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

BY

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ABSTRACT

For a number of years daily observations of surface temperature and salinity have been taken at oceanographic stations (mostly lighthouses) on the B. C. coast. The present thesis is the first attempt that has been made to systematically analyse this data. The annual variation in temperature was seen to follow the general climatological trend of the B. C. coast at each of the stations, although a wide range in the amplitudes of these periodic variations was noted. The factors influencing the amplitude of the annual temperature curves were considered and such effects as, incoming radiation, the extent of turbulence, the degree of shelter and the phenomena of upwelling due to horizontal wind stress (West Coast of Vancouver Island) have been discussed for each of the stations. Correlations were made between available meteorological information and the sea temperature observations and an attempt has been made to determine temperature contours of the B. C. coastal waters during the summer when the surface temperature is least uniform. The salinity observations were treated in an analogous manner to temperature and found to exhibit characteristic periodic annual variations. The stations were classified by means of these variations and the influences of precipitation and fresh water runoff, evaporation and mixing were discussed and correlations with meteorological observations were again made.

ACKNOWLEDGEMENT

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I INTRODUCTION

For a number of years observations of the temperature and salinity of the surface sea water have been made at stations on the British Columbia coast. The procedure adopted is to take a sample of sea water daily at a depth of three feet and to observe the water temperature at the same time. The samples of sea water are sent, together with the temperature data, to the Pacific Oceanographic Group at the Pacific Biological Station, Nanaimo, B.C. for analysis to determine the salinity. The data obtained in this way is collected and published annually by the Pacific Oceanographic Group as 'Observations of Sea Water; Temperature, Salinity and Density on the Pacific Coast of Canada.'

The present thesis gives an account of the first attempt which has been made to analyse this published data systematically to determine, and if possible, account for the behavior patterns of temperature and salinity. The analysis pertains to data available in the period from January 1, 1935 to December 31, 1948, and consists ~~of~~

of approximately 4000 daily observations of temperature and salinity at each of the stations listed below.

Records are available for Departure Bay (Pacific Biological Station) from 1914 and for New Westminster from 1927. The records for the majority of the stations however are more recent. A list of the stations for which extended series of observations are available follows:

EXPOSED STATIONS

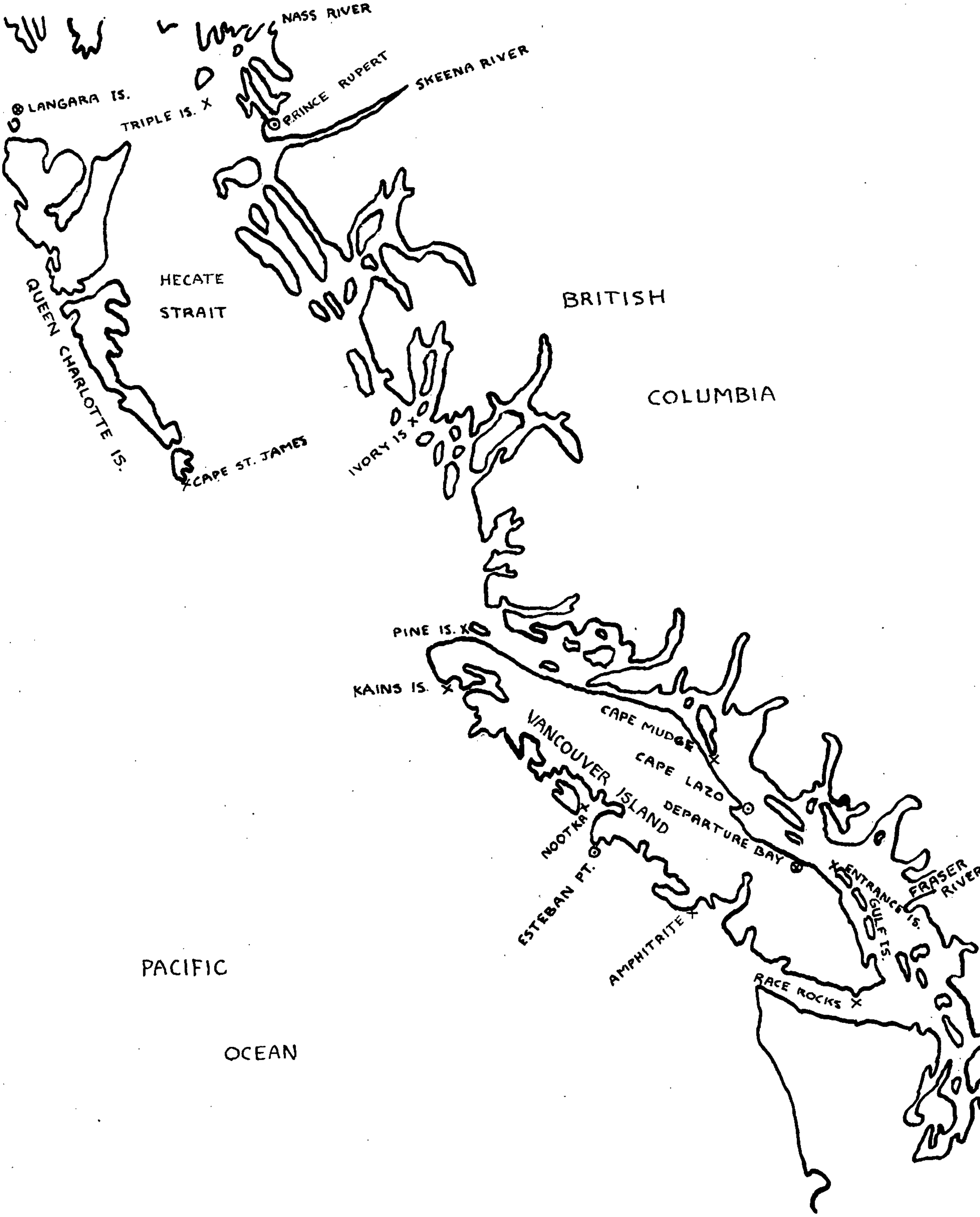
Vancouver Island - West Coast	Observations Commenced
Amphitrite Pt. - Barkley Sound...	August 1934
Nootka - Nootka Sound............	August 1934
Kains Island - Quatsino Sound....	January 1935
Georgia Strait	
Race Rocks - Juan de Fuca Strait	May 1941
Entrance Is. - Georgia St. Central	May 1936
Cape Mudge - Georgia St. North	November 1936
Queen Charlotte Islands - West Coast	
Cape St. James - Queen Charlotte Is.	July 1934
Langara Island - Queen Charlotte Is.	October 1936
Queen Charlotte Sound and Hecate Strait	
Pine Island - Queen Charlotte Sound	January 1937
Ivory Island - Milbanke Sound.......	July 1937
Triple Island - Brown Passage......	November 1939

SHELTERED STATIONS

Southern B. C. Coast	
Departure Bay - Georgia St. West Side	September 1914
New Westminster - Fraser River	February 1927

The geographical location of the oceanographic stations is indicated in Fig. 1, together with the meteorological stations whose records have been used in

FIG. 1



X LOCATION OF STATIONS MAKING DAILY SEAWATER OBSERVATIONS.

⊙ WEATHER STATIONS FROM WHICH METEOROLOGICAL DATA HAS BEEN USED.

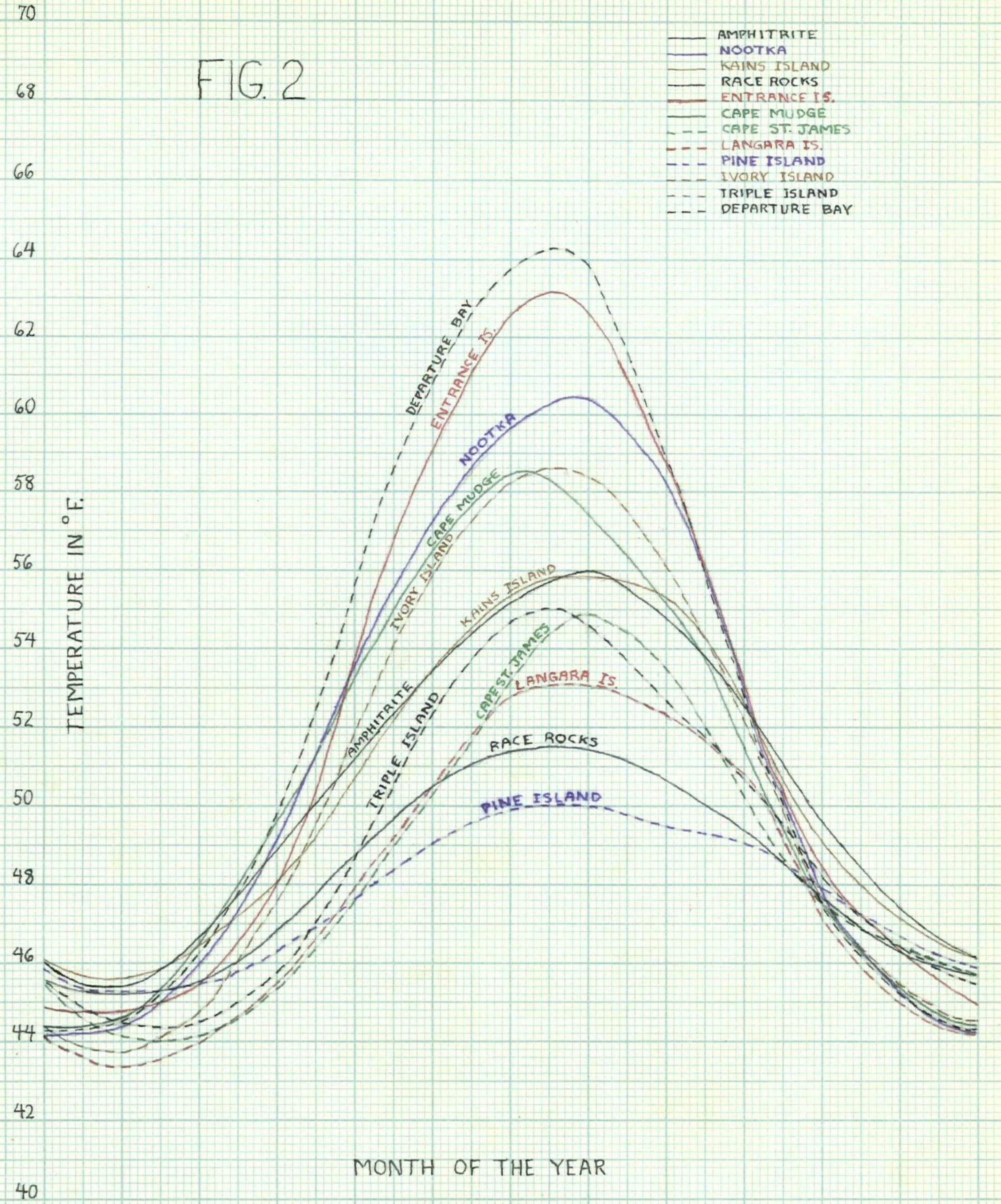
this discussion. All but the last two oceanographic stations are at lighthouses and the observations are made by the lighthouse keepers.

The temperature data have first been examined for periodic trends and for possible correlation with meteorological events and sea water dynamics. Following this the salinity data have been analysed in an analogous manner.

II ANNUAL VARIATION IN SURFACE TEMPERATURE

For the purposes of determining a typical annual variation in temperature at each of the B. C. coastal stations the following procedure was used. The mean temperature was calculated from daily temperature observations throughout each particular month. This is referred to as the 'monthly mean.' The mean of the monthly means has been calculated over the entire period during which observations have been carried on and is referred to as the 'grand monthly mean.' Fig. 2 illustrates the character of the annual temperature curves from the grand monthly means for the stations.

It is seen that these curves are in very close phase agreement, the temperature generally reaching a minimum in February and rising to a maximum in August, thus following the general climatological trend of the B. C. coast. The minimum temperatures at the stations are fairly uniform at 45° F. $\pm$ 1 F$^{\circ}$ in February but there is a notable variation in the amplitude of the temperature curves. The smallest annual temperature range is that for Pine Island, 4.7 F$^{\circ}$ while the largest is that for Departure Bay, 19.7 F$^{\circ}$.



ANNUAL VARIATION OF GRAND MONTHLY MEAN TEMPERATURE OF SEA WATER FROM DAILY OBSERVATIONS AT STATIONS ON THE B.C. COAST.

The significance of these annual temperatures was tested, using Pine Island as the appropriate test case. Applying the Student 't' test (Hoel p. 145) to the data yields a value for t of 10.8 which indicates that the difference between minimum and maximum temperature is highly significant in this case and, as the following discussion shows, will be more so for the other stations which have larger ranges with approximately the same standard deviations.

Values of $\sigma/\sqrt{n}$, the standard deviation of the grand monthly mean, are given in Table I for each of the oceanographic stations. If it is assumed that the sea water is subject to no long range temperature variations of a period comparable to the period during which the data has been analysed, the monthly mean surface temperatures will be normally distributed with a mean m and standard deviation σ . The monthly means for each year for which the oceanographic data is available may be regarded as random samples of this normal distribution, of size n where n is the number of years in which the data is available. Then the sample mean $\overline{x}$ will be normally distributed with mean m and standard deviation $\sigma/\sqrt{n}$. The quantity is the 'unbiassed' standard deviation of the monthly mean, $\sigma = \sqrt{\frac{\Sigma(x-\overline{x})^2}{n-1}}$.

As the standard deviations of the grand monthly means are in all cases small compared with the annual

TABLE 1

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean	Annual Temp. Range in F°
Amphitrite	.35	.42	.38	.44	.39	.44	.48	.31	.25	.29	.54	.46	.40	10.6
Nootka	.45	.34	.44	.35	.27	.34	.43	.32	.30	.39	.41	.44	.37	16.2
Kains Island	.51	.48	.38	.44	.24	.37	.45	.29	.36	.32	.45	.52	.40	10.1
Race Rocks	.34	.30	.18	.18	.26	.20	.25	.12	.11	.11	.29	.28	.22	6.3
Entrance Is.	.23	.24	.27	.39	.33	.49	.50	.50	.44	.38	.34	.35	.37	18.1
Cape Mudge	.38	.36	.45	.42	.50	.24	.30	.26	.31	.34	.37	.38	.36	14.1
Cape St.James	.75	.71	.53	.45	.39	.41	.57	.57	.69	.63	.66	.59	.58	10.7
Langara Is.	.60	.73	.52	.48	.42	.45	.37	.69	.43	.58	.52	.64	.54	9.5
Pine Island	.35	.39	.34	.40	.32	.24	.23	.17	.22	.44	.54	.37	.33	4.7
Ivory Island	.57	.49	.35	.49	.36	.30	.36	.22	.35	.20	.40	.53	.38	14.6
Triple Island	.67	.53	.50	.53	.47	.43	.47	.32	.30	.21	.42	.65	.46	10.2
Departure Bay	.28	.30	.28	.48	.49	.35	.60	.48	.43	.27	.35	.24	.37	19.7

Values of the standard deviation $\sigma/\sqrt{n}$, and the annual range of the temperature curves of Fig. 2.

temperature range (Table 1) then the temperature curves of Fig. 2 may be regarded as representative of the annual variation in sea water surface temperature in the locality of each station. Table I also shows that the values of $\sigma/\sqrt{n}$ for all stations are the same order of magnitude. Therefore as the Pine Island station exhibits the least annual temperature range and an application of the student's t test to monthly mean temperatures in February and August yields a value of $t = 10.8$, the annual temperature variation at all twelve B. C. Coastal stations may be regarded as being highly significant.

III THE VARIATION IN AMPLITUDE OF TEMPERATURE CURVES

The cyclic annual temperature variation from a winter minimum to a summer maximum is attributed to variation in insolation during the year. The large variation in amplitude requires explanation, and may possibly be attributed to some or all of the following:

1. The extent of turbulence and consequent mixing of cold subsurface water with warmer surface water.
2. The phenomena of upwelling of colder, more saline water due to horizontal wind stress as observed on the west coast of Vancouver Island.
3. The comparative degree of shelter or exposure of the particular station.
4. Variation of insolation with latitude.

For the purpose of discussion the twelve B. C. coastal stations are divided into three groups as follows:

A - West Coast Area

Amphitrite
Nootka
Kains Island

B - Georgia Strait Area

Entrance Island
Departure Bay
Cape Mudge
Race Rocks

C - Northern Area

Cape St. James
Langara Island
Pine Island
Ivory Island
Triple Island

The justification for this grouping will appear in the following discussion.

A West Coast Area

During the summertime the prevailing winds along the west coast of Vancouver Island are directed from the north west, parallel to the shoreline. The wind exerts a horizontal frictional stress on the water which is well known to result in a net transport of water in the upper 50 - 200 meters, to the right of the wind direction in the northern hemisphere (Sverdrup, Johnson, Fleming p.500). A net off shore mass transport is produced along the west coast and results in an upwelling of colder, more saline water from below the surface to satisfy continuity requirements as illustrated in Fig. 3. The extent of this upwelling process is discussed in Section X in connection with the annual variation of surface salinity along the West Coast. Upwelling tends to limit the maximum temperature attained during the summer here.

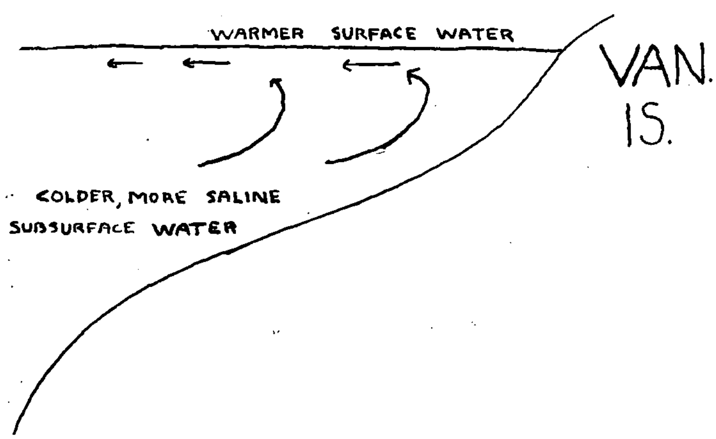


FIG. 3 THE UPWELLING PROCESS ON THE WEST COAST OF VANCOUVER ISLAND.

Kains Island and Amphitrite are representative of general conditions along this coast. The temperature curves for these stations show maximum surface temperatures of 56° F and 55.7°F and exhibit annual ranges of 10.1 F° and 10.6 F° respectively.

Of the three west coast stations Nootka (Fig. 4) is in a more sheltered location than Kains Island and Amphitrite. Its location at the same time protects it from north west winds and it would not be affected by upwelling to the same extent as the latter. Therefore it is to be expected that Nootka will attain a greater maximum temperature during the summer than Kains Island and Amphitrite. Inspection of Fig. 2 shows this to be the case. The maximum temperature at Nootka is 60.4° F and the annual temperature range is 16.2 F°. Nootka is therefore regarded as only being representative of its immediate locale in Nootka Sound.

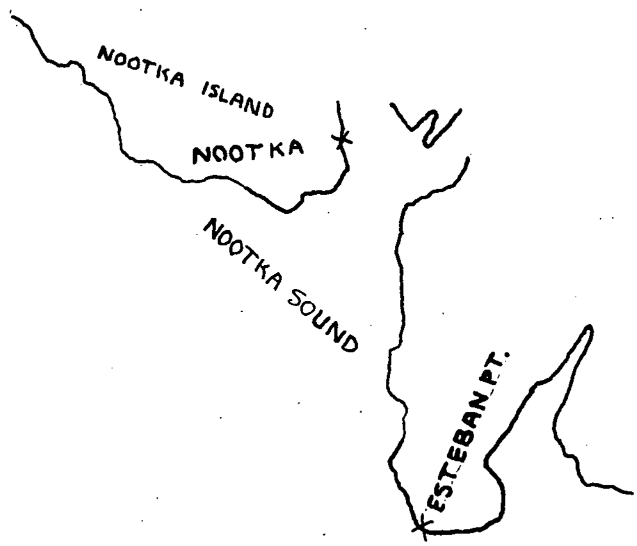


FIG.4 LOCATION OF NOOTKA STATION

As the colder water due to upwelling reaches the surface and is transported toward the open ocean it will be heated due to insolation. Therefore a distinct temperature gradient would be expected perpendicular to the Vancouver Island shoreline. Off shore temperature data is available as a result of an oceanographic survey conducted by Pacific Oceanographic Group during August,1950 (Progress Reports, October 1950). A study of the temperature contours obtained indicate the existence of this temperature gradient and substantiate the described effect of upwelling.

B Georgia Strait Area

The principal factors influencing the maximum temperature attained during the summer at the stations of the Georgia Strait area are the degree of shelter and the extent of turbulence at the particular stations. There is a comparatively small latitude variation among these stations and no upwelling process analogous to that on the west coast of Vancouver Island.

Departure Bay which is the most sheltered of the coastal stations also attains the greatest maximum temperature, 64° F. Because it is sheltered to the extent that it is effectively a harbor and its water is shallow (approximately 20 fathoms on the average) its temperature curve may be regarded only as appropriate to the immediate locality and possibly to other harbors in Georgia Strait.

Entrance Island should be more representative of expected conditions in Georgia Strait. It is an exposed station, although not exposed to the same degree as are Amphitrite and Kains Island since Georgia Straight is almost entirely landlocked. From Fig. 2 it is seen that the temperature curve for Entrance Island reaches a maximum of 63° F, only 1 F° less than that of Departure Bay and about 7 F° greater than that of

Amphitrite and Kains Island. Because the temperature curve for Entrance Island shows a high maximum value it may be concluded that mixing processes with subsurface layers of colder water during the summer are unimportant and that any mixing is conducted only relatively close to the surface in this locality.

Cape Mudge in the northern section of Georgia Strait attains a maximum temperature of approximately 5 F° less than that at Entrance Island which is considerably less than can be accounted for by variation of isolation with latitude. The region to the south of Cape Mudge is a region of convergence of the flood tides from passages to the north and south, but it is not apparent that this would cause mixing of surface waters with subsurface layers. However, because of its location at the southern entrance to Discovery Passage and Seymour Narrows it is suggested that its maximum temperature would be modified due to turbulence caused by the strong tidal currents which are a feature of this region.

It is notable that the temperature curve for Race Rocks, the southernmost station, shows one of the smallest ranges (only Pine Island being less). As Race Rocks is located in an area of violent turbulence this is strong evidence of the important effect of turbulence in modifying the maximum temperature attained at a station. Turbulence is a result of the irregular lateral boundaries of the Gulf Islands (Fig. I), and the strong tidal currents (4 to 6 knots) observed in this area. Georgia Strait water when being transported into Juan de Fuca Strait mixes with ocean water. Colder water from considerable depths is raised to the surface and the mixing of this colder water with surface water will reduce the rise in surface temperature due to insolation. Race Rocks may be regarded as illustrative of a modification of temperature due to turbulence.

C Northern Area

The temperature curves here would be expected to show somewhat lesser amplitudes in general due to a decrease of insolation in the more northerly latitudes. The variation in incoming radiation due to latitude variation over the B. C. coast is about 8%. This would be expected to cause a variation of annual temperature range from 1 to 2 F^{o}. However a change in latitude may result in a change in climatological conditions and this must also be taken into consideration.

The temperature curve for Langara Island (Fig. 2) reaches a maximum of 53^{o} F. This is $3F^{o}$ less than the maximums for Kains Island and Amphitrite, the representative West Coast stations. There is a decrease in annual temperature range of about $1F^{o}$ at Langara Island over these stations (Table 1). However the latitude effect is probably somewhat more significant here than a $1F^{o}$ difference in range would indicate due to the absence of the West Coast upwelling process. A comparison with Entrance Island, representative of Georgia Strait shows a decrease in temperature range of $8.6F^{o}$ although the comparatively high degree of shelter at Entrance Island in this case would certainly be largely responsible for this difference.

The temperature curves of the stations at Cape St. James and Triple Island are observed to have approximately the same ranges, with maximum temperatures of 54.8°F. A decrease in insolation at Triple Island due to its more northerly latitude may be counterbalanced by a higher degree of shelter in comparison with Cape St. James.

Ivory Island exhibits a temperature curve with a maximum of over 58°F. This is considerably higher than the other stations of the Northern Area, and over 2F° higher than Amphitrite and Kains Island on the West Coast. Ivory Island, situated in Milbanke Sound (Fig. 5) is considerably more sheltered than the other northern stations and the temperature curve probably represents only the localized area. The curve may typify the variation to be expected in the inner passages of the Northern Area.

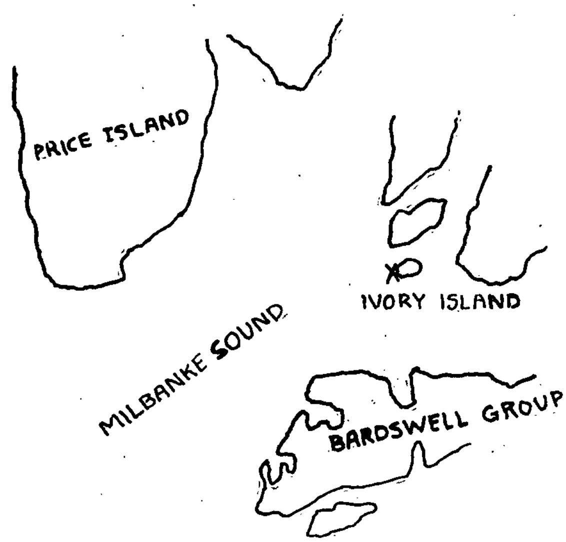


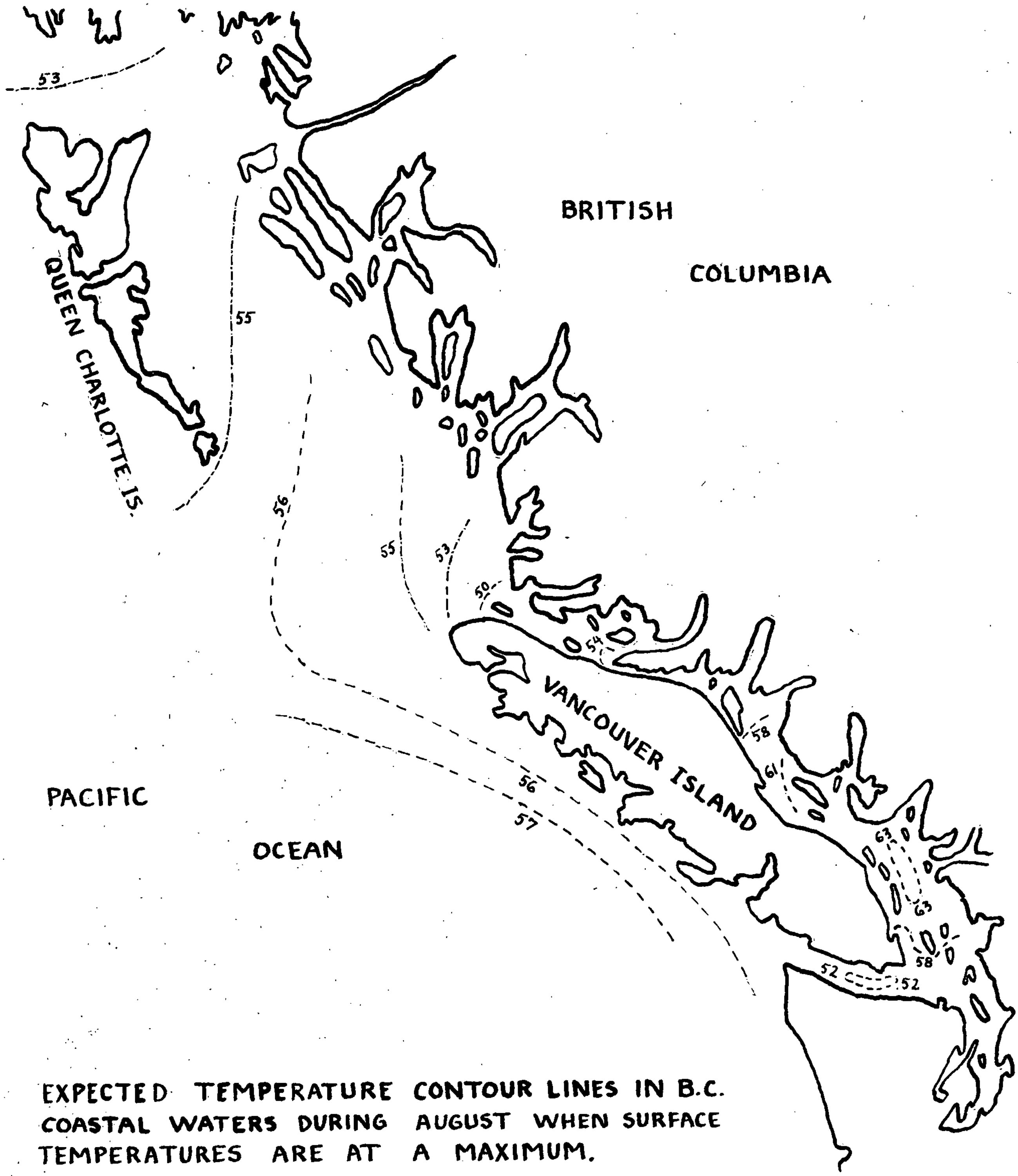
Fig. 5 Location of Ivory Island

Pine Island shows a temperature curve with the smallest range of any of the B. C. coastal stations which is interesting as it is situated at an intermediate latitude. Its location at the northern extremity of Vancouver Island in Queen Charlotte Sound is analogous to that of Race Rocks at the southern extremity in Juan de Fuca Strait. It is suggested that turbulence resulting from irregular bottom topography (reference to charts of the area) and the mixing of the inner waters with the ocean waters would limit the maximum temperature in the manner described at Race Rocks station.

In summarizing, Amphitrite and Kains Island may be regarded as representative West Coast stations and illustrative of the effect of upwelling on temperature curves. Entrance Island is typical of Georgia Strait and shows the effect of a more enclosed and sheltered station. Langara Island is a representative station of the Northern area and its temperature curve demonstrates a decrease in insolation with an increase in latitude. Race Rocks and Pine Island stations illustrate the importance of turbulence in modifying the seasonal variation in temperature.

In general the sea water surface temperature on the B. C. coast may be regarded as approximately uniform at 45° F in February and at an annual temperature minimum during this period. The temperaturesrise from the minimum, rounding to peak values in August. In Fig. 6 an attempt has been made to show temperature contours for the month of August when the B, C. coastal waters have attained their annual temperature maximum. Owing to the limited number of stations from which data is available it must be emphasized that these contour lines are only approximations.

FIG.6



EXPECTED TEMPERATURE CONTOUR LINES IN B.C. COASTAL WATERS DURING AUGUST WHEN SURFACE TEMPERATURES ARE AT A MAXIMUM.

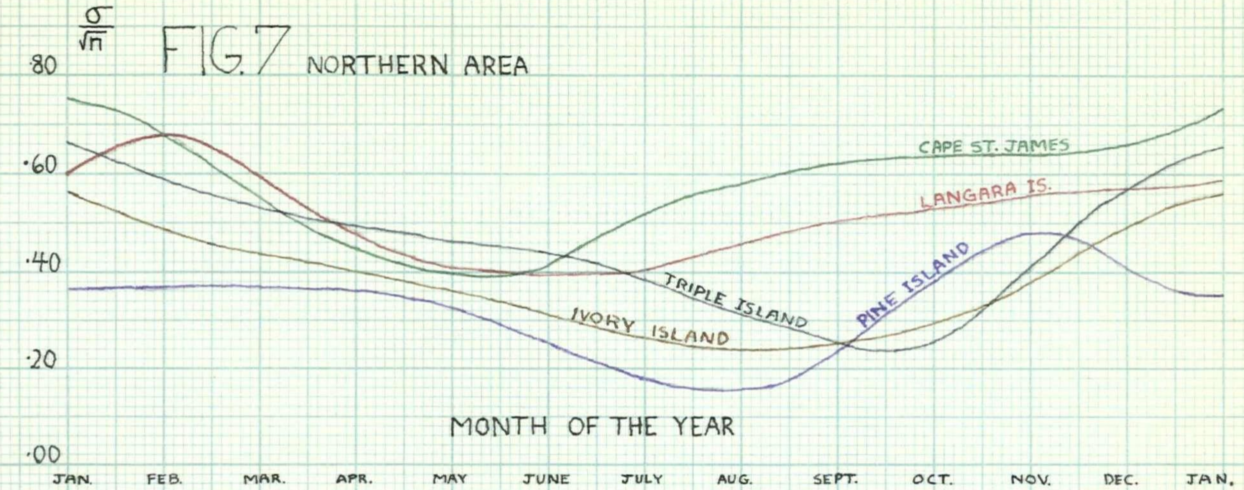
IV STANDARD DEVIATION OF TEMPERATURE

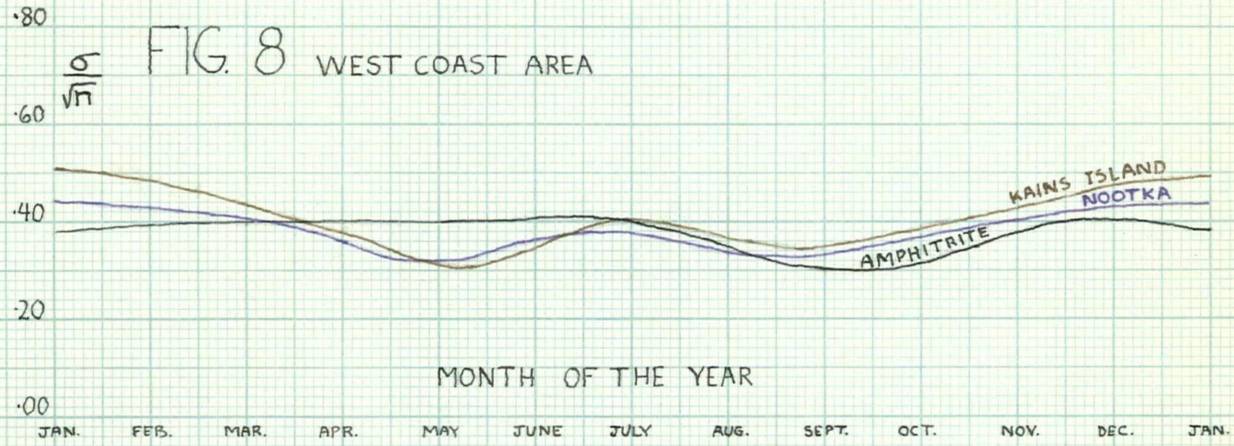
The values of $\sigma/\sqrt{n}$ in Table 1 have been plotted for the stations of each area in Fig. 7, 8, and 9. These give an estimate of the annual variation in standard deviation of the grand monthly means. The following general conclusions may be drawn:

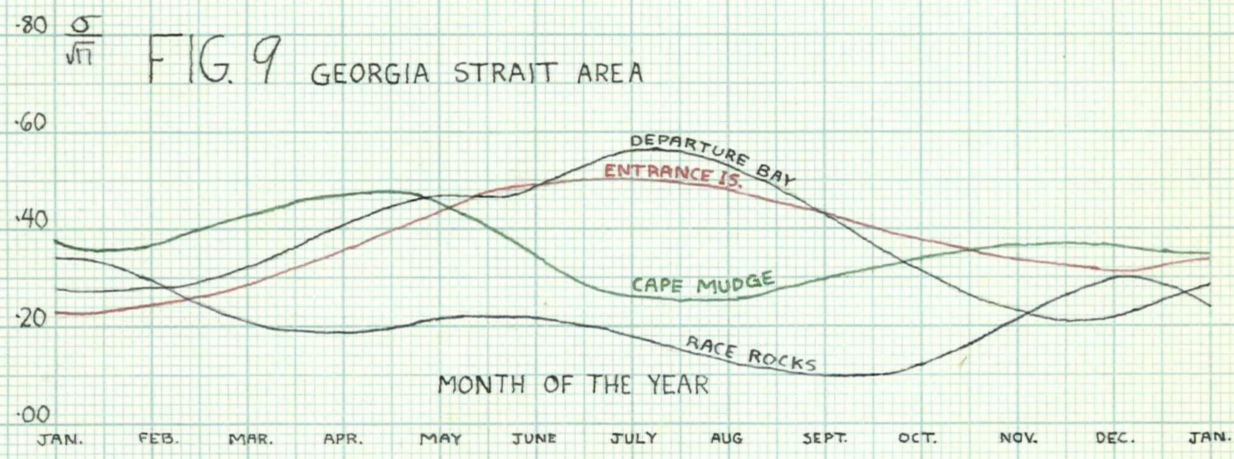
1. As all values of $\sigma/\sqrt{n}$ are small in comparison with the amplitudes of the temperature curves of Fig. 2, then as discussed in Section II, the curves are representative of actual annual variation in sea water surface temperature at the stations.

2. As all values of $\sigma/\sqrt{n}$ are of the same order of magnitude then the probable deviation from normal in any particular year is approximately the same over all B. C: coastal waters.

3. It appears from Fig. 7 that the temperatures at the stations of the northern area seem to vary with regard to $\sigma/\sqrt{n}$ from a maximum in the winter to a minimum in the summer perhaps due to more variable meteorological conditions in the winter. Fig. 8 shows that stations on the West Coast







ANNUAL VARIATION IN THE STANDARD DEVIATION, ($\sigma/\sqrt{n}$)
OF THE TEMPERATURE CURVES OF FIG. 2

have values of $\sigma/\sqrt{n}$ of the same magnitude throughout the year. From Fig. 9 Departure Bay and Entrance Island show temperature variations having minimum $\sigma/\sqrt{n}$ values in the winter and maximum values in the summer.

Mixing of surface water with water at appreciable depths will oppose an extreme temperature deviation from the normal due to unusually high or low radiation income during any particular period. Therefore a comparison of the 'unbiassed' standard deviation of the monthly means, $\sigma = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$ where x is the monthly mean temperature, $\bar{x}$ is the grand monthly mean and n the number of years in which the data was treated, should give a comparative indication of the extent of mixing at particular stations. The calculated values of σ are shown in Table 2. These values are not necessarily in the same ratio as the corresponding values of Table 1, as the value of n differed at several stations. A study of Table 2 shows Race Rocks to have significantly lower standard deviations throughout the year which is attributed to the described effect of mixing. The observed low values of standard deviation at Pine Island from June to August and perhaps those of Triple Island from August to October may be due to the effect of mixing. However, it is difficult to draw conclusions when there is no qualitative basis of comparison. The importance of meteorological conditions in governing the standard deviation in the vicinity of the particular stations must be also taken into consideration. A study of vertical temperature gradients would be necessary

TABLE 2

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Amphitrite	1.3	1.6	1.4	1.6	1.4	1.6	1.8	1.2	1.0	1.1	2.0	1.7	1.5
Nootka	1.7	1.3	1.6	1.3	1.0	1.3	1.6	1.2	1.1	1.5	1.5	1.6	1.4
Kains Is.	1.9	1.8	1.4	1.6	0.9	1.4	1.7	1.1	1.3	1.2	1.7	1.9	1.5
Race Rocks	0.9	0.8	0.5	0.5	0.7	0.5	0.7	0.3	0.3	0.3	0.8	0.8	0.6
Entrance Is.	0.8	0.8	0.9	1.4	1.2	1.7	1.8	1.7	1.5	1.3	1.2	1.2	1.3
Cape Mudge	1.3	1.4	1.6	1.4	1.7	0.8	1.0	0.8	1.0	1.2	1.3	1.3	1.2
Cape St.James	2.5	2.4	1.7	2.0	1.5	1.5	1.9	2.1	2.6	2.3	2.5	2.2	2.1
Langara Is.	1.8	2.0	1.6	1.4	1.2	1.3	1.1	1.9	1.3	1.7	1.5	1.9	1.6
Pine Is.	1.2	1.4	1.2	1.4	1.1	0.8	0.8	0.6	0.8	1.5	1.8	1.3	1.2
Ivory Is.	1.9	1.6	1.2	1.6	1.2	1.0	1.2	0.7	1.2	0.7	1.3	1.8	1.3
Triple Is.	2.0	1.6	1.5	1.6	1.4	1.3	1.4	0.9	0.9	0.6	1.3	2.0	1.4
Departure Bay	1.5	1.0	1.0	1.7	1.7	1.2	2.1	1.7	1.5	0.8	0.9	0.8	1.3

Standard deviations of the monthly mean surface temperatures at the B. C. coastal stations.

to further ascertain the extent of mixing.

V A HARMONIC ANALYSIS OF TEMPERATURE VARIATION

It is apparent from Fig. 2 that a periodic annual variation in temperature exists at each station. To study the character of this periodic variation a harmonic analysis was made of the observations at the different stations. To obtain the equation of a line accurately representing the observed temperature curve at each of the stations a Fourier Series has been assumed,

$$T(X) = a_0 + a_1 \text{ Cos } X + a_2 \text{ Cos } 2X + a_3 \text{ Cos } 3X + b_1 \text{ Sin } X + b_1 \text{ Sin } 2X + b_3 \text{ Sin } 3X$$

where T is the temperature in $^{\circ}$F. and

X is a phase angle taken as 0° at January 1 and increasing by 30° each month.

The coefficients a_0 .... a_3 and b_1 .... b_3 have been evaluated by means of the twelve ordinate scheme (Whittaker and Robinson). The values of the coefficients are tabulated (Table 3) and graphs plotted comparing the observations at each of the stations with the corresponding Fourier Series. Fig. 10 shows the type of fit obtained for Ivory Island station using the coefficients of Table 3, and is representative of the closeness of fit obtained at the other stations. It is to be emphasized that the

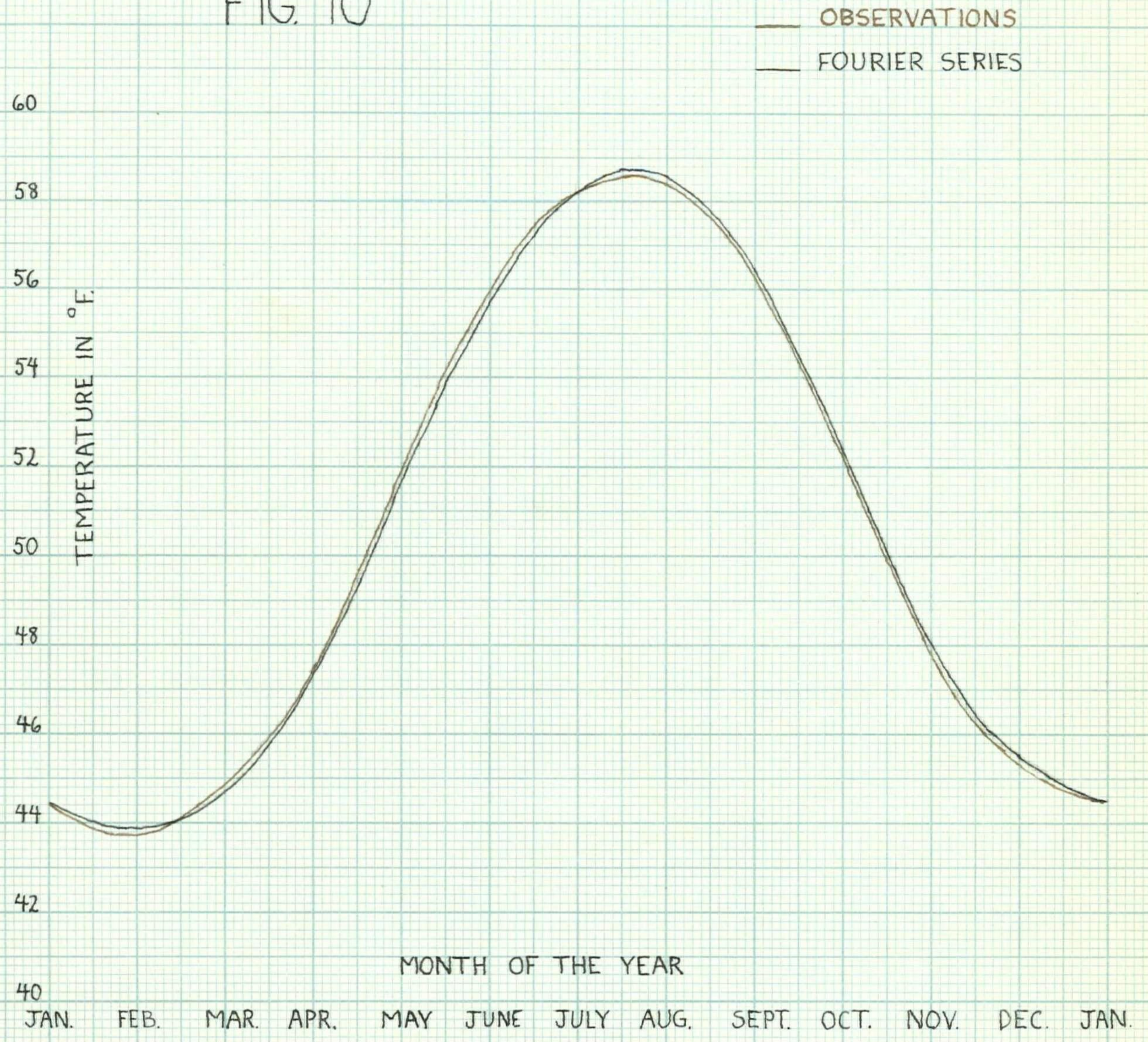
a_o, a_1 Cos X and b_1 Sin X terms predominate while the others are minor corrections to improve the fit.

TABLE 3

Station	a_0	a	b_1	a_2	b_2	a_3	b_3
Amphitrite Pt.	50.58	-4.62	-1.95	- .05	.13	.12	-.15
Nootka Light	51.60	-8.15	-1.93	.38	.73	.40	.07
Kains Island	50.47	-4.82	-2.17	.23	.30	.22	.18
Race Rocks	48.28	-2.97	-1.28	.13	.01	.12	.12
Entrance Is.	52.29	-9.03	-2.62	1.55	.58	.23	-.12
Cape Mudge Lt.	50.90	-7.10	-0.90	.50	.20	.05	.05
Cape St.James	48.54	-4.10	-2.82	.80	.68	.05	-.37
Langara Is.	48.00	-4.32	-2.50	.18	.35	.07	.20
Pine Island	47.72	-1.97	-1.33	.10	-.15	-.03	.07
Ivory Island	50.50	-7.18	-2.32	.75	.38	.28	.08
Triple Island	49.03	-4.43	-2.44	.93	.03	-.12	.16
Departure Bay	52.81	-9.90	-1.82	1.30	.63	.25	-.17

Fourier coefficients calculated from sea water surface temperature observations at B. C. coastal stations.

FIG. 10



A COMPARISON OF THE OBSERVED ANNUAL TEMPERATURE CURVE AT IVORY ISLAND AND ITS CORRESPONDING FOURIER SERIES.

VI CORRELATION OF TEMPERATURE BETWEEN STATIONS

It is of interest to determine whether or not the temperatures at individual stations deviate from their mean temperature curves of Fig. 2 in an identical manner for a particular period. This can be determined statisically by use of the correlation coefficient r .

$$r = \frac{\Sigma(x-\bar{x})(y-\bar{y})}{n\,\sigma_x\,\sigma_y}$$

Where x and y are the monthly mean temperatures of the stations being correlated, σ_x and σ_y their standard deviations, and $\bar{x}$ and $\bar{y}$ their grand monthly means for the particular month, during n years in which observations have been made at the stations under consideration. Correlation coefficients were first calculated among stations in each of the three main groups and are presented in Table 4. The values of r indicate a good correlation among stations of the West Coast area and the Northern area, although rather poor correlation among the stations of Georgia Strait area.

TABLE 4

		January	April	July	October
West Coast Area	Nootka And Amphitrite	.63	.85	.93	.80
	Kains Island	.73	.79	.84	.79
Georgia Strait Area	Entrance Is. And Departure Bay	.28	.54	.62	.83
	Cape Mudge	.34	.56	-.30	.68
	Race Rocks	.65	.82	-.01	-.21
Northern Area	Ivory Island And Cape St.James	.99	.43	.79	.58
	Langara Is.	.97	.67	.69	.28
	Pine Island	.92	.98	.78	.74
	Triple Island	.97	.73	.91	.39

Correlation of monthly mean temperature between stations in each of the three areas.

For purposes of comparison correlation coefficients have also been calculated between each station and Ivory Island, which has arbitrarily been selected as the reference station. These are given in Table 5. The data has been treated from the period 1941 to 1948 as it is reasonably complete during this period and a comparison of results is likely to be more significant. As these correlation coefficients are in general quite high we may conclude that the sea water surface temperatures over B. C. coastal waters tend to deviate from their long period mean values in an identical manner during a particular period. Cape Mudge in July (Table 5) is a notable exception, and the stations of Georgia Strait in general show comparatively poor correlation amongst each other as indicated by the correlation coefficients at each station with reference to Entrance Island (Table 4). This may be due to the complex dynamics of Georgia Strait.

An inspection of Table 5 also indicates a better correlation between stations in winter, as represented by January, than in summer, as represented by July.

TABLE 5

Ivory Island And	Jan.	April	July	Oct.	Station Mean
Amphitrite Pt.	.84	.87	.84	.77	.83
Nootka Light	.94	.98	.80	.64	.84
Kains Island	.93	.97	.75	.74	.85
Race Rocks	.77	.52	.38	.46	.54
Entrance Island	.35	.92	.75	.54	.64
Cape Mudge	.96	.95	-.02	.71	.66
Cape St. James	.99	.43	.79	.58	.70
Langara Island	.97	.67	.69	.28	.65
Pine Island	.92	.98	.78	.74	.85
Triple Island	.97	.73	.91	.39	.75
Departure Bay	.93	.92	.72	.86	.86
Mean for Month	.87	.81	.68	.61	

Correlation coefficients for monthly mean temperatures at B. C. coastal stations with reference to Ivory Island station during the period 1941 to 1948.

VII CORRELATION OF SEA WATER SURFACE TEMPERATURE WITH AIR TEMPERATURE

It is apparent from the temperature curves of Fig. 2 that the surface sea water temperature follows very closely the general climatological trend of the B. C. Coast. To determine this correlation more closely, air temperature curves have been determined and plotted for weather stations corresponding to each of the three groups of oceanographic stations. The data on air temperatures was obtained from the Monthly Records, Department of Transport, Meteorological Division and has been treated in a similar manner to the sea water temperature data.

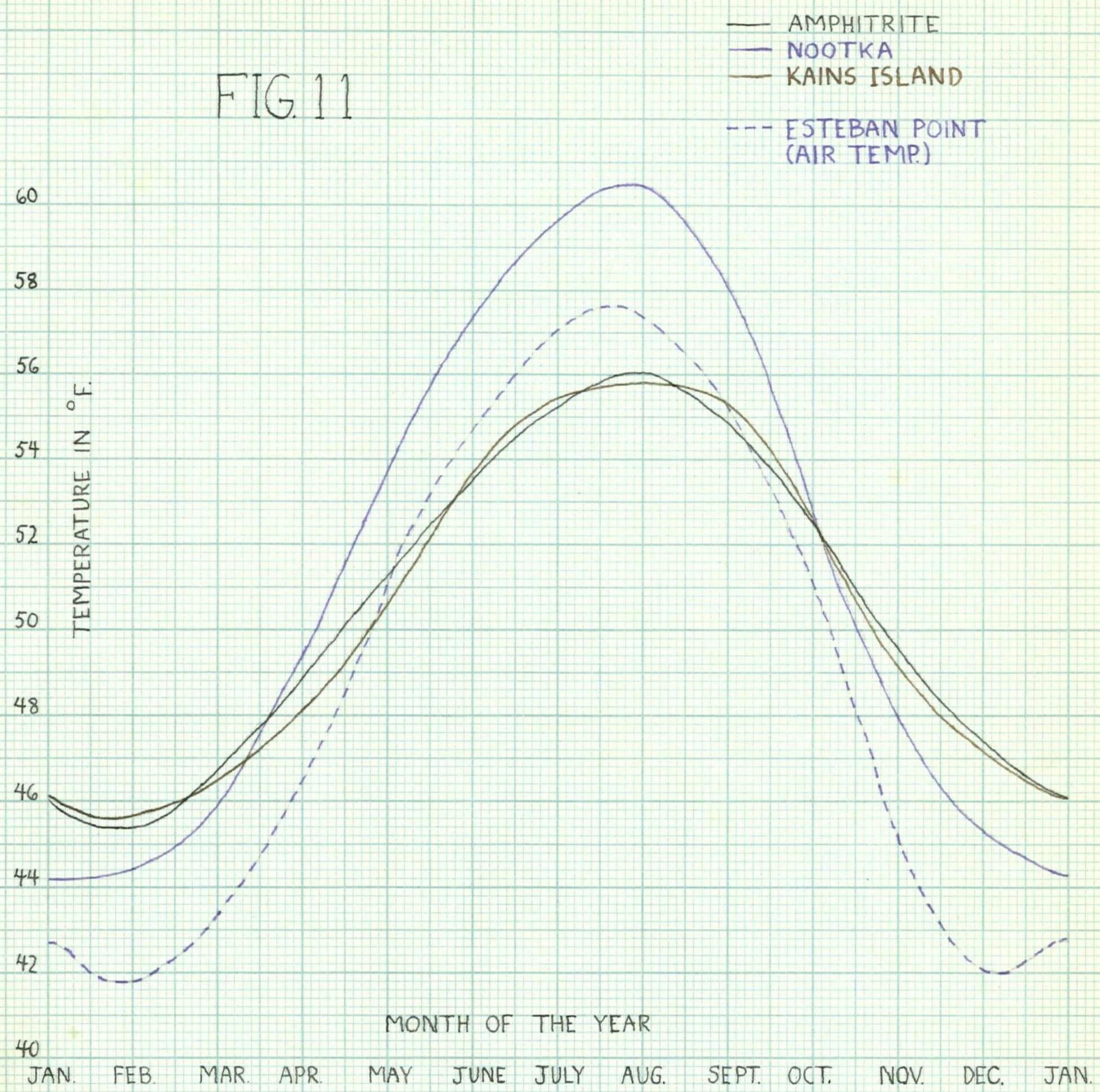
The weather stations selected as representing climatological conditions are as follows:

1. Esteban Point................West Coast Area
2. Departure Bay
   Cape Lazo ....Georgia Strait Area
3. Langara Island
   Prince Rupert................Northern Area

Owing to the limited number of meteorological stations from which data was available, it was not possible to select weather stations that coincided with the oceanographic stations. However the above stations, while they may not give a true representation of weather data applicable to the oceanographic stations, should give a sufficient approximation. The geographical location of these weather stations is indicated in Fig. 1.

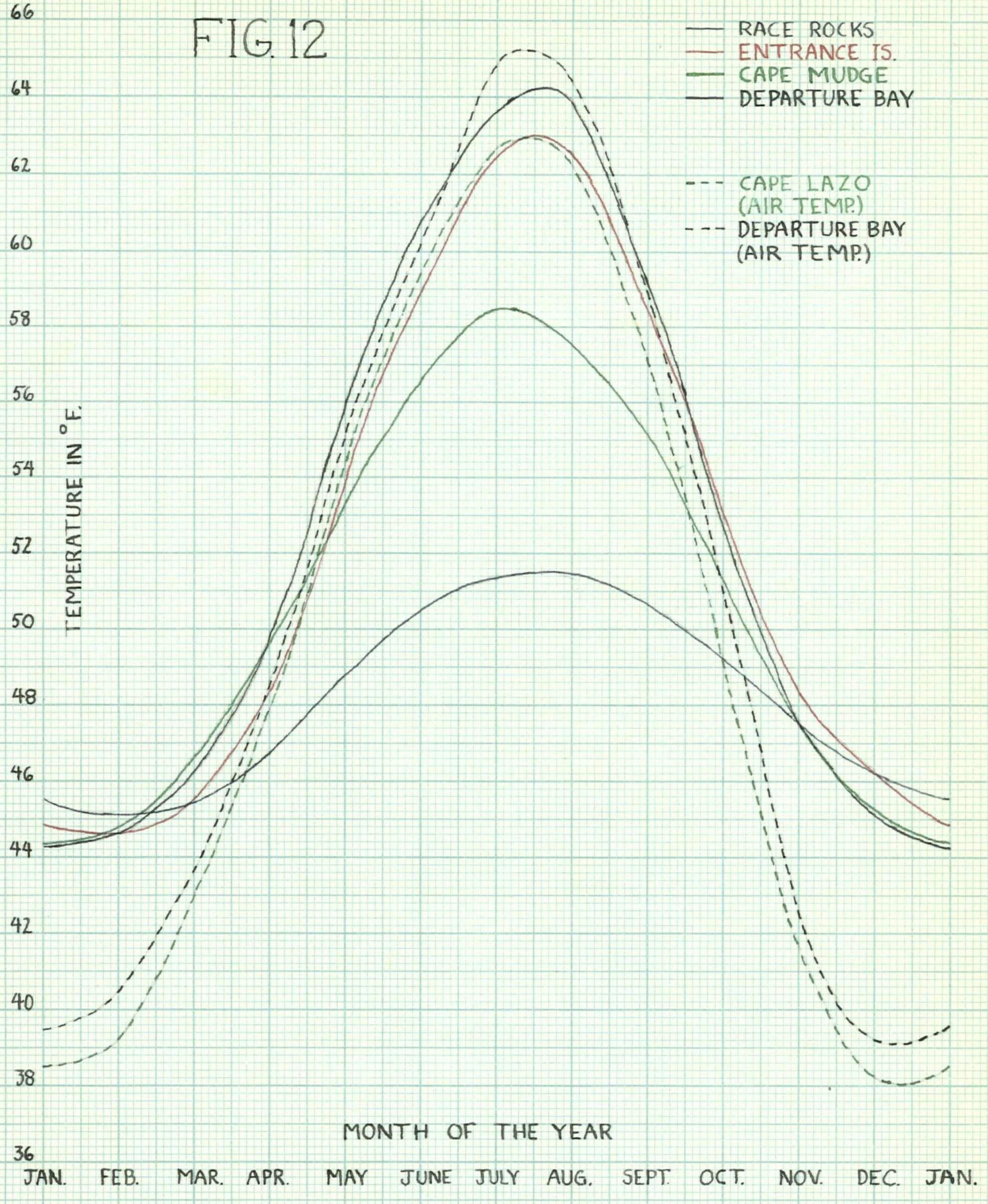
The procedure followed in treating the data was to average the daily recorded maximum and minimum air temperatures over each month and then take the average of the two mean values. This temperature is referred to as the monthly mean. The data was treated from 1938 - 48 and the monthly means averaged over this period. The values are referred to as the grand monthly means. They have been plotted in Fig.'s 11, 12,and 13 along with the sea temperature curves of the oceanographic stations and indicate the character of the annual variation in air temperature in the vicinity of the weather stations.

These curves are seen to be in complete phase agreement with the temperature curves at the oceanographic stations suggesting that the annual variation in insolation is the chief factor in controlling the annual variation of sea temperatures. The amplitudes of the air temperature curves are considerably larger than the sea temperature curves. In the winter the minimum air temperature is less than the sea temperature and in the summer the maximum air temperature exceeds that of the sea. Insolation primarily controls the cyclic variation of both air and sea but because



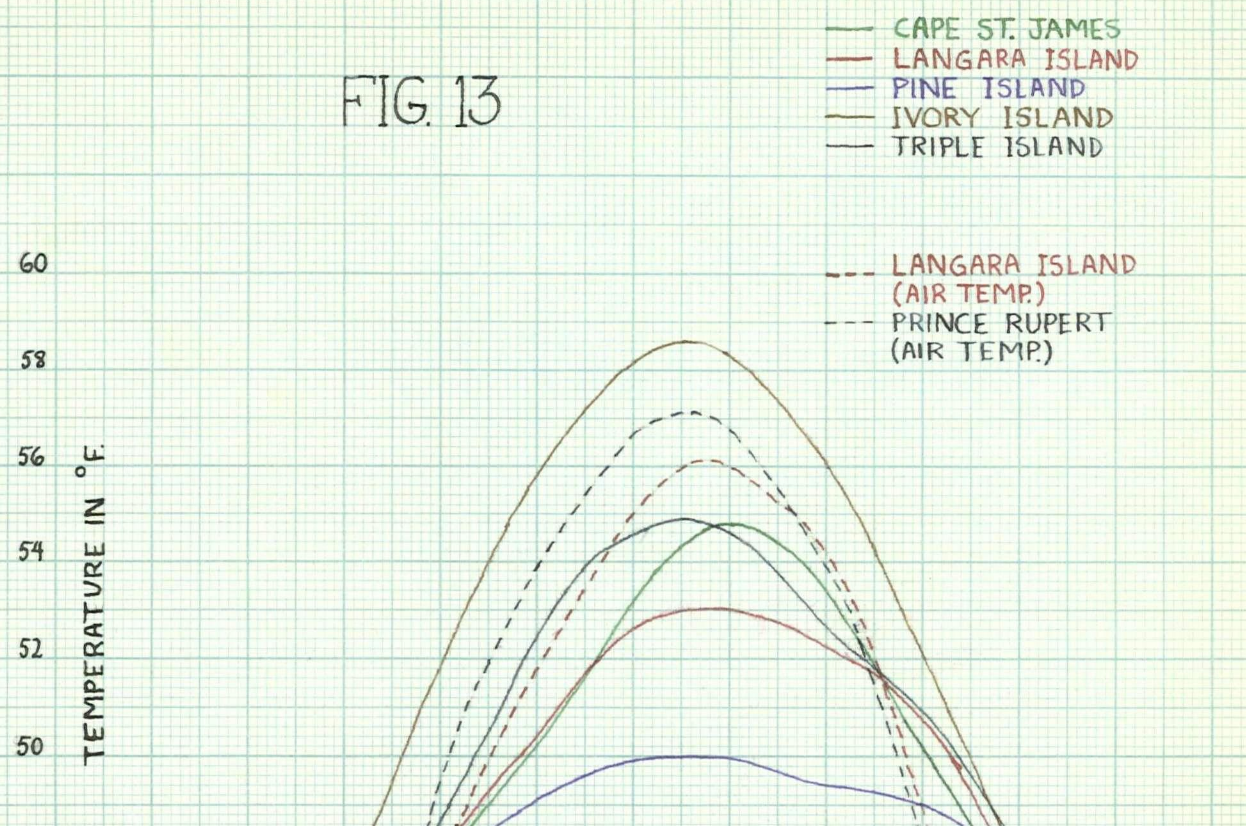
ANNUAL SEA AND AIR TEMPERATURE VARIATIONS AT STATIONS OF THE WEST COAST AREA.

FIG. 12



ANNUAL SEA AND AIR TEMPERATURE VARIATIONS AT STATIONS OF THE GEORGIA STRAIT AREA

FIG. 13



ANNUAL SEA AND AIR TEMPERATURE VARIATIONS AT STATIONS OF THE NORTHERN AREA.

sea water has a much larger thermal capacity than air the time rate of change of temperature is considerably less. The temperature difference at the boundary of the two media results in an exchange of heat. During the winter months thermal energy is transferred from sea water to air through processes of radiation, conduction and evaporation. During the summer months heat may be conducted from air to sea water, although eddy conductivity is then greatly reduced (Sverdrup, Johnson, Fleming, p. 114) and transfer is very much less efficient.

The oceanographic stations selected as representative of general conditions in each of the three areas are seen to conform closely to this pattern as illustrated in Fig.'s 11, 12 and 13. Notable exceptions to the above description are Nootka (Fig. 11) and Ivory Island (Fig. 13) at which the sea temperatures throughout the year exceed the air temperatures at the weather stations selected to represent their respective areas. This supports the argument put forward in Section III that, because of the comparatively high degree of shelter of these stations, they do not typify the conditions of their surrounding area but only represent their immediate locale.

To illustrate the influence of air and sea temperature on each other correlation coefficients have again been calculated. The correlation coefficient has been applied here to determine whether or not if the air temperature was observed to deviate from its temperature curve in a particular period the corresponding sea temperature would follow this deviation. The values of r have been calculated between the monthly means for air and sea water throughout the period 1938-48 inclusive. They are given in Table 6.

The values found for the correlation coefficients are in general quite high. This indicates that the primary source of heat is the same for both air and sea water and emphasizes the importance of the influence of one on the other. It should be pointed out that in the case of Cape St. James, January and April, (Table 6) the readings of 1940 spoiled the correlation and suggest possible instrument error here. When the correlation was made neglecting the 1940 readings calculations of r gave values of .84 and .53 respectively. There are however other discrepancies, particularly in the Georgia Strait area which may be attributed to the complex dynamics of the area.

TABLE 6

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

Values of the correlation coefficients of monthly mean air and sea temperatures at the B. C. coastal stations during the period 1938 - 48.

VIII THE EFFECT OF CLOUD COVER ON SURFACE TEMPERATURE

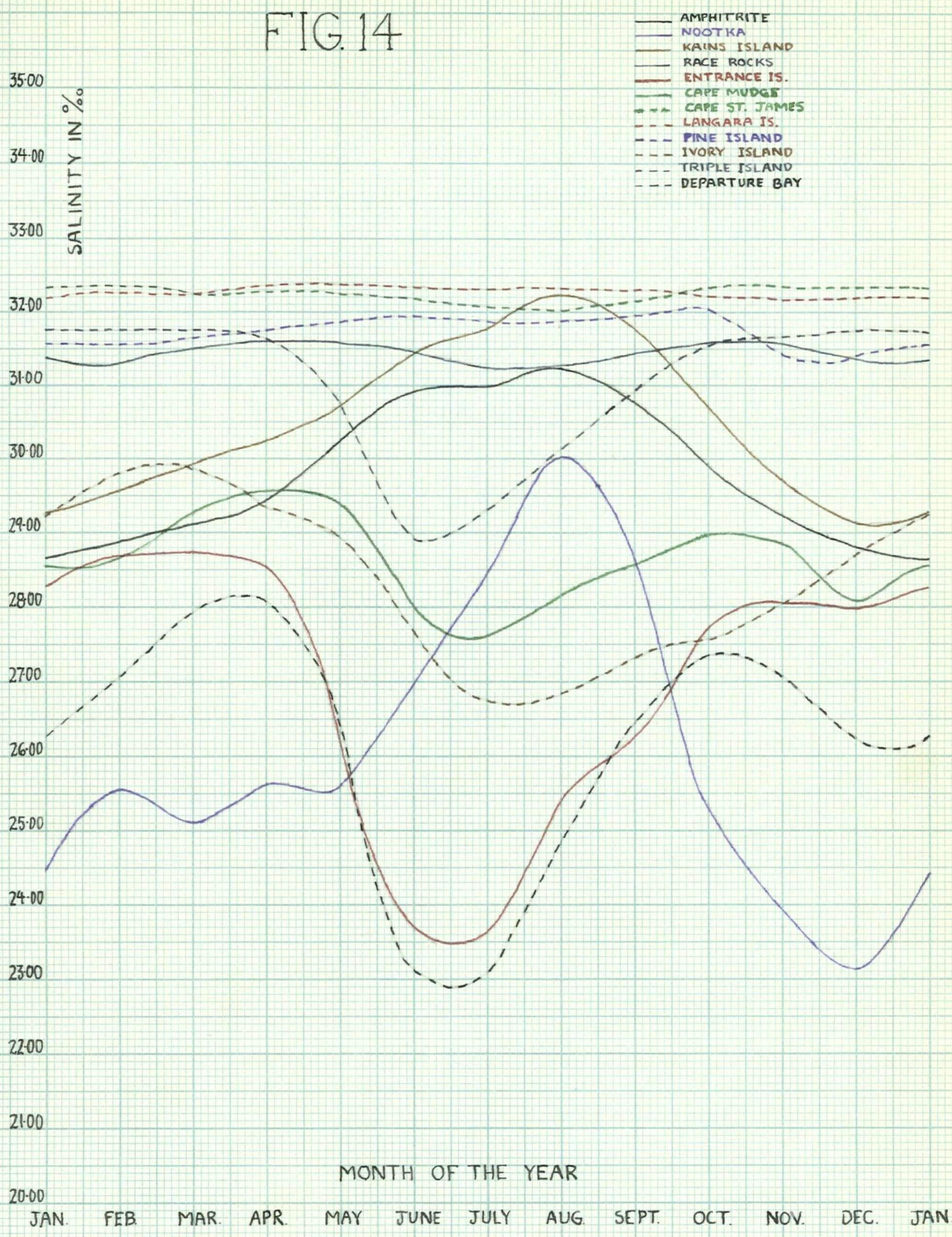
In an effort to determine more specifically the influence of meteorology on surface temperature the effect of cloud cover was investigated. A high percentage cloud cover is expected to reduce the incoming radiation reaching the sea surface. However with the sun penetrating through scattered clouds the incoming radiation may be increased due to reflection from the clouds. Also effective back radiation may be decreased in the presence of clouds due to an increase in radiation from the atmosphere (Sverdrup, Johnson, Fleming; p. 101). It is therefore not apparent that a direct relationship between cloud cover and surface temperature would exist.

Data on cloud cover was obtained from the Monthly Records of the Department of Transport, Meteorological Division. Observations of the cloud cover in tenths are taken at specified times (usually three or four observations spaced six hours apart). The Monthly Records provide the monthly mean of the daily observation time. The values were averaged and assumed to represent the monthly mean percentage cloud cover in the vicinity of the particular station. To investigate a possible direct relationship the correlation was calculated between monthly mean percentage cloud cover and monthly mean sea temperature at Amphitrite (Esteban Pt. weather station cloud cover data) and Langara Island (Langara Island weather station cloud cover data). Calculations however gave no evidence of a correlation and it is concluded that more extensive data on cloud cover is necessary to determine the effect of cloud cover on surface temperature.

IX ANNUAL VARIATION IN SURFACE SALINITY

Before discussing further meteorological influences such as precipitation, evaporation and wind force a general analysis of salinity data is necessary. Salinity is defined as the total amount of solid material in grams contained in one kilogram of sea water when all the carbonate has been converted to oxide, the bromine replaced by chlorine, and all organic matter completely oxidized. It is always expressed in parts per thousand for which the symbol $^{o}/_{oo}$ is used. The manner in which the data has been treated is analogous to that described in the preceding discussion on temperature. A mean salinity was calculated from daily salinity observations throughout each month and is referred to as the monthly mean. The mean of these monthly means was calculated over the entire period in which observations have been carried on and is again referred to as the grand monthly mean. The grand monthly mean salinities have been plotted for each month in Fig. 14. These curves describe the annual variation in salinity in the vicinity of each of the oceanographic stations.

FIG. 14



ANNUAL VARIATION OF GRAND MONTHLY MEAN SALINITY AT STATIONS ON THE B.C. COAST.

A study of Fig. 14 indicates that the salinity curves catagorize the stations into three distinct groups as follows:

A Those stations at which the salinity increases to a maximum during the summer months:

Amphitrite

Nootka

Kains Island

B Those stations at which the salinity decreases to a minimum during the summer months:

Entrance Island

Departure Bay

Cape Mudge

Ivory Island

Triple Island

C Those stations at which the salinity remains fairly constant throughout the year:

Langara Island

Cape St. James

Pine Island

Race Rocks

The surface salinity is mainly determined by three processes.

1. Decrease of salinity by precipitation on the sea and fresh water run off from the land.

2. Increase of salinity by evaporation.

3. Change of salinity by processes of mixing

The following sections give a discussion of the mechanisms involved in controlling the annual variation of surface salinity for each of the above three groups of oceanographic stations.

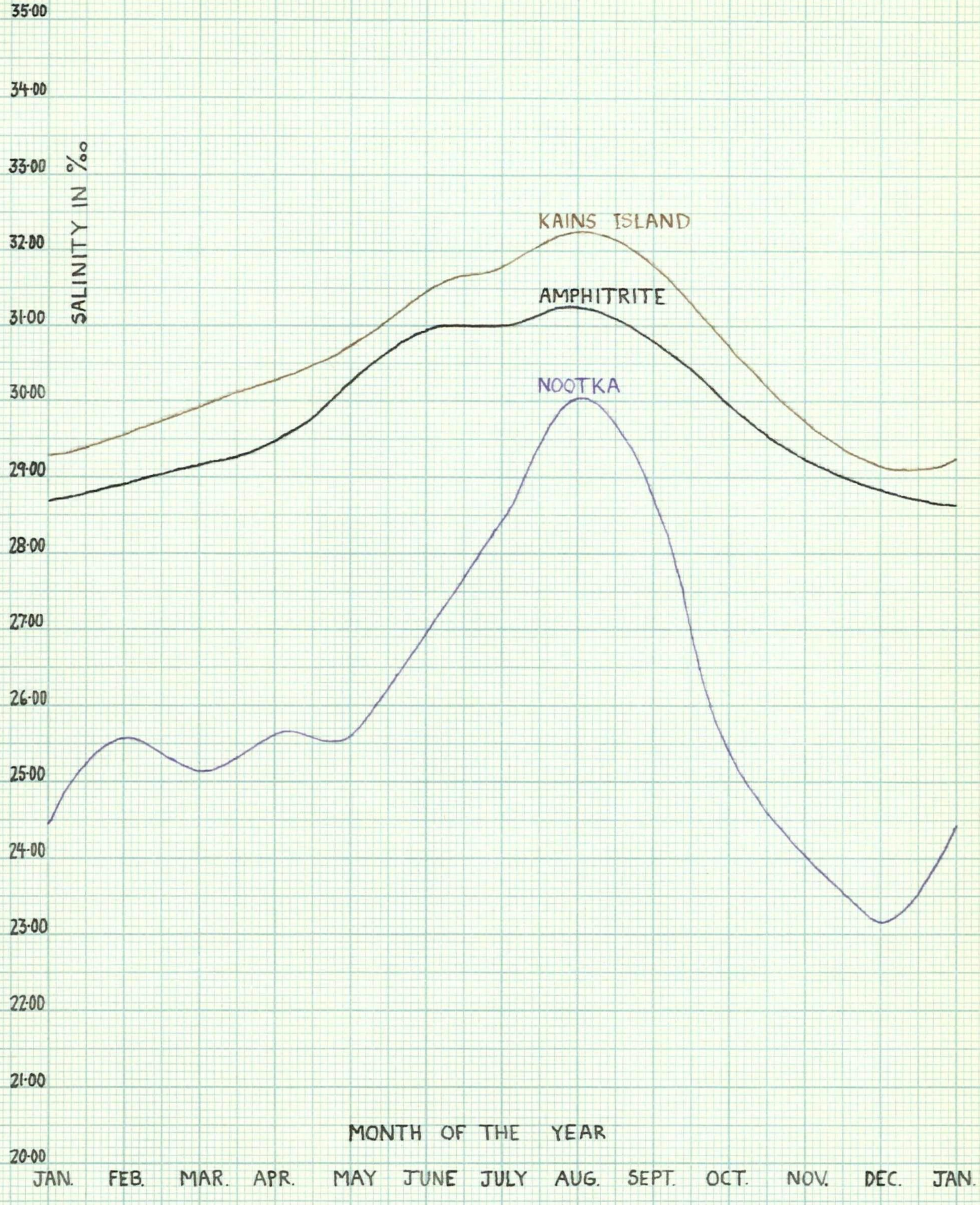
X THE STATIONS AT WHICH SALINITY INCREASES TO A MAXIMUM DURING THE SUMMER MONTHS

It is notable that those stations at which there is an increase in salinity during the summer months (Fig.15) are the stations on the West Coast of Vancouver Island. To verify the significance of the salinity curves the standard deviation $\left(\sigma/\sqrt{n}\right)$ of the grand monthly means have been calculated for Amphitrite. This treatment is similar to that discussed in section II with temperature, and the quantity σ is again the 'unbiassed' standard deviation $\sigma = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$ where X now represents monthly mean surface salinity and n is the number of years during which the data has been treated. Calculations yield the following values of $\sigma/\sqrt{n}$ for Amphitrite.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
.21	.23	.20	.26	.23	.26	.25	.13	.22	.22	.33	.18

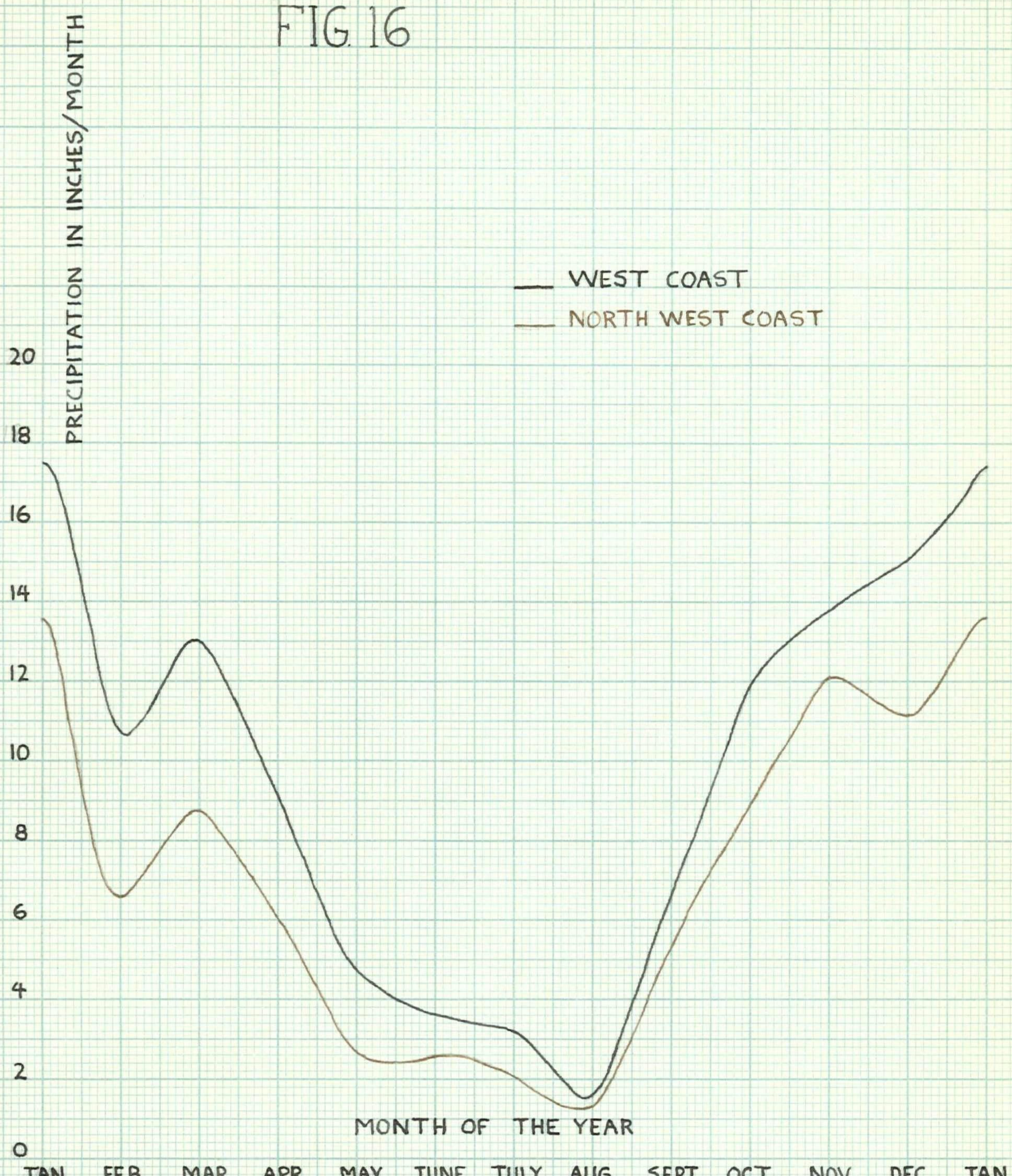
Since the annual range of salinity at Amphitrite is 2.5 $^{o}/_{oo}$ the above values for $\sigma/\sqrt{n}$ indicate that the change from winter to summer is significant. As the standard deviations for the other stations are similar to those at Amphitrite their annual changes may also be considered significant.

FIG. 15



AVERAGE ANNUAL VARIATION OF SALINITY AT THE STATIONS WHICH SHOW A PEAK SALINITY DURING THE SUMMER MONTHS.

FIG 16



AVERAGE ANNUAL VARIATION IN PRECIPITATION ON THE WEST COAST OF VANCOUVER ISLAND DURING THE YEARS 1941, 2, 4, 5 AND 6.

The character of the salinity curves (Fig. 15) is attributed to annual variation in precipitation and the upwelling process which was previously discussed (Sec. III). Precipitation here includes both that which falls directly on the sea and that which falls on the land and then runs off the land into the sea. The latter is referred to in the following discussion as 'runoff'. The precipitation (Fig.16) varies from 15 inches per month during the winter to a minimum of 2 or 3 inches per month during the summer. Evidence would indicate that along the West Coast the time lag between precipitation falling on land and the resultant runoff is small. Therefore the runoff is expected to follow approximately the same form of annual variation as precipitation and substantiates the importance of precipitation in determining annual variation in salinity.

To examine the importance of precipitation in controlling the salinity on the West coast correlation coefficients have again been calculated. The correlation coefficient has been used to determine whether in a particular period when monthly mean precipitation deviated from the grand monthly mean the corresponding salinity showed an inverse deviation. The values obtained are shown in Table 8.

These values are in general high indicating correlation although there are several anomalies present. Precipitation during preceding months would affect a monthly mean

TABLE VIII

	Amphitrite	Nootka	Kains Island
January	- .01	- .98	- .88
February	- .65	- .80	- .79
March	- .08	- .35	- .17
April	- .98	- .94	- .99
May	- .77	- .02	- .09
June	- .91	- .75	- .66
July	- .49	- .85	- .53
August	- .09	- .09	- .30
September	- .63	- .52	- .96
October	- .92	- .75	- .70
November	- .53	- .82	- .34
December	- .62	- .83	- .87

Correlation coefficients between monthly mean precipitation on the West Coast of Vancouver Island and monthly mean salinity at the oceanographic stations on the West Coast during the years 1941, 2, 4, 5, and 6.

salinity to some extent but there are other factors which must be taken into consideration. The most important of these is upwelling which will be discussed later.

A comparison of the salinity curves and annual variation in precipitation indicates the possible existence of an inverse proportionality relation. Observed grand monthly mean values of salinity $^{o}/_{oo}$ at Amphitrite have been plotted against the corresponding values of precipitation (inches per month) in Fig. 17. The smoothed curve has been extrapolated so that when precipitation P = 0, salinity S = 31.70. A relation $P = \frac{K}{S} - C$ has been assumed where K and C are constants to be evaluated. Calculations from the observed values of P and S indicate an average value of K = 4620 and $C = -\frac{K}{31.70} = -146.$

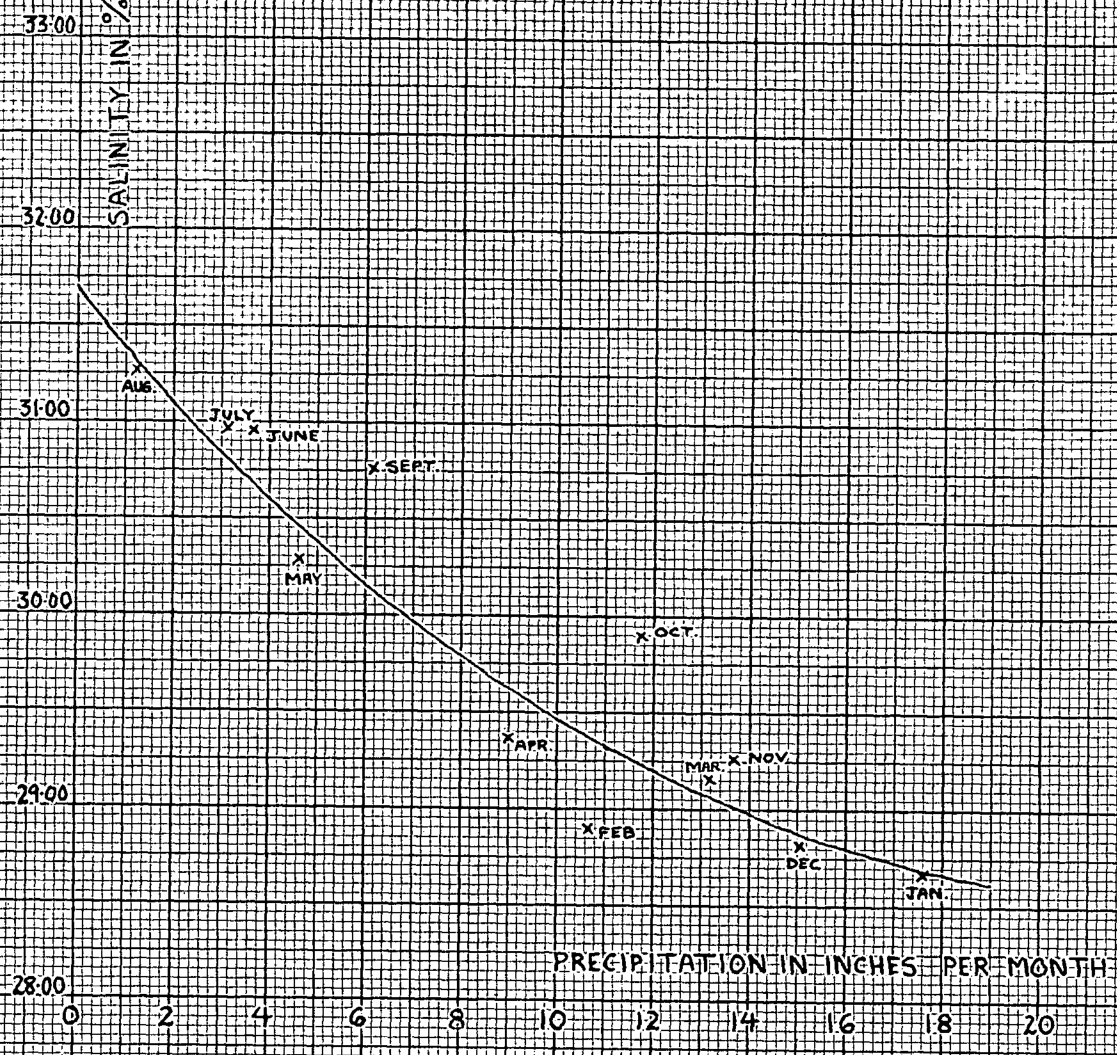
Then $S = \frac{4620}{P - 146}$ S in $o/_{oo}$
P in inches/month

Calculations of salinity from the observed monthly mean precipitation along the West coast using this idealized representation in which precipitation alone is assumed to control salinity results in a salinity curve for Amphitrite as illustrated by the dotted line in Fig. 18.

Objections to this idealized treatment are:

1. It neglects the effect of upwelling of more saline water during the summer due to horizontal wind stress.
2. It neglects the effect of evaporation in increasing salinity.

FIG 17



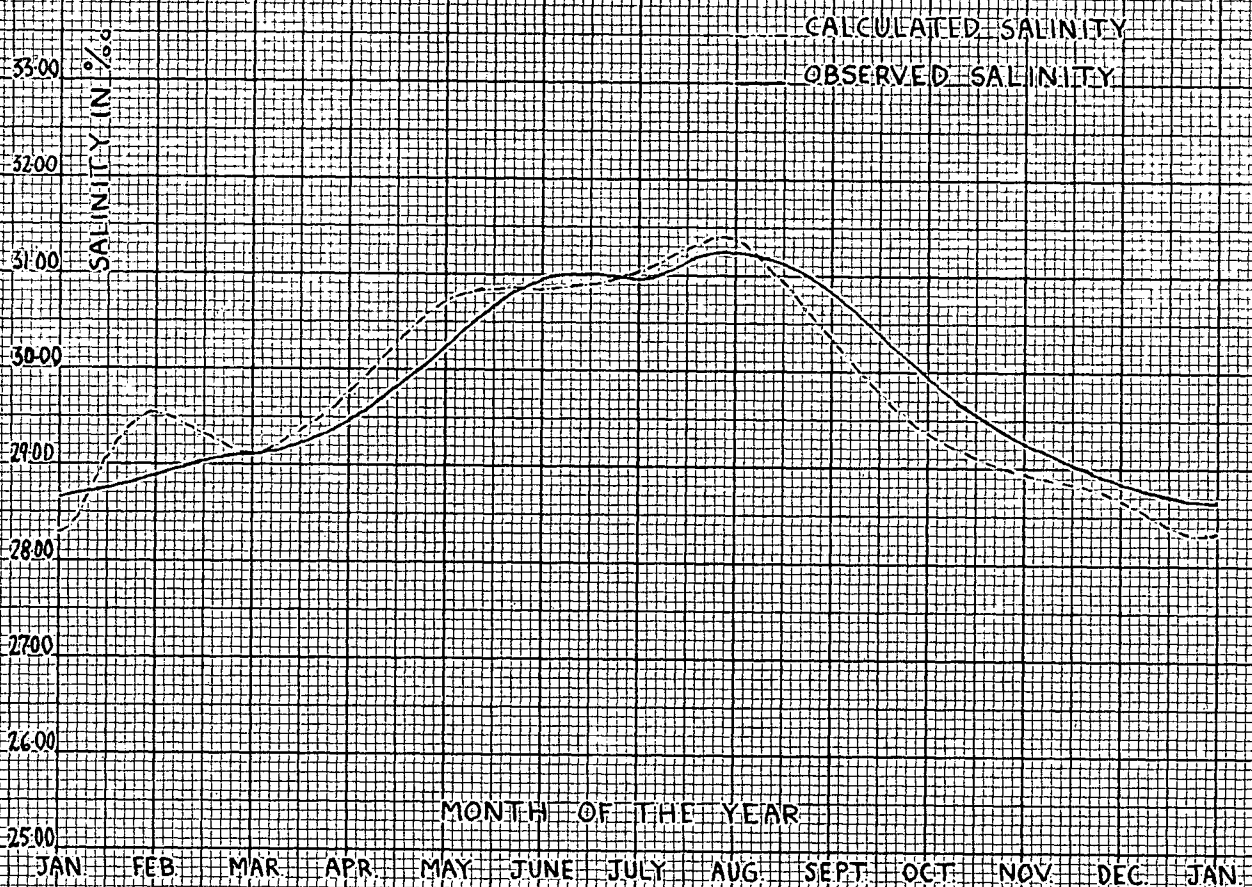
A RELATION BETWEEN GRAND MONTHLY MEAN SALINITY AT AMPHITRITE AND GRAND MONTHLY MEAN PRECIPITATION ON THE WEST COAST OF VANCOUVER ISLAND.

3. It neglects the effect of precipitation during preceding months on monthly mean salinity.
4. There may be an appreciable time lag between precipitation and runoff in certain cases and the justification of treating runoff as coincident with precipitation is then questionable.
5. The assumption that average precipitation as observed along the West coast is representative of a particular locality is questionable.

The neglect of evaporation seems justified to a first approximation. Values of energy used for evaporation in the Eastern North Pacific (Jacobs; 1942) give an average value of 77 gram calories per square centimeter per day at 50° N. lat. which would produce an average evaporation of 1.6 inches per month. This will be balanced by precipitation in the summer when precipitation is at an annual minimum and throughout the rest of the year will be small in comparison with precipitation.

Upwelling as previously explained (Sec. III) can only occur when the prevailing wind direction is north west, i.e. from May to September as shown in Fig. 19. Fig. 17 shows the salinity curves for Amphitrite and Kains Island to be increasing significantly before the period in which upwelling can be expected to occur and supports the importance of precipitation in controlling salinity. However as the maximum rate of increase of observed salinity has a time lag of approximately

FIG. 18



A COMPARISON OF THE OBSERVED ANNUAL VARIATION OF SALINITY AT AMPHITRITE AND A CALCULATED SALINITY CURVE ASSUMING SALINITY TO BE INVERSELY PROPORTIONAL TO PRECIPITATION.

two weeks behind the calculated values (Fig. 18), this would indicate that upwelling must be considered.

The salinity curve for Kains Island is of the same form as that for Amphitrite and the mechanisms involved in controlling salinity are regarded as similar. In general, salinity is slightly higher throughout the year at Kains Island. This is attributed to a lower precipitation on the north west coast, as shown in Fig. 16.

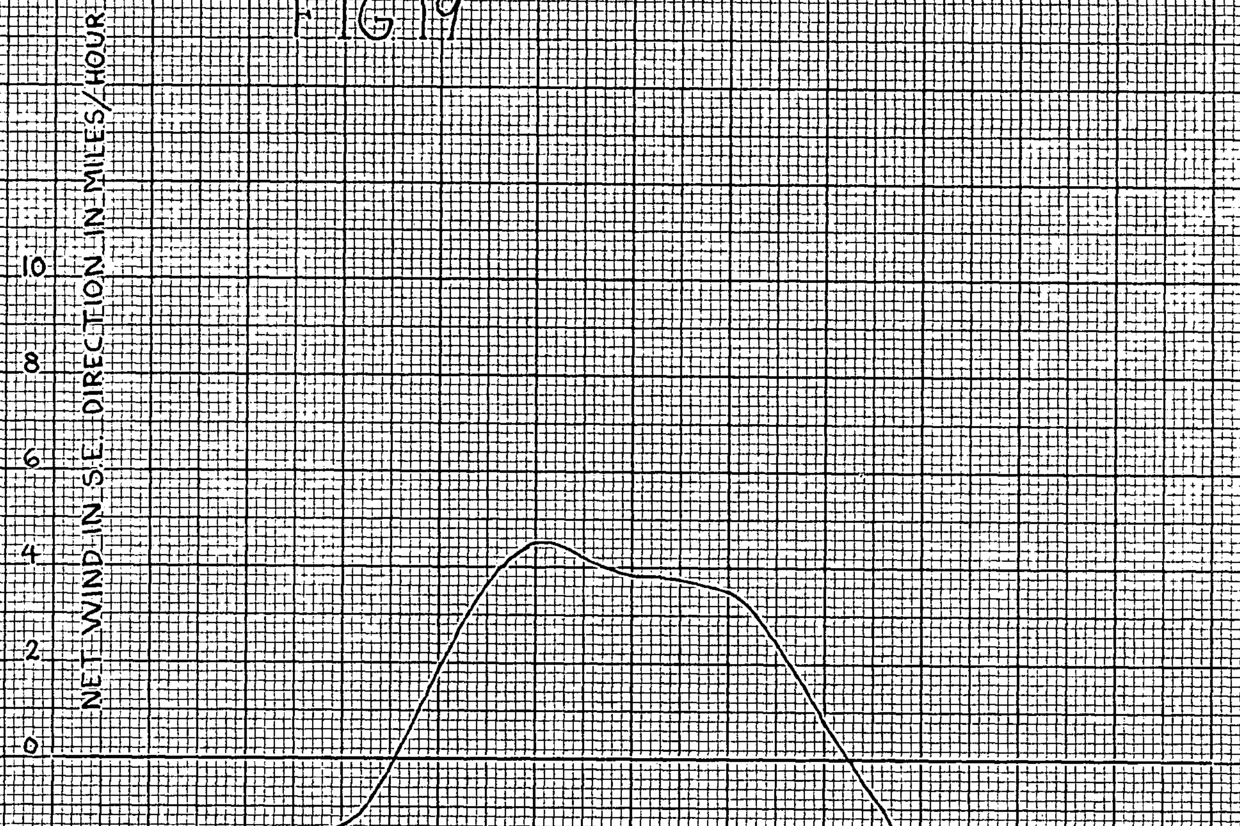
Reference to Fig. 15 shows the salinity at Nootka to be lower than that at Amphitrite and Kains Island throughout the entire year although the annual range is greater. The more sheltered location of Nootka would prevent fresh water runoff from being dissipated from the surface through mixing processes to the same extent as at Amphitrite and Kains Island. Consequently during the winter when precipitation is heavy the surface salinity would be expected to be lower as is observed from the salinity curves.

If it is assumed that at Nootka an inverse proportionality relationship exists similar to that at Amphitrite an empirical relation

$$S = \frac{2210}{P - 76.3} \qquad \begin{array}{l} S \text{ in } {}^{0}/_{00} \\ P \text{ in inches/month} \end{array}$$

is derived from the observations. Calculation here results in a salinity curve described by the dotted line in Fig. 20. This curve shows obvious discrepancies from the observed salinity. The most apparent disagreement is in the rate of increase of

FIG 19

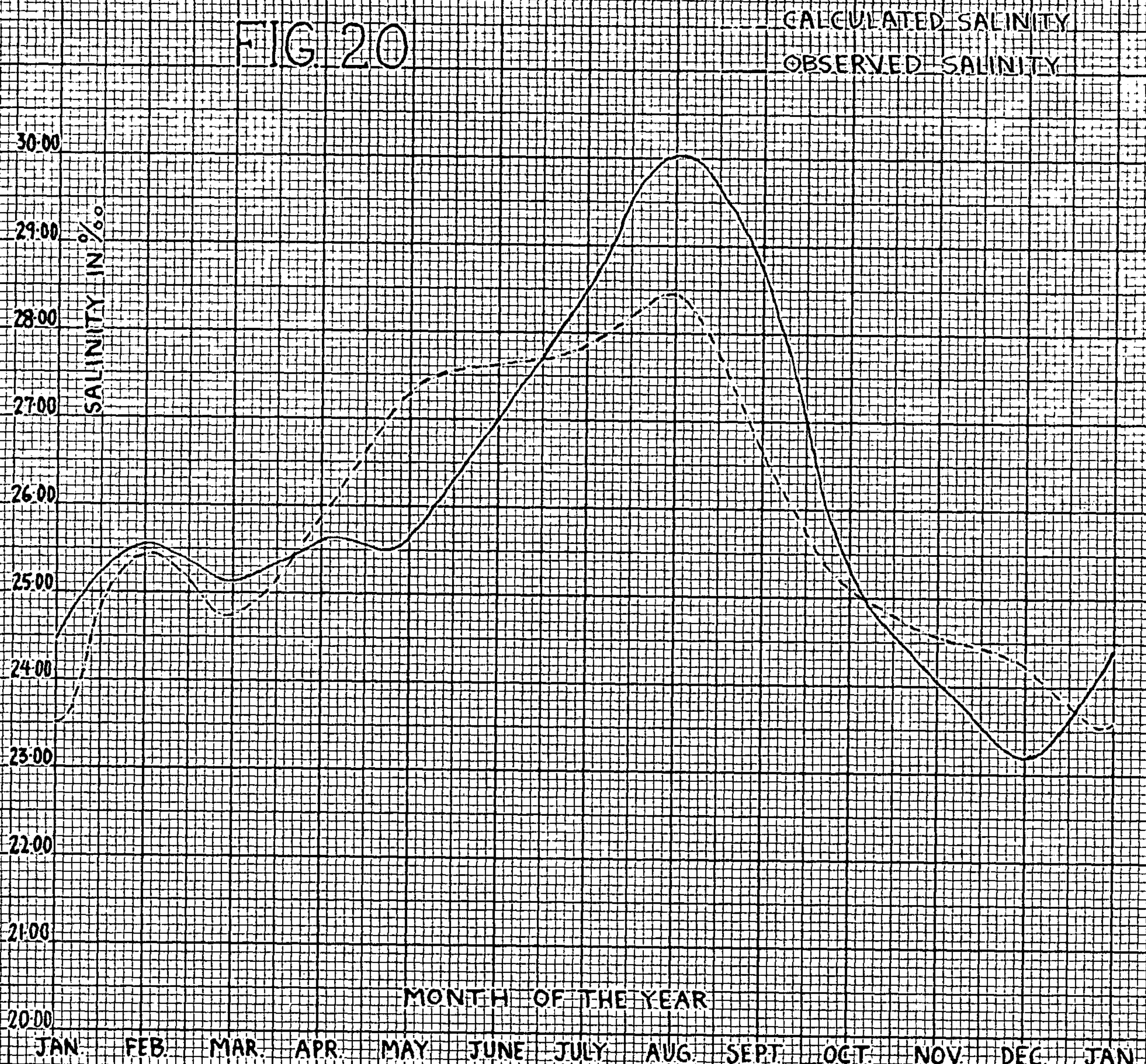


ANNUAL VARIATION IN AVERAGE NET EFFECTIVE WIND VELOCITY PARALLEL TO THE WEST COAST OF VANCOUVER ISLAND FROM OBSERVATIONS ON THE WEST COAST DURING 1941, 2, 4, 5 AND 6.

salinity between May and August. The observed increase is much greater than that predicted by a decrease in precipitation alone. In the case of Nootka station the mean air temperature is always less than that of the sea (Fig. 11) and, although relative humidity is high, evaporation may become important during the summer when precipitation is low. Upwelling may further contribute to this increase although because of the sheltered location of Nootka (Fig. 4) and its protection from north west winds it is probable that evaporation may be of more consequence than upwelling in contributing to an increase in salinity.

In a further attempt to determine the importance of upwelling, correlation between wind and salinity has been determined from May to September when the prevailing wind in north west. Coefficients have been calculated between the monthly mean wind velocity component in the north west direction (Monthly Records of the Department of Transport, Meteorological Division) and monthly mean salinity for the years 1941, 2, 4, 5, and 6. Values of the correlation coefficients are shown in Table 9. These indicate a correlation during May, June and July although the lack of correlation during August and September seems surprising. Fig. 21 shows the effective wind velocity component to be relatively small in September although comparatively high in August. However the deviations from the mean salinity curve become small in August and this may have

FIG. 20



A COMPARISON OF THE OBSERVED ANNUAL VARIATION OF SALINITY AT NOOTKA AND A CALCULATED SALINITY CURVE ASSUMING SALINITY TO BE INVERSELY PROPORTIONAL TO PRECIPITATION.

TABLE IX

	Amphitrite	Nootka	Kains Island
May	.36	.34	.87
June	.90	.95	.86
July	.73	.30	.64
August	-.75	-.47	-.10
September	-.46	-.21	.19

Correlation coefficients between monthly total wind mileage in north west direction on the West coast of Vancouver Island and monthly mean salinity at the oceanographic stations on the West coast during the years 1941, 2,4,5, and 6.

obscured correlation.

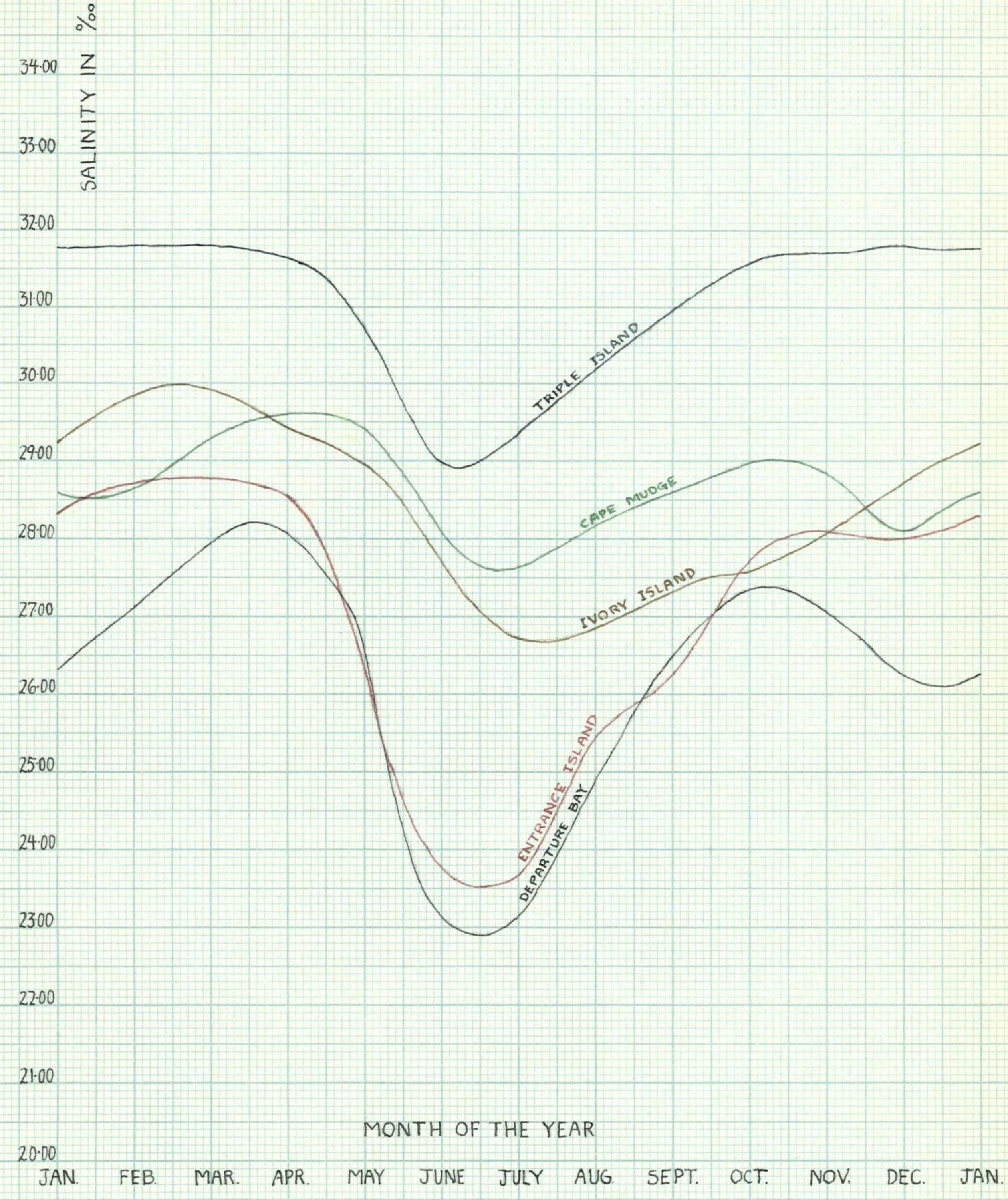
In summarizing the factors controlling annual variation of salinity here it is concluded that variation in precipitation and upwelling are both important. Because they are acting approximately coincidentally it is difficult to obtain an estimate of their relative orders of importance in controlling the observed increase of salinity to its summer maximum. Evidence indicates no appreciable time lag between precipitation and runoff here and the runoff has been regarded as varying in the same manner as the precipitation observations (Fig. 16). However the runoff may be of greater importance than precipitation falling directly on the sea in influencing salinity at the West coast stations. At present there is no data available on fresh water runoff to obtain a quantitative comparison of precipitation on sea water and runoff and determine this.

XI THE STATIONS AT WHICH SALINITY DECREASES TO A MINIMUM DURING SUMMER

The stations at which there is a decrease in salinity during the summer months are situated along the coastline, comparatively close to the mainland. Fig. 21 shows the annual variation of grand monthly mean salinity at these stations. Precipitation on the sea and evaporation, having opposing influences on salinity could not be expected to account for the observed large annual range in salinity. It must be therefore assumed that the sharp decrease in surface salinity during the early summer is due to fresh water runoff from the mainland as it is at a maximum discharge rate during this period.

Evidence of the importance of fresh water discharge from the Fraser River is shown in the salinity curves for Entrance Island, Departure Bay and Cape Mudge (Fig. 21). The stations are all situated in Georgia Strait which acts as a catch basin for runoff from the Fraser River. During the winter the heavy precipitation is stored in the mountainous areas of interior British Columbia and in the spring and early summer when air temperatures become warmer is transported by

FIG. 21



AVERAGE ANNUAL VARIATION OF SALINITY AT THE STATIONS WHICH SHOW A MINIMUM SALINITY DURING THE SUMMER MONTHS.

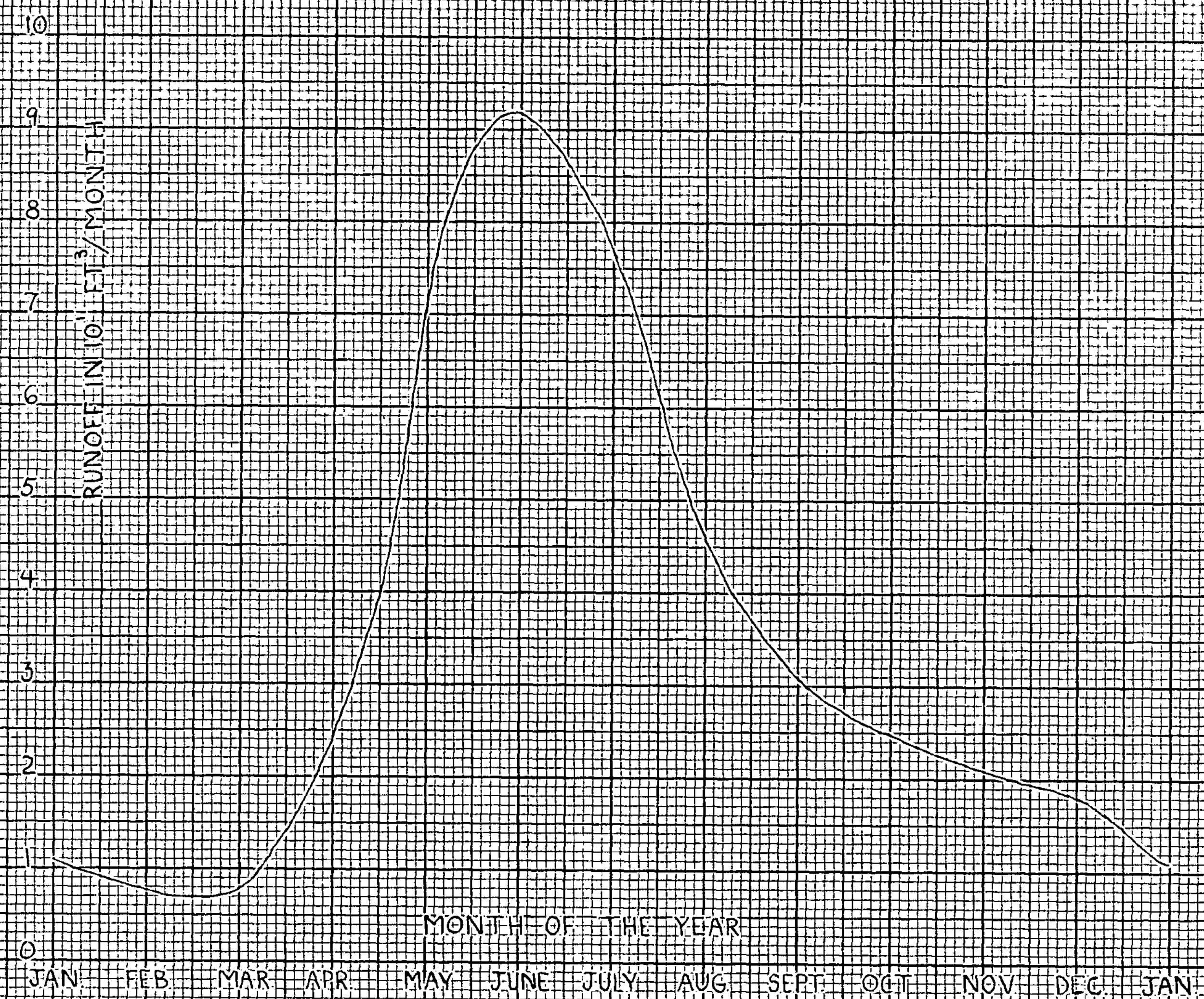
the Fraser River into Georgia Strait.

Fig. 22 illustrates the average annual variation of this Fraser River runoff from observations made at Hope, B.C. from 1935 - 41 with corrections applied as recommended by the Water Resources Division of the Department of Resources and Development in order that the data be applicable to discharge into Georgia Strait. The discharge is seen to increase from a minimum of approximately 0.7 X 10" cubic feet per month in March to a maximum of 9.2 X 10" cubic feet per month in June; an increase of 13 times the March minimum.

A comparison of the salinity curves of Fig. 23 and the annual variation of Fraser River runoff in Fig. 22 indicates a time lag of approximately 25 days between the peak discharge rate of the Fraser River and the corresponding minimum salinities at Entrance Island and Departure Bay. Similarly the time lag at Cape Mudge is approximately 30 days. Examination of the records for the individual years supports these values although the daily observations are subject to anomalies due to precipitation, evaporation and mixing processes and tend to obscure a definite value of time lag. However the time lag appears to vary over a considerable range from year to year.

It is interesting that the time lag at Cape Mudge is only 30 days in comparison to 25 days at Entrance Island (and Departure Bay) when it is noted that the distance from

FIG. 22



ANNUAL VARIATION IN FRESH WATER RUNOFF FROM THE FRASER RIVER, FROM OBSERVATIONS AT HOPE B.C. (1935-41), WITH CORRECTIONS, TO APPLY TO THE DISCHARGE INTO GEORGIA STRAIT.

Sandheads Lightship at the mouth of the Fraser River to Cape Mudge is 90 nautical miles as compared with 20 nautical miles to Entrance Island. The apparent inconsistency is attributed to the influence of the runoff of the preceding months on the minimum salinity observed. A comparison of the time at which the runoff (Fig.22) first starts to rise significantly and the corresponding time when each of the oceanographic stations first shows a significant decrease in salinity should be more consistent with the dynamics of Georgia Strait because runoff during preceding months may be disregarded. The time lags observed in this manner are 17 days to Entrance Island, 25 days to Departure Bay and 48 days to Cape Mudge. The ratio of the linear distances from the mouth of the Fraser River to Entrance Island and Cape Mudge is 1 to 4.5 and the ratio of the corresponding time lags is 1 to 3. Recent oceanographic surveys have indicated the existence of a prevailing anti clockwise circulation in Georgia Strait but it is not known that this circulation acts as far north as Cape Mudge. However horizontal mixing must be considered and it must be remembered that it is not yet definitely established that it is Fraser River water that influences salinity at Cape Mudge.

The fresh water from the Fraser River on reaching Georgia Strait will be dissipated from the surface through mixing processes, the dissipation increasing with distance from the river. Therefore assuming Cape Mudge to be influenced by Fraser River water it is to be expected that the annual range in salinity will be considerably less at Cape Mudge than at Entrance Island and Departure Bay. The salinity curves verify this, showing an average annual range of 2.00‰ at Cape Mudge as compared with 5.20‰ and 5.10‰ at Entrance Island and Departure Bay respectively.

The location of Triple Island (Fig.1) is such that its surface salinity will be influenced by variation in the fresh water discharge of the Nass and Skeena Rivers which are of the same phase as that of the Fraser River (Fig.22). Its salinity curve illustrates this influence and shows an average annual range of 2.80‰ with a minimum of 28.95‰ in June.

Ivory Island, while not located near any large rivers is close to the mainland and at a latitude where precipitation is observed to be particularly heavy. It is suggested that the collective runoff of the area causes the observed decrease in salinity to a summer minimum here.

XII THE STATIONS AT WHICH SALINITY REMAINS CONSTANT THROUGHOUT THE YEAR

The remaining stations show no marked annual variation in salinity. The locations of Cape St. James, Langara Island and Pine Island are such that there are no major influences to cause an annual variation in salinity and they are only subject to small, short term fluctuations due to precipitation, evaporation and wind induced mixing. In the case of Race Rocks one might expect the Fraser River to influence surface salinity but as previously discussed the intense mixing of the area probably reduces the effect.

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