. Leim for their interest and assistance in the preparation of this paper.

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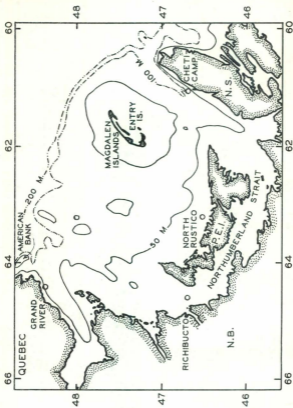


Figure 1. South-western Gulf of St. Lawrence with location of stations.

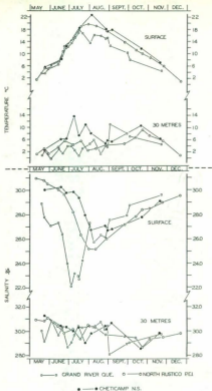


Figure 2. Temperature and salinity variations from May to December 1947, at the surface and at 30 metres for Grand River, Que.; North Rustico, P.E.I.; and Cheticamp, N.S.

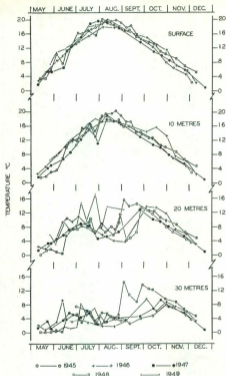


Figure 3. Temperature variations from May to December, during the period 1945-1949 at different depths for North Rustico, P.E.I.

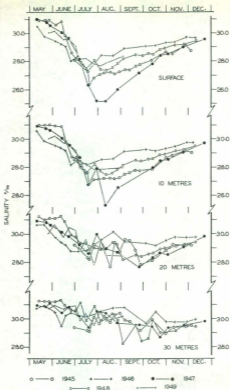


Figure 4. Salinity variations from May to December during the period 1945-1949 at different depths for North Rustico, P.R.I.

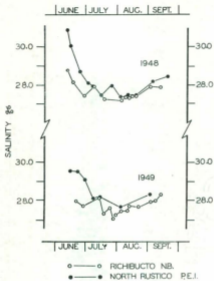


Figure 5. Surface salinity variations from June to September in 1948 and 1949, for Richibucto, N. B. and North Rustico, P.E.I.

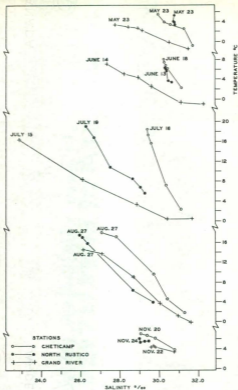


Figure 6. Temperature-salinity relationships for Cheticamp, N.S.; North Rustico, P.E.I.; and Grand River, Que., from Spring to Autumn, 1947.

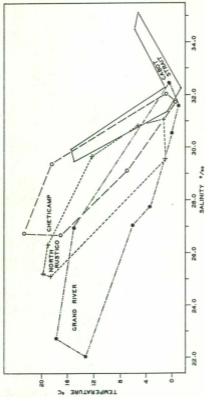


Figure 7. Envelopes of all temperature-salinity curves, from May to December, 1947, for Grand River, Que.; North Rustico, P.E.I.; Cheticamp, N. S. and representative deep stations in the Laurentian Channel near Cabot Strait.

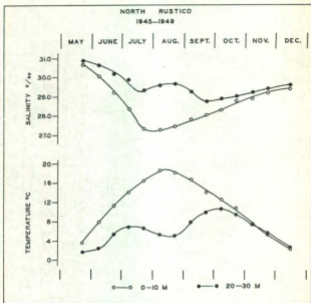


Figure 8. Semi-monthly averages of temperature and salinity, 1945-1949, for North Rustico, P.E.I., at two different levels: 0-10 metres and 20-30 metres.

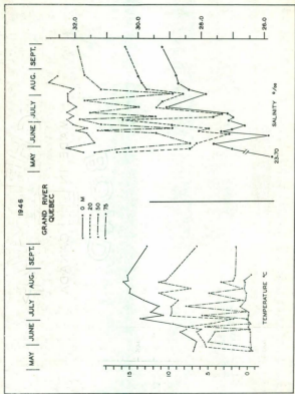


Figure 9. Temperature and salinity variations at Grand River, Que., from May to September, 1946, at four different depths.

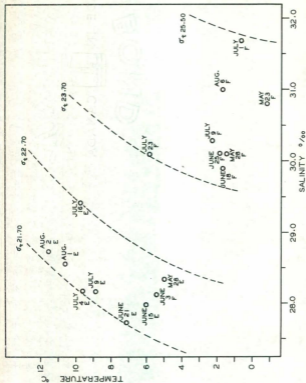


Figure 10. Temperature-salinity characteristics in relation to the stage of the tide: ebbing (E) or flooding (F), for the waters off Grand River, Que., at 50 metres, from May 23rd to August 6th, 1946.

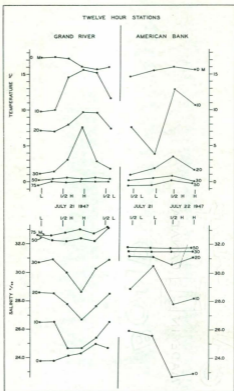


Figure 11. Temperature and salinity variations at different depths, during a tidal cycle, for two adjacent stations along the Gaspé Coast, July 21-22, 1947.

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