

**FISHERIES RESEARCH BOARD  
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MANUSCRIPT REPORTS OF THE BIOLOGICAL STATIONS

No.

476

Title

Oceanographic Studies off the Canadian Pacific Coast, 1951

Author

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1952

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MANUSCRIPT REPORTS OF THE BIOLOGICAL STATIONS

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Geographic Names of the Canadian Pacific Coast, 1911

Author

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1952

PACIFIC OCEANOGRAPHIC GROUP

Nanaimo, B.C.

OCEANOGRAPHIC STUDIES OFF THE CANADIAN PACIFIC COAST, 1951.

by

L.A.E. Doe

P.O.G. File: N 7-20-2  
August 1, 1952.

## Foreword

The following is a brief report introduced by Dr. J.L. Hart, F.R.S.C., to the annual meeting of the Royal Society of Canada at Montreal in June 1952. It represents a partial synopsis of the results of recent oceanographic investigations off the Pacific Coast of Canada by the Pacific Oceanographic Group.

A more complete presentation of this research is in preparation at present (August, 1952) and will shortly be presented for publication by the Fisheries Research Board of Canada.

Oceanographic Studies off the Canadian Pacific Coast, 1951

by

L.A.E. Doe

In 1950 the Pacific Oceanographic Group undertook an exploratory investigation of physical oceanographic conditions in the Pacific Ocean within some 300 to 650 miles west of the Canadian Coast. To date four surveys have been completed, in August 1950, May 1951, August 1951, and March 1952, comprising serial observation of salinity and temperature to depths variously of 900, 1000, and 1200 metres on the several cruises.

This presentation deals with the observations from two of these surveys, carried out in May and August of 1951.

Properties of the water

(a) Layer structure

The temperature-salinity curves of the area tend to consist of three segments corresponding to three principal layers of water properties. (figure 1). The top segment represents what we shall call the "upper" layer, which is some 100 metres in depth, and of relatively constant salinity. This is interpreted as the layer which is completely mixed by winter storms, a supposition which is supported by the observation that in March 1952 it was in general both isosaline and isothermal. The seasonal thermocline in summer occurs entirely in this layer.

Between the upper layer and a depth of some 150 metres is the salicline, corresponding to the second or horizontal segment of the T-S curve. This is the layer of permanent stability maximum, below the

influence of seasonal change, which effects continuity between the relatively fresh upper layer and the saline deep layer.

Beneath the salicline, and extending to the maximum depth sampled, is the deep layer, corresponding to the bottom segment of the T-S curve. In this layer both salinity and density ( $\sigma_t$ ) appear to vary linearly with the logarithm of depth to a very close approximation (figure 2). This relation in the case of salinity has been recorded by Tully (MS, 1949) who is at present preparing a more comprehensive treatment of the occurrence of logarithmic gradients in the sea. A similar relation has been observed in the case of temperature beneath the thermocline and is mentioned by Pattullo in a recent Progress Report of the Scripps Institution of Oceanography (1951). In the present case the linear variation of temperature with the logarithm of depth in the deep layer appears only slightly less consistent than that of salinity and  $\sigma_t$ .

In August (figure 3) the T-S curves were similar to those in May in most respects except for the elongation of the top segments, corresponding to the growth of the seasonal thermocline. There was also somewhat more vertical salinity variation in the upper layer, due to the relative advection of lower salinity surface water. Such stratification would be expected to be less apparent in the earlier season owing to more recent wind mixing and the less pronounced development of thermal stability.

(b) Regions

In Figures 1 and 3 broken lines have been drawn approximately parallel to the Coast, separating the area into two regions. In the west region the upper layer was characterized by a salinity of approximately 32.50‰...

and relatively little vertical gradient. In the east region the salinity of the upper layer was less constant, being less than  $32.50\text{‰}$  at the surface and having a greater vertical gradient.

In the deep layer, the T-S curves of the west region were of relatively constant shape and passed through or close to the point  $T = 4.00^{\circ}\text{C}$ ,  $S = 34.00\text{‰}$ . In the east there was a progressive displacement of the curves upwards, and to the right with distance shoreward, corresponding to a downwards inclination of the isotherms relative to the isosalines.

In two additional regions along the western edge of the area, the T-S curves indicate properties which do not fit well into the pattern of either east or west region: 1. At stations E7 - E9, May, and E1 - E2, August, the temperature at the top of the deep zone was of the order of a degree lower than at the adjacent stations on both lines E and G, resulting in a marked "flattening" of the T-S curve of the deep layer. 2. At the southwest corner, at stations A12 - A16 and B1, May, and A1 - A5, B2, August, the upper zone was more saline than the west region. These two regions suggest that the western extremity of the area borders on the "Sub-Aleutian" water observed by Goodman and Thompson on their line of stations from Dutch Harbour to Juan de Fuca Strait in 1935. (Goodman and Thompson, 1940).

(c) Surface Temperatures

In May (figure 4) the surface water was warmest at the coast and became progressively colder to the westward. In the vicinity of the boundary between east and west regions there was a change of temperature of the order of half a degree, decreasing to the westward, but this does not

appear to have been definitive of the two regions. Water immediately west of Vancouver Island was warmer than that found elsewhere.

In August surface temperatures were coldest immediately adjacent to the coast, with a sharply rising gradient to seaward. A broad band of maximum temperature with negligible east-west gradient covered the east region and part of the west region. Beyond this, temperatures tended to drop very slightly to the westward. The principal gradient was the gradual decrease from 16°-16.5° on line A at the south to 13.5°-14° on line G at the north end of the area. Surface temperatures do not appear to have been definitive of regions or water-masses, except for the region of cold water immediately adjacent to the coast, attributed to upwelling.

#### Dynamic Topography and Gradient Currents

Owing to the location of the area in relation to the path of the west wind current as it approaches the coast of North America, it is possible that the conditions for the assumption of gradient flow are not fulfilled. Furthermore, an appreciable horizontal gradient of density ( $\sigma_t$ ) was observed at 900 metres, which strongly suggests motion at this depth. It is probable, however, that the calculation of dynamic heights of the sea surface, assuming that the 900-decibar surface is level, will give an indication of at least the principal direction of flow and the order of magnitude of the current speeds.

The dynamic topographies of the sea surface relative to 900 decibars illustrated in Figures 6 (May) and 7 (August) indicate a predominantly northward flow, with maximum velocities of the order of 10 to 15 cm. per second (0.2 to 0.3 knots) and mean velocities considerably smaller.

Calculated gradients at successively deeper surfaces indicate that the speed decreased with depth and at 300 metres was approximately one half that at the surface. The fact that the contours of dynamic height cross the division between east and west regions suggests, however, either that the flow was not normal to the calculated gradients, or that mixing was occurring without friction or acceleration. Since the latter is improbable, it follows that the calculated contours are not a precise indication of current trajectory in this case.

#### Isentropic Analysis

The method of isentropic analysis, due primarily to Rossby, (1936, 1937) has the advantage that it does not necessarily assume gradient flow. Temperatures have been plotted on a series of  $\sigma_t$  surfaces for each cruise. Figures 8, 9, and 10 respectively depict a typical surface chosen from each of the three layers in August.

The conclusions drawn from this method of analysis may be summarized as follows:

- (a) The over-all pattern of circulation was very similar in the two periods.
- (b) Most of the contours traversed the area from south to north, and the surfaces generally sloped upwards to the west, suggesting that the predominant directions of flow was northward.
- (c) In the upper and salicline layers there was evidence also of -
  - (1) a movement from the westward, turning towards the north;
  - (2) a warm tongue intruding from the southwest;
  - (3) a southward movement of colderwater just west of the Queen Charlotte Islands.

- (d) In the deep layer the predominant movement appears to have been to the northward. The water was warmest near the coast.

#### Summary and Conclusions

The T-S diagrams of Figures 1 and 3 show that the water of this area is part of the sub-arctic water mass designated by Sverdrup, Johnson and Fleming (1942) as occupying the northeastern portion of the Pacific Ocean. These curves show strong similarity to those observed by Goodman and Thompson in this area, and somewhat less similarity to some of those reproduced in "The Oceans" (Sverdrup et al, 1942) for the Bushnell stations of 1934 between the Aleutians and Hawaii.

The properties of the water indicate the existence of three principal layers. The upper layer seems to represent the maximum depth of mixing in the annual cycle of weather. It is vertically homogeneous in winter, and stratified primarily by temperature in summer. The deep layer is marked by characteristic logarithmic gradients and is separated from the upper layer by a highly stable salicline.

In 1951 there were two principal regions distinguished by a change in salinity of the upper layer and by a change of horizontal gradients in the deep layer. Surface temperatures generally decreased to the west in May, and to the North in August.

The principal direction of flow was northward, with some evidence of a convergence of drifts from the south and the west. Velocities in general were small, and decreased with depth, representing mean transports of the order of two miles per day at the surface. In such a system considerable variability in the pattern of flow is expected.

The area of investigation was apparently located to the north of the median line of advance of the west wind drift as it approached the coast of America. The water moving to the northward probably represented the left branch of the west wind drift when it divided at the coast to form the Alaska Gyral and the California Current.

## References

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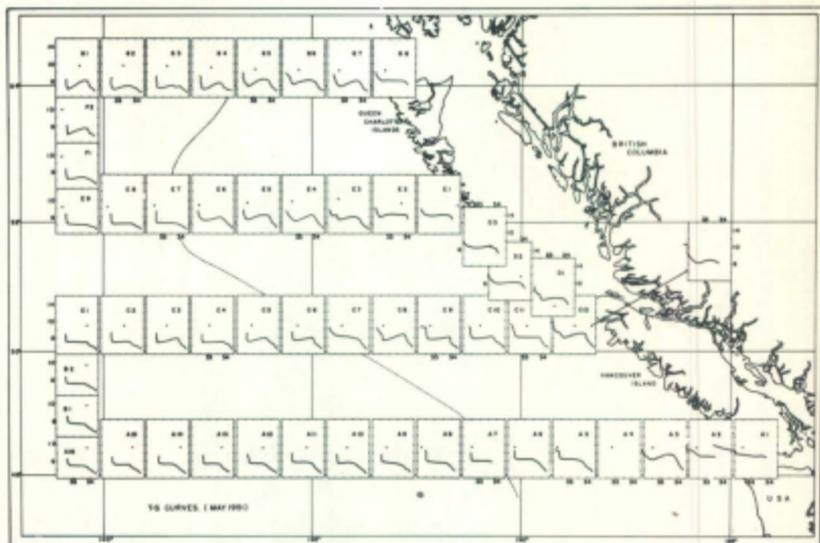


Figure 1.

Temperature - salinity curves,  
cruise 1-51, May 1951.

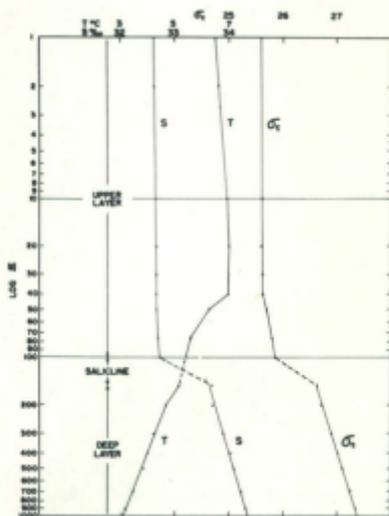


Figure 2.

Graphs of S, T, and  $\sigma_t$  with the logarithm of depth in metres at station A 15, May 1951. Note the linear relations in the deep layer.

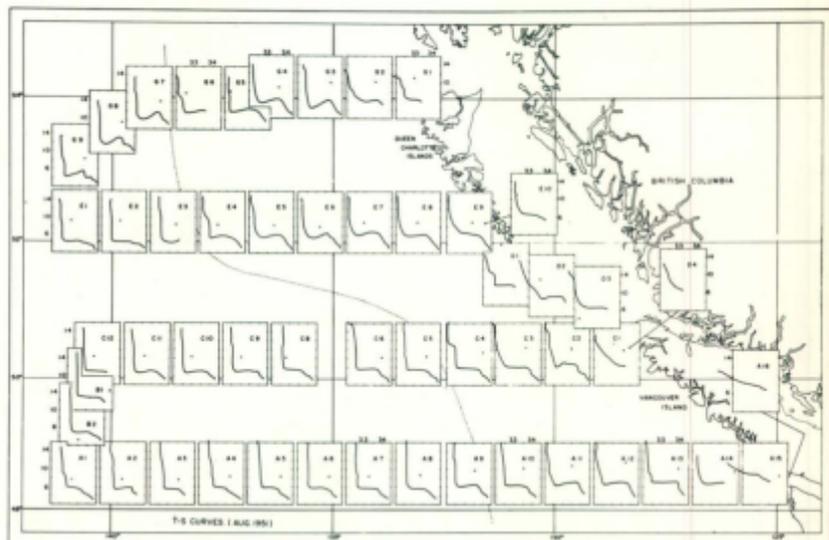


Figure 3.

Temperature - salinity curves,  
cruise 2 -51, August 1951.



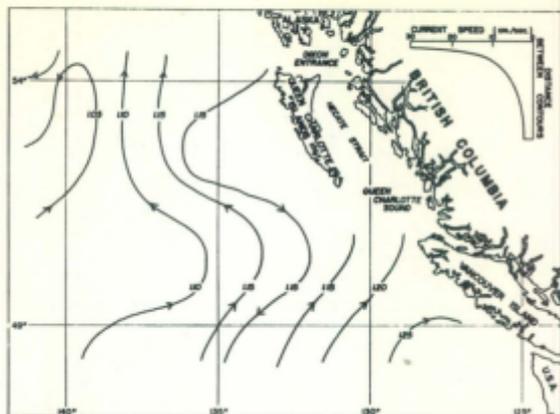


Figure 6.

Dynamic height anomalies of sea surface  
relative to 900 decibars, May 1951.  
Contour interval: 0.05 dynamic metres.

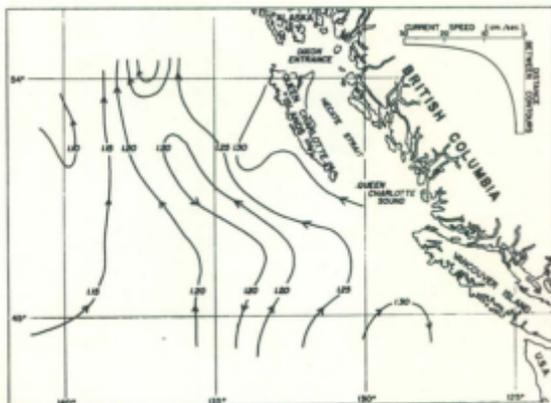


Figure 7.

Dynamic height anomalies of sea surface  
relative to 900 decibars, August 1951.  
Contour interval: 0.05 dynamic metres.

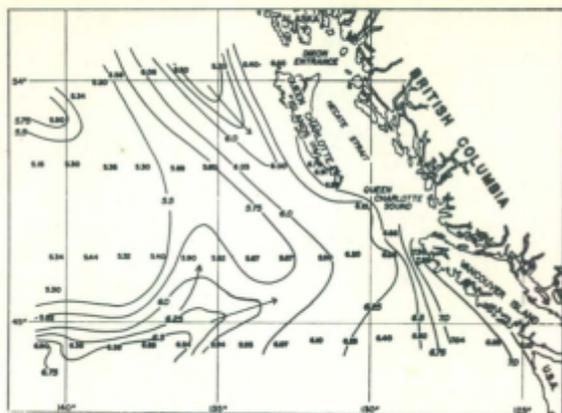


Figure 8.

Temperatures at  $\sigma_t = 25.75$ , August  
1951. Depth Range: 37 - 130 m.

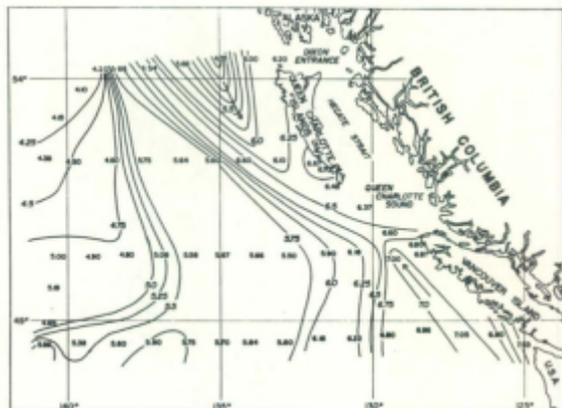


Figure 9.

Temperatures at  $\sigma_t = 26.0$ , August  
1951. Depth Range: 44 - 150 m.



