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THE SEASONAL VARIATION OF THE TEMPERATURE AND SALINITY OF THE SURFACE WATERS OF THE BRITISH COLUMBIA COAST.

by

G.L. Pickard and D.C. McLeod

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Abstract

Grand monthly means of daily observations of surface sea water temperature and salinity from twelve light stations along the British Columbia coast during the 13 years 1935 to 1948 have been analysed. In general the temperatures reach a minimum of 44°F± 1° in January and February. The maximum varies from 50° to 64° in August. The warmest waters occur in bays protected from wind action, and the coldest waters occur in regions of turbulent mixing due to wind or strong currents. The salinity along the mainland coast is a minimum in early summer, associated with the maximum run-off from melting snow. Along the west coast of Vancouver Island the minimum occurs in mid-winter, associated with maximum precipitation, which is not stored as snow in this region. At the southern and northern tip of the Queen Charlotte Islands there is little or no variation of salinity because there is no land drainage of consequence in the vicinity.

In passes between Georgia Strait and the sea where the waters are mixed to homogeneity by strong tidal currents the annual variation of temperature and salinity is reduced, and in some cases entirely suppressed.

On the west coast of Vancouver Island it is shown that the annual cycle is affected by the dominant winds and upwelling of deep ocean waters.

The Seasonal Variation of the Temperature and Salinity of the Surface Waters of the British Columbia Coast.[1]

by
G.L. Pickard and D.C. McLeod.[2]

1. Introduction

For a number of years daily observations of the temperature and salinity of the surface sea water have been made under the direction of the Pacific Oceanographic Group at stations on the British Columbia coast. The information is published annually as 'Observations of Sea Water Temperature, Salinity and Density on the Pacific Coast of Canada,' (1947-1952) and the amount of data now available is sufficient to warrant investigation to determine their significance. This paper embodies the results of a preliminary analysis which indicates the general trend of temperature and salinity values along the coast and may serve as a background for more detailed use or study of the data.

In addition an attempt has been made to account for the main features of the temperature and salinity cycles in terms of known geophysical principles. In some cases, however, the evidence from these surface temperature and salinity data alone is insufficient to complete the explanations and the present discussion therefore points out several lines for further research into the principles governing the cycles in this region.

Records are available from some localities since 1914 but in the majority of cases the systematic recording commenced about 1935. This study considers only data from 1935 to 1948 so that the conclusions for the different stations have substantially equal statistical weight.

The locations of the observing stations are indicated in Figure 1, all but two of them being at lighthouses where the temperature observations are made and water samples obtained by the lightkeepers (Hollister, 1949, 1951 and 1952). The samples are taken from a depth of three feet on the rising tide, within one hour of the high water, during the daylight hours.

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1 Communication No. 2 from the Institute of Oceanography, University of British Columbia.

2 Now with the Imperial Oil Company of Canada.

2. Variation in Range of Surface Temperature

The seasonal variation in temperature reflects the variation in insolation during the year, but may be subject to a number of modifying influences including:

(1) variation in insolation with latitude,
(2) the effect of horizontal and vertical movements of water such as permanent currents, upwelling and turbulence,
(3) the degree of exposure of the station to wind and waves,
(4) evaporation and other factors not taken into account in detail in the present analysis.

For convenience in discussion the twelve stations are divided into three groups as:

Northern Group	West Coast Group	Georgia Strait Group
Langara (Island)	Kains (Island)	(Cape) Mudge
Triple (Island)	Nootka (Island)	Departure Bay
(Cape) St. James	Amphitrite (Point)	Entrance (Island)
Ivory (Island)		Race Rocks
Pine (Island)		

It will be shown that this grouping, which was in the first instance geographical, is also justified to some extent by the similarity in temperature and salinity cycles in each group, but that it is not the only grouping which can be devised.

3. Annual Variation in Surface Temperatures

The general trend of the temperatures was obtained by calculating the mean temperature for each month's observation (monthly mean) and then the mean for all Januarys, all Februarys, etc. (grand monthly mean). Smoothed curves through the grand monthly means are plotted in Figures, 2 3 and 4 and indicate the general character of the annual temperature variations. The salient features are: (1) that maxima, and minima, occur within the same month at all stations except Mudge, where the maximum occurs in July, while the others all occur in August, (2) that while the minimum temperatures (in February) lie within the small range from 43.5°F to 45.5°F, the maxima (in July/August) are more widely distributed from 50°F to 64°F, and (3) consequently the annual range of temperature varies widely from station to station, from 5° at Pine Island to 20° at Departure Bay. If the data are taken year by year the more detailed examination presented in the following paragraphs shows that with minor exceptions the character of the temperature cycle exhibited by the grand monthly means is also typical of that for individual years.

4. Year to Year Fluctuations

In Figure 5 are given values of the standard deviations of the monthly means. This quantity is a measure of the year to year deviation of the monthly mean from the data of Figures 2-4. To reduce congestion the standard deviations for the stations have been plotted in three groups, the geographical grouping used in the earlier figures being retained. The smallness of the values indicates, by application of the Student 't' test, that the annual range of temperature is very significant. Accordingly the curves of Figures 2-4 may be regarded as typical for the respective stations.

It will be seen that except for Race Rocks and St. James the mean values of the standard deviations are closely grouped between 1.2° and 1.6° and do not bear any direct relationship to the annual range of temperature at the individual stations.

5. Correlation of Temperature between Stations

To determine whether or not these fluctuations in temperature were of the same relative magnitude, and in the same sense, for all the stations for any one year, the correlation coefficients between the temperatures at several pairs of stations were calculated. The temperature data were first examined within each geographical group by determining the correlation coefficients between the temperature at a selected comparison station and that at the remainder in turn. Ivory was then selected as comparison station for the whole coast, and the correlation coefficients between the temperature there and at all the other stations in turn were calculated. The results are given in Tables I and II.

Table I indicates that the year to year fluctuations in temperature discussed in the preceding section were in the same sense and of about the same relative extent for all the stations in the Northern and in the West Coast groups, but that the fluctuations for the Georgia Strait group were less regular. The correlation between the temperatures at Ivory and at Nootka in Table II indicates that for the Northern and West Coast stations taken as a group the year to year variations were of the same character, while the correlations between the temperatures at Ivory and Entrance were lower in value and indicate a somewhat less systematic behaviour for the Georgia Strait group.

It is obvious that there will be differences in the rates of heating and cooling, which probably explains the variation of the correlation coefficients in April and October. Although the summer maximum generally occurs in August there is considerable variation from station to station within the calendar month which is not reflected in this analysis. When the maximum occurs in July, as at Mudge, a negative correlation results because of the arbitrary monthly grouping of the data.

However from the data in Table II it is concluded that from year to year the surface sea water temperatures over the whole of the B.C. coast tend to deviate from the long period mean in much the same manner.

6. Harmonic Analysis of the Temperature Fluctuations

The regularity of the temperature curves of Figures 2-4 suggested that it might be possible to represent them by a simple harmonic formula. It was found that the temperature could be represented by the first few terms of a Fourier series:

$$T(X) = A + A_1 \cos X + A_2 \cos 2X + \ldots\ldots\ldots$$
$$+ B_1 \sin X + B_2 \sin 2X + \ldots\ldots\ldots$$

where $T(X)$ is the temperature in °F and X is a phase angle taken as 0° for January, 30° for February, etc. to 330° for December. The coefficients A, A_1, B_1 etc. were evaluated and are given in Table III. The actual temperature curves are reproduced in most cases within 0.5°F by the series with five terms as above. Even closer agreement may be obtained by adding terms in 3X but it is doubtful if the additional terms are significant in view of the magnitude of the year to year fluctuations.

There is no immediately obvious physical significance in the simplicity of the series representing the temperature curves but it may be convenient for mathematical development to be able to represent the temperature changes in such a manner.

7. Correlation between Sea and Air Temperatures

A comparison was made between the surface sea water temperature and the air temperature. Since meteorological data were not obtained at all the light stations it was not possible to make direct comparisons. Instead, meteorological data for 1938-48 were obtained from the Monthly Records, Meteorological Division, Department of Transport for available stations which appeared to be representative of each of the three areas, and a comparison was made with these. The air temperature stations selected were:

Northern Area :	Langara and Prince Rupert
West Coast Area :	Esteban
Georgia Strait Area:	Departure Bay and Lazo

The means of the daily maximum and of the daily minimum temperatures were calculated for each month and the mean of these two taken as the mean temperature for the month. Grand monthly means were then calculated to indicate the general trend of the air temperatures for comparison with the water temperatures. The grand monthly mean air temperature curves are plotted in Figures 2, 3 and 4 and are shown to be in complete phase agreement with those for the sea, although the amplitudes of the air temperature curves are generally the greater. The higher temperature of the sea during the winter causes heat to be transferred from sea to air by conduction and evaporation and, under some circumstances, radiation. The consequent moderation of coastal winter climates is well known.

The deviations of the sea temperatures from the mean have been compared with the deviations of the air temperatures from their mean by calculating the correlation coefficients between these two quantities for each of the stations. The results are given in Table IV, and show that there is in general good agreement between the two. It must be emphasized that this does not necessarily imply that departures from the mean air temperature are the cause of the sea temperature departures.

8. Further Comments on the Temperature Cycles

8.1 West Coast Group.

It is suggested that the primary influence (para. 2) among this group is the upwelling which is known to occur during the summer in this region. The prevailing wind at this time is directed to the southeast, i.e. parallel to the coast, and the resulting stress on the water surface causes a net mass transport of water in the upper layers in a direction to the right of the wind, i.e. offshore (Tully, 1937b). This wind-transported water is replaced by colder water upwelling from depths not exceeding 600-900 feet (Sverdrup, 1938) and it is this which limits the maximum temperature attained in the region. The temperature curves for Kains and for Amphitrite are almost identical and are representative of the water on the open coast. The maximum temperature at Nootka is 4.5° higher, probably because the sampling station is in a more sheltered location in Friendly Cove (Hollister, 1951) than are those of the other two stations. The data for Nootka may therefore be of most value as typical of conditions in a bay rather than in the open sea.

It is possible also that the stability associated with marked salinity gradients may be a factor in increasing the temperature range at an individual station. In this connection it may be remarked that in discussing the salinity distribution on the West Coast it is suggested (para. 9.1) that the larger rise in salinity at Nootka than the other two stations is a result of the concentration of the fresh water in the upper layers (Tully, 1937a). This increases the stability of the water and thereby reduces the vertical mixing with cooler water, and leads to a larger temperature rise in the surface water.

The transport of warmed water offshore in the summer and the continued upwelling of cool water should result in an appreciable temperature gradient normal to the Vancouver Island shoreline, with the temperature increasing seaward. Offshore surveys conducted by the Pacific Oceanographic Group show such an increase in temperature and this fact must be born in mind when considering the lighthouse data (Tully, 1937b; Doe, 1951).

8.2 Georgia Strait Group.

The stations in this group are sheltered from the direct influence of the ocean and the change of temperature with season is likely to be determined chiefly by the change in insolation.

The water at Departure Bay attains the highest mean temperature for any of the stations, probably because it is in a very sheltered location in a shallow bay of 20 fathoms average depth.

The neighbouring station of Entrance Island where the water temperatures are generally about one degree lower than at Departure Bay may be regarded as typical of the exposed waters of Georgia Strait. The higher summer temperatures here and at Departure Bay compared with those at Kains and Amphitrite which are at approximately the same latitude are the result of the lack of upwelling, and of the shelter from the wind and consequent reduction in the wave induced mixing of the upper water layer.

The Mudge station is located inside the entrance to Discovery Passage which leads into Johnstone Strait, the northern link with the ocean, and the maximum temperature here is 5° less than at Entrance. The tide floods southward, while the ebb which is stronger flows northward. Consequently the Georgia Strait water possesses a net motion to the north upon which is superimposed the tidal oscillation. The sea water observations are made near the time of high tide when the flow is southward (flood), wherefore the data represent Georgia Strait water which has ebbed and flowed at least once. There are data to show that these waters are mixed to homogeneity through the whole depth of the channel (180 feet). Therefore it is concluded that the observations at Mudge represent the average properties of the upper 180 feet of Georgia Strait water, which may be expected to be less variable than the surface water observed at 3 feet depth at Entrance.

The annual range of temperature at Race Rocks is the second smallest of that of any of the stations. This undoubtedly results from its location in a region of considerable turbulence. The water coming from seaward undergoes appreciable mixing in the strong tidal streams of Juan de Fuca Strait, while the surface water from Georgia Strait, which might be expected to contribute to an increase in temperature, is in fact thoroughly mixed with the deeper cold water through 600 feet of depth during its passage through the San Juan Archipelago (Tully, 1942). This station provides one of the more extreme instances of the moderation of surface temperature by vertical mixing associated with turbulence.

8.3 Northern Group.

The maximum temperatures at St. James, Triple and Langara are 1° to 3° lower than those on the West Coast of Vancouver Island and it is possible that this is partly due to the difference in insolation between these groups whose stations are in comparable exposures. But, the difference in insolation due to change of latitude between the most southerly (Amphitrite) and most northerly (Langara) stations on the coast is only 8% which can account only in part for the difference in maximum temperatures; in particular the difference between St. James and Langara is greater than could be accounted for by the latitude difference alone. The higher maximum at Ivory is the result of its more sheltered location and its temperature cycle may be expected to be typical of the waters of the inland passages in northern British Columbia. It is not easy to account for the small range of temperature at Pine Island (only 5 1/2°). This station, from its intermediate latitude, might be expected to have an intermediate mean temperature whereas it has the lowest for any of the stations. Lacking detailed information on the nature of the currents and circulation in this vicinity it is presumed, from the small annual range of temperature (and of salinity), that the upper coastal waters are mixed with deeper ocean water at all seasons.

8.4 Overall Assessment of the Temperature Cycles.

To summarize the above discussion, we can select Kains or Amphitrite as equally representative of the Vancouver Island Pacific Coast, St. James as representative of the middle region and Langara as representative of the extreme north, with Nootka as possibly representative of the bays or inlets in the West Coast. Race Rocks, Mudge, and Pine are typical of regions of much turbulence, while conditions in the body of Georgia Strait may be best represented by those at Entrance.

In general the surface sea water temperatures on the British Columbia coast may be regarded as at a sensibly uniform annual temperature minimum of 45°F (± 1°) in February, rising in August to widely distributed maxima (50° - 64°F).

9. Annual Variation of Surface Salinity

The monthly and grand monthly mean salinities were calculated for the twelve stations, and smoothed curves through the values are plotted in Figure 6. It is evident that the stations fall into three distinct groups:

(1) Salinity increasing to a maximum in the summer, (Amphitrite, Kains and Nootka).

(2) Salinity decreasing to a minimum in the summer, (Triple, Ivory, Mudge, Departure Bay and Entrance).

(3) Salinity substantially constant throughout the year, (Langara, St. James, Pine and Race Rocks).

The same cause (insolation) is responsible directly or indirectly for both temperature and salinity changes. In some localities the two may be closely correlated (e.g. absorption or solar energy may both raise the temperature of the water and, by increasing the evaporation, increase the salinity at the same time). However, the temperature and salinity changes, although correlated in time, may in other cases be of different character and, in fact, the similarity between the temperature cycles contrasts markedly with the three distinct classes of salinity cycle just mentioned. For instance, this independence in behaviour can occur because the addition of fresh water (e.g. from a river) to sea water while inevitably causing a change in salinity may effect none in temperature if the two waters happen to have the same temperature before mixing, although such a circumstance in this area would be fortuitous.

Before discussing the salinity changes at the various stations the difference in the character of the run-off of fresh water from the mainland rivers and from the rivers on Vancouver Island and the Queen Charlotte Islands must be mentioned. The larger mainland rivers are fed by streams from the high mountains where the heavy winter precipitation is stored in glaciers and snowfields and their run-off reaches a maximum in June following the maximum rate of melting. On the other hand the rivers of Vancouver Island and the Queen Charlotte Islands respond directly to precipitation because they are fed by streams from lower mountains where storage in the form of snow does not occur to any great extent. (See also, Tully, 1938). Some stations such as Langara and St. James are remote from rivers and are not subject to these influences.

9.1 Stations with Summer Salinity Maxima

These are the three stations Amphitrite, Nootka, and Kains on the West Coast of Vancouver Island and the changes in salinity between winter and summer are found to be statistically significant. The increase in salinity in the summer was at first attributed entirely to upwelling of more saline water but further consideration suggested that another factor, the variation in precipitation during the year, might also be effective. Figure 7A shows the average precipitation during the year for the West Coast, and comparison with Figure 6 shows that decrease in precipitation is accompanied by increase in salinity and vice versa. Since an increase in salinity in the neighbourhood of the coast could be attributed equally as well to decrease in fresh water run-off as to upwelling it seemed desirable to investigate the two processes further.

Since, as explained above, the transport of surface water occurs in a direction to the right of the wind, an indication of the extent of upwelling to be expected may be obtained from the occurrence and magnitude of the component of the wind directed to the southeast at the coast. This quantity, obtained from the Monthly Records of the Meteorological Division, is plotted in Figure 7B. It will be noted from Figures 6 and 7B that although the wind has a southeast component only from mid-April to mid-September yet the salinity commences to increase in January and to decrease in August. Since the average precipitation figures show a decrease from January to August, and thereafter an increase, it suggests that this factor may exert a major influence on the salinity, the changes of salinity following closely on changes in precipitation for the reasons already mentioned.

To determine the relative importance of upwelling and precipitation in controlling the salinity, the relation in Figure 8 was plotted in which the points indicate the corresponding mean values of salinity and precipitation for each month. If these points are joined consecutively the resulting line shows a sharp increase in salinity from May to June (just after the southeasterly directed wind commences), and a decrease after September or October (just after this wind has ceased). Since the upwelling process involves the movement of considerable masses of water it is only to be expected that there will be some lag between the change of the wind and the establishment or cessation of significant upwelling. It is possible that a careful study of the correlations between wind, precipitation and sea temperature in detail for individual years would yield valuable information on the rate of development and of decay of the mass transport of the surface waters due to the wind stress.

A point which requires explanation is that while the change of salinity ascribed to precipitation and that ascribed to upwelling respectively are the same at Kains as at Amphitrite, the changes at Nootka are appreciably greater. At Nootka the maximum salinity is 1 - 2 °/°° less than at the other two stations but the minimum is 6 °/°° less. The difference may arise wholly, or in part, from the fact that the positions where the water samples are taken at Kains and at Amphitrite (Hollister, 1951) are on the open coast exposed to the ocean swell, while the samples at Nootka are taken in Friendly Cove in a more sheltered location which is less subject to waves and where the fresh water is still concentrated in the upper layers giving a low surface salinity (Tully, 1937a). It is also possible that local inequalities in rainfall (common on the B.C. coast) might play some part in explaining the increased slope of the precipitation-controlled part of the salinity change. These factors however should not affect the increase due to upwelling.

A simple formula may be devised for each station to describe the mean salinity changes, using the precipitation and wind speed as variables, but it is doubtful if such an empirical formula has any fundamental significance. The essential feature to be recognized is that both precipitation and upwelling contribute to the determination of the salinity change. It is probable that an analysis of the data day by day would yield a better quantitative understanding of the part played by the two processes, and determine the reason for the difference between Nootka and the other stations.

9.2 Stations with Summer Salinity Minima

The summer minima in salinity exhibited by the stations Triple, Ivory, Mudge, Entrance, and Departure, along the mainland coast are undoubtably due to the river discharges during this period. Triple is influenced by the Skeena River, Ivory by the Dean and Bella Coola Rivers, and the stations in Georgia Strait by the Fraser River.

The average Fraser River discharge rises from a minimum of 0.8×10^{11} cubic feet / month in March to a maximum of 9×10^{11} cubic feet / month in late May, while the salinities at Entrance and Departure commence to fall in early April and reach minima in Mid-June. The time lag is due to the interval required for the fresher water to reach these stations after circulating in Georgia Strait. The further delay in arrival at Cape

Mudge indicates the longer time required for the Fraser River water to reach this more distant station. The annual range of salinity here is reduced because the waters in 180 feet of depth are mixed to homogeneity in Discovery Passage. This corresponds to the reduction of the temperature variation discussed in paragraph 8.2.

The Fraser and Skeena River waters which cause the salinity minima at the widely separated regions of Entrance and Triple stations, come largely from snow melt in substantially the same inland region. Therefore these salinity minima occur at the same time and follow closely the maximum river discharge. The less marked change at Ivory is presumed to be due to the smaller stored runn-off in this region, that from the Dean and Bella Coola Rivers combined being about 10% of that of the Fraser River.

9.3 Stations with Small Annual Range of Salinity.

Langara and St. James are remote from appreciable sources of fresh water and consequently little change in salinity during the year is observed or expected.

The small annual change in salinity at Mudge and Race Rocks is due to the mixing of the surface and deep waters in the turbulent passages as was discussed (para. 8.2) in connection with the temperature cycles. Mudge is the less saline, and more variable of these two because it is dominated by the upper 180 feet of Georgia Strait discharge, whereas at Race Rocks the depth of mixing is of the order of 600 feet, and is affected by the intrusion of upwelled ocean water into Juan de Fuca Strait (Tully, 1942).

The constancy of the temperature and salinity at Pine presumably results from the vertical mixing due to the tidal currents, and winds in the region of Queen Charlotte Sound. The small annual change at these stations, and at Race Rocks in particular, suggests that the salinity here could be taken as a measure of the prevailing salinity of oceanic water from which the dilution by fresh water at the coastal stations could be determined.

10. Climatic Grouping

These temperature and salinity cycles may be regarded as climatic indices corresponding to the temperature and precipitation cycles in the atmosphere. In this sense there are three climatic regions, which are defined in terms of the salinity cycles, since the temperature cycles are similar over the whole coast. At positions far removed from the influence of rivers oceanic conditions prevail; there is a moderate range of temperature change from winter to summer, but little or no variation of salinity. Along the coast where the surface salinity is dominated by run-off, from rivers draining the regions of snow storage, the salinity tends to be lowest in early summer. Along the ocean coast of Vancouver Island, and probably the bays and inlets of the Queen Charlotte Islands, where the winter and summer rainfall runs off directly, the salinity tends to be lowest in the winter.

In each of these regions there are three type locations which modify the climatic cycle. The effects of heating and dilution are conserved at the surface in harbours and bays where the wind effects are small, and the variations are maximum. In open seaways where the wind stirs the water the variations are less but extend to appreciable depths. In passes, narrows, and seaways having turbulent tidal currents, the waters are mixed to homogeneity throughout the depth, so that the seasonal variations are reduced.

The stations are arranged according to this plan in Table V which appears to provide a more acceptable grouping than the purely geographic or salinity classifications.

Mudge is grouped with Race Rocks because they both represent regions of total mixing although the former includes about 180 feet of depth and the latter includes about 600 feet. Pine evidently represents oceanic water, subject to upwelling, and mechanical mixing from the tidal currents in the vicinity. The small annual change at these stations suggests that the salinity here could be taken as a measure of the prevailing salinity of oceanic water from which the dilution by fresh water at the coastal stations could be determined.

The grouping of the remaining stations is evident, both from geographical and salinity considerations.

11. Conclusions

The salinity cycles fall into three distinct groups which appear to be susceptible of simple explanation; but the temperature cycles, although similar among themselves in broad features, differ in details which do not in all cases sub-divide the stations into the same groups as do the salinity variations.

The West Coast stations exhibit very similar fluctuations in temperature from the mean, but while the temperature and salinity cycles are the same at Kains Island and Amphitrite, Nootka differs in having larger annual ranges of both quantities. The annual change in temperature at these stations is limited by the upwelling of cooler water, and this being more saline, affects the salinity in addition to the change associated with the annual precipitation cycle.

The temperature and salinity cycles at Pine Island and Race Rocks have similar characteristics but, though Cape St. James and Langara Island might be added to this group by virtue of their small range of salinity, they show much larger temperature ranges and the highest year to year deviations from the mean of any of the stations.

Entrance Island and Departure Bay form a natural group, typical of Georgia Strait, while Cape Mudge, Triple Island and Ivory Island have in common intermediate temperature ranges but salinity characteristics similar to those at Entrance Island and Departure Bay.

Therefore neither the natural salinity grouping nor the geographical grouping is completely satisfactory by itself and it is suggested that the grouping of Table V which combines both features is most realistic.

Summary

The annual temperature cycle is similar at all stations, with minima (45°F ± 1°) occurring in February and maxima in August. The annual range of temperature varies from 5° at Race Rocks to 20° at Departure Bay. The smallest annual ranges, at Race Rocks, Pine Island and Cape Mudge, are attributed to the effect of turbulent mixing with deep, cold, water, the intermediate ranges at the stations exposed to the Pacific Ocean are associated with the upwelling of cold water due to the summer wind stress, while the largest annual ranges occur at the stations such as Departure Bay and Nootka which are sheltered from the open ocean and where the water is not subject to vertical mixing.

Three distinct salinity cycles are evident. The stations on the west coast of Vancouver Island exhibit salinity maxima in the summer due to the upwelling and to the seasonal decrease in precipitation, the stations on the mainland coast show a summer salinity minimum due to the diluting effect of the fresh water run-off from the main rivers. There is scarcely any annual change in salinity at Cape St. James, and Langara because they are far removed from the influence of big rivers, and at Pine Island, and Race Rocks because the small amount of brackish surface water is mixed with such a considerable depth of saline water in the turbulent passages.

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TABLE I Correlation coefficients for monthly mean sea temperatures between stations by groups.

	Between:	Jan.	Apr.	Jul.	Oct.
Northern Group	Ivory and				
	Langara	.97	.67	.69	.28
	Triple	.97	.73	.91	.39
	St. James	.99	.43	.79	.58
	Pine	.92	.98	.78	.74
West Coast Group	Nootka and				
	Kains	.73	.79	.84	.79
	Amphitrite	.63	.85	.93	.80
Georgia Strait Group	Entrance and				
	Cape Mudge	.34	.56	-.30	.68
	Departure Bay	.28	.54	.62	.83
	Race Rocks	.65	.82	-.01	-.21

TABLE II Correlation coefficients for grand monthly mean sea temperatures for all stations relative to Ivory Island.

Between:	Jan.	Apr.	Jul.	Oct.
Ivory and				
Langara	.97	.67	.69	.28
Triple	.97	.73	.91	.39
St. James	.99	.43	.79	.58
Pine	.92	.98	.78	.74
Kains	.93	.97	.75	.74
Nootka	.94	.98	.80	.64
Amphitrite	.84	.87	.84	.77
Mudge	.96	.95	-.02	.71
Departure Bay	.93	.92	.72	.86
Entrance	.35	.92	.75	.54
Race Rocks	.77	.52	.38	.46

TABLE III Fourier coefficients for representation of annual temperature variation of surface sea-water temperature in the form:

$$T(X) = A + (A_1 \cos X + B_1 \sin X) + (A_2 \cos 2X + B_2 \sin 2X) + (A_3 \cos 3X + B_3 \sin 3X)$$

Station	A	A_1	B_1	A_2	B_2	A_3	B_3
Langara	48.00°	-4.32°	-2.50°	.18°	.35°	.07°	.20°
Triple	49.03	-4.43	-2.44	.93	0	-.12	.16
St. James	48.54	-4.10	-2.82	.80	.68	.05	-.37
Ivory	50.50	-7.18	-2.32	.75	.38	.28	.08
Pine	47.72	-1.97	-1.33	.10	-.15	0	.07
Kains	50.47	-4.82	-2.17	.23	.30	.22	.18
Nootka	51.60	-8.15	-1.93	.38	.73	.40	.07
Amphitrite	50.58	-4.62	-1.95	-.05	.13	.12	-.15
Mudge	50.90	-7.10	-0.90	.50	.20	.05	.05
Departure Bay	52.81	-9.90	-1.82	1.30	.63	.25	-.17
Entrance	52.29	-9.03	-2.62	1.55	.58	.23	-.12
Race Rocks	48.28	-2.97	-1.28	.13	0	.12	.12

(N.B. Values calculated from above formula and coefficients to be rounded off to nearest 0.1°.)

TABLE IV Mean correlation coefficients between monthly mean air and sea temperatures from 1938 - 48.

	Air temp.	Sea temp.	Jan.	Apr.	Jul.	Oct.
Northern Group	Langara	Langara	.92	.86	.62	.72
		St. James	.26 (.84)	.15 (.53)	.63	.52
		Triple	.90	.82	.92	.05
		Ivory	.70	.84	.24	.69
		Pine	.81	.72	.74	.38
West Coast Group	Esteban	Kains	.88	.75	.91	.92
		Nootka	.66	.77	.89	.89
		Amphitrite	.91	.88	.89	.88
Georgia Strait Group	Lazo	Mudge	.28	.88	-.35	.81
		Entrance	.15	.67	.73	.70
		Departure Bay	.75	.95	.76	.85
		Race Rocks	.79	.70	.32	.43

(N.B. Figures in brackets for St. James are obtained when readings for 1940 are omitted, suggesting possible instrument error this year.)

TABLE V Classification of Daily Sea Water Observation Stations according to climatological region and type location

Location	Region		
	Oceanic	Coastal	
	No Runoff	Direct Runoff	Stored Runoff
Harbours and Bays	-	Nootka	Departure
Coastal Seas	Langara St. James	Kains Amphitrite	Entrance Ivory Triple
Straits Turbulent Seaways	Pine	-	Race Rocks Mudge

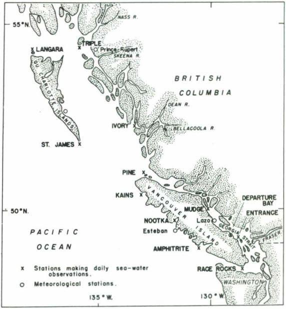

Figure 1.

Chart showing location of stations making daily seawater observations.

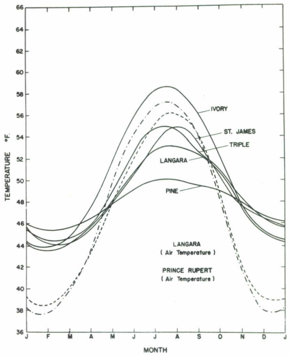

Figure 2.

Mean monthly sea and air temperatures in the Northern area.

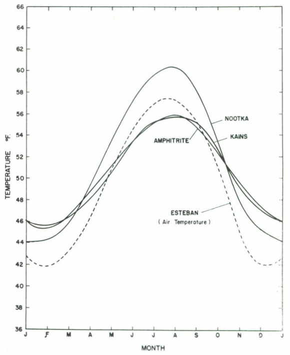

Figure 3.

Mean monthly sea and air temperatures on the west coast of Vancouver Island.

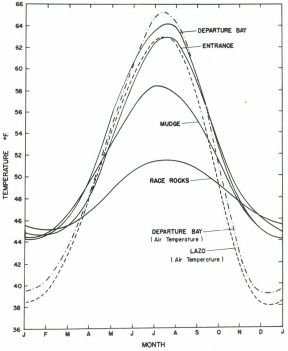

Figure 4.

Mean monthly sea and air temperatures in the Georgia Strait area.

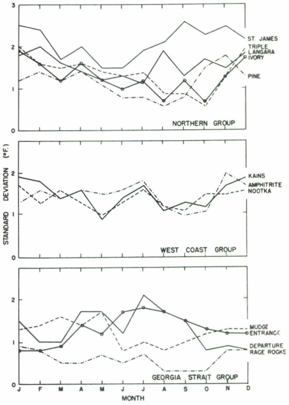

Figure 5.

Standard deviations of monthly mean temperatures about grand monthly means.

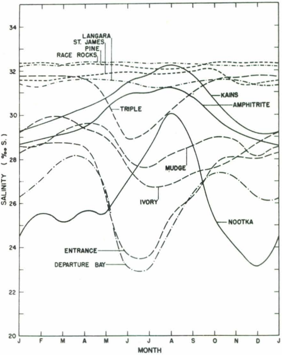

Figure 6.

Mean monthly salinity at stations on the British Columbia coast.

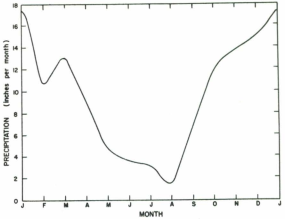

Figure 7A.

Mean monthly precipitation on west coast of Vancouver Island for years 1941,2,4,5 & 6.

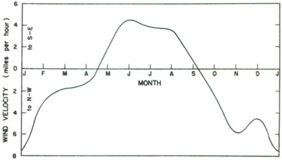

Figure 7B.

Mean monthly wind speed component parallel to west coast of Vancouver Island for years 1941,2,4,5 & 6.

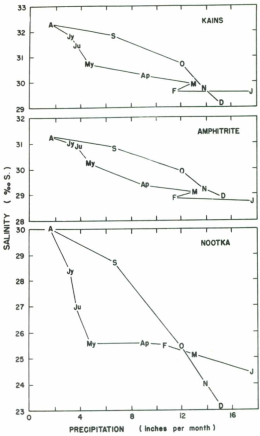

Figure 8.

Mean salinity v. mean precipitation for stations on west coast of Vancouver Island.