

Canadian Joint Committee on Oceanography



Annual Reports of the Oceanographic Groups  
for  
1955-56

St. Andrews, N. B.  
April 3rd, 1956.

## FOREWORD

The annual report of the Chief Oceanographer for the year 1955, was distributed as of December 5th, 1955. This reported in general terms on the activities under the Joint Committee on Oceanography.

Herewith are the annual reports of the Oceanographers-in-Charge of the Atlantic and Pacific Oceanographic Groups. These reports deal in some detail with the results of the projects carried forward during the fiscal year 1955-56, and supplement the report of the Chief Oceanographer.

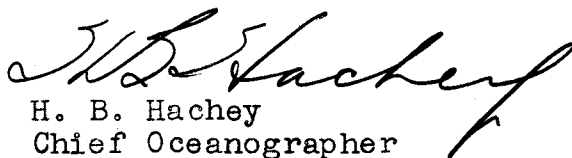
These reports are under the following authorships:

Atlantic Oceanographic Group - H. J. McLellan,

Oceanographer-in-Charge

Pacific Oceanographic Group - J. P. Tully,

Oceanographer-in-Charge.

  
H. B. Hachey  
Chief Oceanographer

St. Andrews, N. B.  
April 3rd, 1956.

## Annual Report

### Atlantic Oceanographic Group

#### Introduction

1. The Atlantic Oceanographic Group, under the Canadian Joint Committee on Oceanography, is responsible for the furthering of oceanographic activities related to the waters contiguous to the Atlantic and Arctic coasts of Canada.

2. The program of oceanographic investigations carried out by the Group is designed to meet the immediate and long term requirements of the Fisheries Research Board of Canada and of the Royal Canadian Navy. Both organizations have need of a general knowledge of the physical and chemical properties of the waters and of the processes which maintain or modify these properties. Both have specific problems related to particular regions within the large area of interest. To fulfill these requirements, the program of studies is aimed at the creation of a file of recorded data from which the answers to most inquiries may be obtained, the detailed investigation of specified regions or problems, and the investigations of processes fundamental to the understanding of water conditions within the area.

3. The Group is a co-operative venture, the Royal Canadian Navy furnishing and equipping a research vessel and the Fisheries Research Board providing personnel, laboratory space and certain classes of equipment. While the Group carries out its own program of research, its aims can only be

met by stimulating interest within other organizations and by encouraging co-operation in the collection of oceanographic information. The eager co-operation of the Fisheries Research Board of Canada's Biological Stations at St. Andrews, N.B. and St. John's, Newfoundland, the Canadian Hydrographic Service, the Naval Research Establishment, the Quebec Marine Biological Station, and other organizations, materially assists towards the attainment of the oceanographic objectives. On an international basis, co-operation is maintained with the Woods Hole Oceanographic Institution and the U.S. Hydrographic Office, and there is an exchange of all data collected in waters of common interest.

#### Personnel

4. During the past year the staff of the Atlantic Oceanographic Group consisted of the following:

Mr. H. J. McLellan	Oceanographer-in-Charge (Senior Scientist)
Dr. L. Lauzier	Senior Scientist (Transferred from A.B.S. Oct. 1)
Dr. N. J. Campbell	Associate Scientist (Transferred from P.O.G. Apr. 1)
Mr. W. B. Bailey	Assistant Scientist
Dr. R. W. Trites	Assistant Scientist (Seconded to P.O.G. to <del>May</del> 1)
Mr. A. E. Collin	Assistant Scientist (From July 8)
Mr. J. G. Clark	Technician II

Mr. J. A. Sullivan	Technician I (on leave of absence from Sept. 19)
Mr. G. B. Taylor	Assistant Technician III
Mr. J. H. Hull	Assistant Technician III
Mr. N. A. Clarke	Assistant Technician III (Term from May 16)
Mr. C. C. Cunningham	Assistant Technician II
Mr. A. W. Holt	Assistant Technician II (From Nov. 1 to Mar. 31)
Mrs. M. M. Irwin	Stenographer 2B
Professor D. G. MacGregor	Associate Scientist (Seasonal)
Mr. R. D. Graham	Student Assistant (Seasonal)
Mr. L. A. Higgs	Student Assistant (Seasonal)
Mr. W. V. Carson	Technician I (From Jan. 30 1956 to Feb. 24, 1956)

5. Dr. Lauzier, who has worked closely with the Group for some years, was transferred from the staff of the Biological Station on October 1st.

6. Dr. Campbell joined the Group on April 1st and has taken charge of the Arctic investigations of the Group.

7. Dr. Trites, who had been on leave of absence while attending the University of British Columbia, completed the work for a Doctor's degree and returned on ~~May~~<sup>June</sup> 1st to resume his normal duties. Since October, he has been on loan to Naval Research Establishment, Dartmouth, N.S., a change in status which does not to any extent preclude his furthering oceanographic investigations of interest to the Group.

8. Mr. Collin came to the Group in July from graduate work in the Department of Geography at the University of Western Ontario. He has been assigned to work on the Arctic project.

#### General Program

9. The field program of the Group has again been extremely heavy. Since June 1955 seven cruises in two ships logged over 42,000 miles, occupying a total of 692 oceanographic stations and making 1800 BT observations. This required a total of 1180 man days at sea, an average of 84 days per man. This impressive total includes the northern cruise of H.M.C.S. "Labrador" which took a party of three to the field for close to a six months period.

10. The results of 20 surveys over the network on the Scotian Shelf are now available for the period 1950 to date. These surveys were undertaken on specific request of the fisheries biologists for environmental data on the area. Little but descriptive work has yet been carried out on the data. Dr. Trites has commenced a study of these data from the point of view of yielding information regarding circulation patterns, their seasonal and year to year variations, and heat budget parameters.

11. Dr. Lauzier has five papers in press describing features of the water masses in the Gulf of St. Lawrence. A second detailed survey of the estuary was completed in June

and observations were made in this region in December and February. These data are being studied with the aim of elucidating the dynamics of the formation of the Gaspe Current.

12. Two opportunities were afforded to occupy stations in the Strait of Belle Isle, once in early July while H.M.C.S. "Labrador" was enroute north and once in September when C.N.A.V. "Sackville" was surveying in Newfoundland waters. These are the first full scale surveys since the 1923 expedition and it will be of interest to make the comparison of water conditions in the two periods.

13. H.M.C.S. "Labrador" was restricted to operating in the Foxe Basin area in 1955 because of military commitments. In spite of these commitments, and due in a large part to the interest of the Commanding Officer in furthering the scientific program, an impressive program of observations was carried out in this hitherto little known area. A reasonably complete picture of these waters is being synthesized from the data. The occurrence of subsurface waters with temperatures depressed below their normal freezing point presents an extremely interesting problem.

14. Mr. Bailey has prepared a manuscript report on the results of the 1954 Arctic survey and has a paper in press on his observations of the deep water in Baffin Bay and the northern channels.

15. During September and October a survey was carried out in Newfoundland waters. The Strait of Belle Isle was covered as well as the 200 fathoms plateau north of the Grand Banks and the Grand Banks area itself.

16. An examination of data previously collected in Malpeque Bay, P.E.I. has been carried out in preparation for a full scale investigation of this estuary required in connection with oyster studies projected by the Biological Station, St. Andrews, N. B.

17. A major item in the program of the Group is the maintenance of a library of oceanographic data for the area. This is augmented by the addition of bathythermograph data from Canadian agencies, all of which are processed and card indexed in the St. Andrews Laboratories, by bathythermograph cards supplied on an exchange basis from United States agencies, and by filing on cards the results from hydrographic stations occupied by all agencies within the area of interest.

#### Associated Programs

18. A number of vessels operated by the Biological Station, St. Andrews, N. B. made bathythermograph observations in association with biological investigations. The Group will be involved in the processing of these data. In addition serial sampling of the water column in Northumberland Strait was carried out regularly in connection with lobster larvae

studies.

19. Six major vessels were involved in the summer program of the Canadian Hydrographic Service. These vessels make oceanographic observations on passage to and from survey areas. As in other years, a member of the Atlantic Oceanographic Group visited each ship before sailing to ascertain that they were completely prepared for the observations. The data and water samples are turned over to A.O.G. for processing at the completion of the season's work.

20. The Naval Research Establishment regularly makes a major contribution to the files of oceanographic data. During the year, the bathythermograph observations from a large number of cruises have been forwarded for processing as well as a quantity of water samples for titrating.

A bathythermograph is maintained on Sambro Lightship for twice daily observations and the plotted results made available to A.O.G. An arrangement is in operation which permits N.R.E. to make full use of all oceanographic data in the A.O.G. files. A close liaison is maintained and there is exchange of personnel, equipment and services as required from time to time.

21. There has been a marked increase in the number of bathythermograph observations taken by R.C.N. ships in the last year. Results from 15 cruises, a total of 559 BT slides, have been forwarded to A.O.G. for processing.

22. An opportunity was afforded to co-operate with the Dominion Observatory in an amphibious seismic survey of the Sable Island area and the southern Gulf of St. Lawrence. The research vessel C.N.A.V. "Sackville" acted as shot vessel and carried recorders and personnel. This was accomplished in conjunction with the summer survey by suitable adjustment in schedule.

23. Personnel from the Biological Station, St. Andrews, were carried on two seasonal surveys to make observations of fish eggs and larvae, and on the early autumn survey of Newfoundland waters personnel from the Biological Station, St. John's, Newfoundland, were carried and assisted with plankton studies.

#### Facilities

24. In January 1955 the Group was moved to new quarters provided by the modification of an existing building on the grounds of the Biological Station. The resulting increase in efficiency has been noticeable. Operations are still handicapped by the lack of suitable laboratory space for salinity titrations but this matter is being looked after in construction plans.

#### General Liaison

25. Liaison was maintained with all organizations having an interest in oceanographic problems of the Western North Atlantic.

26. All members of A.O.G. maintain some form of liaison with workers of the Biological Station, St. Andrews, N. B. The close association of the two organizations permits immediate discussion on matters of common interest. On a more formal basis, the responsibility for this liaison is assumed by Dr. L. Lauzier, who keeps well informed of the programs carried out by each organization, and advises on their possible interrelations.

27. International liaison is maintained by the Oceanographer-in-Charge. Copies of all BT records were supplied to the Woods Hole Oceanographic Institution and the U. S. Hydrographic Office and those organizations in return furnished copies of their records for the areas of common interest.

28. Surface water temperatures from St. Andrews, N.B. and Entry Island, Que. were supplied daily to the Meteorological Service of Canada.

29. Information was supplied on request to the Department of Mines & Technical Surveys on the potassium and magnesium content of the waters of the Atlantic Coast.

### Some General Results

30. Current measurements in Foxe Basin showed a marked residual current southward along the western shore which persisted from Fury and Hecla Strait to Evans Strait and a compensating northward flow along the eastern side, at least in the northern part. This is indicative of a regular cyclonic

circulation in the Basin.

31. Studies of conditions in the estuary of the St. Lawrence indicate that intense mixing is brought about by tidal oscillations at the head of the Laurentian Channel where waters from the Saguenay and the St. Lawrence are mixed with the more saline Gulf waters. This mixed water flows out of the area in what is probably the beginning of the Gaspé Current. Other rivers provide significant contributions to the circulation and probably also energy in the form of hydraulic head to maintain the Gaspé Current and other features of the circulation. Particularly significant are the Bersmis, Outardes and Manicouagan rivers.

32. A large part of the ice encountered in Foxe Basin was found to be discoloured. Samples were collected and preliminary examination shows the contaminant to be of marine origin. It is thought that late autumn storms probably stir up the shoal waters bringing sedimentary material into suspension and that this material becomes consolidated into the ice.

33. There is reason to believe that short term forecasting of water temperatures from the St. Andrews data may be done with some reliability. An equation has been derived which one enters with the annual mean for the previous year and the minimum monthly mean for the year in question (usually February), and derives the annual mean for the year in question. This means that the general level of temperature

for the year may be predicted in March. With some reservation these results may be applied to the whole of the Atlantic Coast of Canada.

34. Analysis of the 1954 "Labrador" data indicates that the deep water (deeper than 1250 metres) in Baffin Bay probably originates in the Arctic Ocean at depths of about 250 metres and flows into Baffin Bay through Smith Sound. This seems a more logical explanation of this water than that hitherto put forward.

#### Incidental Activities

35. The Oceanographer-in-Charge presented a paper entitled "Major Offshore Projects of the Atlantic Oceanographic Group" at a symposium on recent oceanographic expeditions held at the annual meeting of the American Geophysical Union.

36. The Oceanographer-in-Charge gave a talk on "The Application of Hydrography to Fisheries" at a meeting of representatives of the fishing industry held at St. Andrews June 28th.

37. Mr. Bailey gave a number of illustrated lectures on his experiences during the 1954 cruise of H.M.C.S. "Labrador".

38. Dr. Lauzier attended the annual meeting of the International Commission on the North West Atlantic Fisheries in the capacity of assistant adviser to the Canadian Commissioners.

#### Publications

39. The following papers have been published since

January 1955 or are currently in press:

- Bailey, W. B. Arctic Oceanography. Trade News 7(7), p. 14,  
January 1955.
- Bailey, W. B. Summer surface temperatures in the Canadian  
Atlantic. Fish. Res. Bd. Can. Prog. Rept. Atlantic,  
No. 63, 16-18, November 1955.
- Bailey, W. B. On the origin of the deep Baffin Bay water.  
J. Fish. Res. Bd. Can. - IN PRESS.
- Bailey, W. B. Water temperatures around North America.  
Fish. Res. Bd. Can. Prog. Rept. Atlantic - IN PRESS.
- Lauzier, L., R. W. Trites and H. B. Hachey. Some features  
of the surface layer of the Gulf of St. Lawrence. Bull.  
Fish. Res. Bd. Can. - IN PRESS.
- Lauzier, L. and W. B. Bailey. Features of the deeper waters  
of the Gulf of St. Lawrence. Bull. Fish. Res. Bd. Can. -  
IN PRESS
- Lauzier, L. Hydrographic features of the waters of Bay of  
Islands, Newfoundland, in the autumn. Bull. Fish. Res.  
Bd. Can. - IN PRESS.
- Lauzier, L. Variations of temperature and salinity in shallow  
waters of the southwestern Gulf of St. Lawrence. Bull.  
Fish. Res. Bd. Can. - IN PRESS.
- Lauzier, L. Bottom temperatures on the Magdalen Shallows.  
Bull. Fish. Res. Bd. Can. - IN PRESS.
- MacGregor, D. G. Currents and transport in Cabot Strait.  
J. Fish. Res. Bd. Can. - IN PRESS.

- McLellan, H. J. Changes in bottom temperatures on the Scotian Shelf. J. Fish. Res. Bd. Can. 12(3), 375-386, 1955.
- McLellan, H. J. Bottom temperatures on the Scotian Shelf. IV. Winter (1952). Fish. Res. Bd. Can. Prog. Rept. Atlantic, No. 62, 10-11, March 1955.
- McLellan, H. J. Bottom temperatures on the Scotian Shelf. V. Summary. Fish. Res. Bd. Can. Prog. Rept. Atlantic, No. 63, 14-17, July 1955.
- McLellan, H. J. Hydrography can help you haul in more fish. Canadian Fisherman 42(10), 6-8, 1955.
- McLellan, H. J. Major offshore projects of the Atlantic Oceanographic Group. Trans. Am. Geophys. Union 36(3), 520, 1955.
- McLellan, H. J. On the sharpness of oceanographic boundaries south of Nova Scotia. J. Fish. Res. Bd. Can. - IN PRESS.
- Trites, R. W. The oceanography of Chatham Sound, British Columbia. J. Fish. Res. Bd. Can. - IN PRESS.

#### Manuscript Reports

40. The following manuscript reports have been distributed:

Anon. Temperature and salinity distribution of the waters of the Laurentian Channel in 1953 and 1954. MS Rept. Bio. Sta. No. 605, 7 pp. (with 26 figures).

- Anon. Temperature and salinity distribution of the waters of the southwestern Gulf of St. Lawrence from 1950 to 1954. MS Rept. Bio. Sta. No. 606, 7 pp. (with 24 figures).
- Bailey, W. B. Oceanographic reconnaissance in the Canadian Archipelago (1954). MS Rept. Bio. Sta. No. 603, 145 pp.
- Lauzier, L. Bottom temperatures on the Magdalen Shallows. MS Rept. Bio. Sta. No. 593, 30 pp.
- MacGregor, D. G. Interim report on the study of hydrographic sections across Cabot Strait. MS Rept. Bio. Sta. No. 594, 22 pp.

41. The following summary reports are attached:

- (a) ~~Seasonal~~ Surveys - H. J. McLellan and R. W. Trites
- (b) Slope Water Studies - H. J. McLellan
- (c) Surface Water Temperatures in 1954-1955. - L. Lauzier
- (d) Temperature Foreshadowing - L. Lauzier
- (e) Hydrography of Malpeque Bay Area - L. Lauzier
- (f) Currents and Transport in Cabot Strait - D. G. MacGregor
- (g) Early Summer Survey of the Gulf and Estuary of St. Lawrence - L. Lauzier
- (h) Effect of Bottom Configuration on the Temperature and Salinity Distribution near the Entrance of the Saguenay River - L. Lauzier
- (i) Winter Survey of Water and Ice Conditions in the Gulf of St. Lawrence - L. Lauzier
- (j) Winter Conditions in the Bay of Fundy (1954) - W. B. Bailey

- (k) On the Origin of the Deep Baffin Bay Waters - W. B. Bailey
- (l) Some Features of the Waters of the Canadian Archipelago -  
W. B. Bailey
- (m) H.M.C.S. "Labrador" 1955 Arctic Cruise - N. J. Campbell
- (n) Bottom Topography of Foxe Basin and Foxe Channel - N. J.  
Campbell
- (o) Biological Observations Foxe Basin - N. J. Campbell
- (p) Current Measurements in Foxe Basin - N. J. Campbell
- (q) Ice Conditions Foxe Basin and Foxe Channel - N. J. Campbell
- (r) Very Cold Waters in Foxe Basin Area - N. J. Campbell
- (s) Autumn Survey of Newfoundland Waters - W. B. Bailey
- (t) Oceanographic Observations by the Canadian Hydrographic  
Service on the Atlantic Coast - W. B. Bailey
- (u) Seismic Survey - R. W. Trites
- (v) Technical Services - L. Lauzier

H. J. McLellan  
Oceanographer-in-Charge.

St. Andrews, N. B.  
April 3, 1956.

## Seasonal Surveys

The long term program of seasonal surveys, initiated in 1950, has been continued. Three surveys were carried out in 1955 and a winter survey in 1956. The research vessel C.N.A.V. "Sackville" underwent an extensive refit in early 1955, precluding the winter survey. She was in service again to commence the spring survey on June 10th.

During the spring and summer surveys an observer from the Biological Station, St. Andrews, N.B. was carried for the purpose of making a study of fish eggs and larvae in the upper layers. The timing of the summer cruise was arranged so that co-operation could be extended to the Dominion Observatory in carrying out a seismic survey in the Gulf of St. Lawrence and the Sable Island area.

A study of the accumulated data pertaining to water conditions on the Scotian Shelf has been initiated to ascertain to what extent circulation patterns may be inferred from the distribution of the physical variables. It would appear that there is promise of some success in the application of principles of dynamic calculations in spite of the inherent limitations presented by the shoalness of the waters. Preliminary studies indicate that more detailed observations in the shoal "Middle Ground" - "Sable Island" area may be required to adequately show the full circulation pattern on the shelf.

Observations of the phosphate content of the waters on

the Scotian Shelf were made during the summer survey as a preliminary to a planned study of the nutrient cycle in these waters.

H. J. McLellan and R. W. Trites

## Slope Water Studies

While no part of the field program in 1955 was aimed particularly at furthering studies of the slope water region these investigations are continuing. Seasonal surveys locate the inner boundary of the Slope Water on three lines to follow fluctuations in its location.

The data from a cruise in July 1954 is being studied. This cruise surveyed the waters in the Laurentian Channel outward from Cabot Strait, and in the region bounded by the 57°W. meridian, the Gulf Stream and the southwestern edge of the Grand Banks. An exceedingly complex system of intermingling water masses existed at the time of survey. A large anti-cyclonic eddy of Gulf Stream water protruded into the centre of the area. No true Labrador water was present west of the Tail of the Banks, though some degenerated remnants were observed along the slope and in the Laurentian Channel. The deeper waters of the Gulf of St. Lawrence appeared to have a closed circulation, which, though it included the Cabot Strait area, was confined north of the 46th parallel.

The importance of this area as one of intense horizontal mixing is emphasized by the results of this survey.

H. J. McLellan

Surface Water Temperatures in 1954 -1955

Continued observations of water temperatures, taken twice daily, at six points along the Canadian Atlantic coast revealed a general decrease in 1955 as compared to the previous year. The accompanying Table I gives the monthly averages of temperatures at the six points from October 1954 to December 1955. The observations were taken at St. Andrews, N. B., Lurcher Lightship, N. S., Halifax Harbour, N. S., Sambro Lightship, N. S., Entry Island, Quebec, and Port Borden, P.E.I.

The decrease in temperature was most noticeable during the last quarter of 1954 with a small repercussion in the first quarter of 1955. The last quarter of 1955 also showed a decrease in temperature which indicates that the autumnal and early winter cooling was intense during the period 1954-1955.

Comparison of the data of Table I with the normal monthly means listed in Table II bring out the differences between the various points. At St. Andrews, N. B. all the monthly means but one (December 1955) were above normal. At Lurcher Lightship most of the means were below normal and some of them by as much as  $1.0^{\circ}\text{C}$ . in May and June. In Halifax Harbour, N. S. the means for the first half of the year 1955 were slightly above normal, those for the second half were definitely below normal. At Sambro Lightship, N. S. the monthly means up to and including September were equal to or above normal. No data are available for the last quarter of the year. At Entry Island, Quebec, the means

show some variations above and below normal. At Port Borden, P.E.I. in Northumberland Strait, the monthly means were lower than the average from June to December 1955.

In the Bay of Fundy area and along the outer coast of Nova Scotia, some of the temperatures were below normal at Lurcher Lightship and in Halifax Harbour, N.S. but not at St. Andrews and Sambro Lightship. This might be due to the fact that after September the prevailing winds in the area had a more northerly component than usual or were stronger than normal for these months. Such wind action would result in upwelling along the coast, lowering the temperatures at Halifax Harbour but not at Sambro Lightship, at Lurcher Lightship but not at St. Andrews, N. B.

L. Lauzier

TABLE I

Monthly surface water temperatures along the Canadian Atlantic Coast

<u>Year</u>	<u>Month</u>	<u>St. Andrews N.B.</u>	<u>Lurcher Light- ship, N.S.</u>	<u>Halifax Harbour N.S.</u>	<u>Sambro Light- ship, N.S.</u>	<u>Entry Is. Que.</u>	<u>Port Borden P.E.I.</u>
1954	Oct.	12.2+	--	11.3+	13.2+	9.3-	11.8+
	Nov.	8.6-	9.8-	8.3-	10.2-	4.8-	6.1-
	Dec.	5.4-	7.5-	5.2-	8.4-	2.0-	1.7-
1955	Jan.	3.4+	5.1-	3.3+	6.9+	0.6+	-0.6+
	Feb.	2.0-	3.4	-	5.5+	-	-1.2-
	Mar.	2.3-	3.2+	1.6-	3.4-	-	-1.0+
	Apr.	4.7-	4.0	3.6-	6.9+	1.8+	2.5+
	May	7.7-	5.2-	6.6-	5.9-	5.4	8.0-
	June	10.0-	7.4-	10.2	12.6+	9.5	13.0-
	July	12.9+	9.5-	12.8-	15.1+	14.7-	16.9-
	Aug.	13.8	11.3-	15.8+	17.7+	17.2+	18.9+
	Sept.	12.7-	-	12.7-	15.6+	--	16.2+
	Oct.	11.2-	-	11.5+	-	9.8+	11.5+
	Nov.	8.3-	9.7-	7.3-	-	5.5+	5.4-
	Dec.	3.4-	6.8-	3.2-	-	-0.4-	-1.0-

- Decrease as compared to the previous year

+ Increase as compared to the previous year

TABLE II

Normal Surface Water Temperatures

Period	St. Andrews N.B.	Lurcher Lightship N.S.	Halifax Harbour N.S.	Sambro Lightship N.S.	Entry Is. Que.	Port Borden P.E.I.
	1921-55	1929-36 1950-55	1926- 1955	1935- 1955	1930- 1955	1951- 1955
<u>Month</u>						
Jan.	1.7	5.0	2.3	3.9	-	-1.4
Feb.	0.4	3.6	0.9	2.2	-	-1.4
Mar.	1.2	3.2	1.2	1.8	-	-1.0
Apr.	3.6	4.2	3.3	3.4	0.9	1.7
May	6.6	6.2	6.4	5.8	4.8	7.2
June	9.8	8.4	10.3	9.8	8.2	13.1
July	12.6	10.4	13.6	14.1	14.8	17.6
Aug.	13.2	11.5	15.1	16.5	17.3	19.2
Sept.	12.6	12.6	14.4	15.6	14.8	17.1
Oct.	10.7	11.3	11.6	13.0	10.0	11.8
Nov.	7.8	9.3	8.2	9.5	5.1	6.1
Dec.	4.2	7.0	4.7	6.3	0.8	1.2

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### Temperature Foreshadowing

Since 1921 the annual mean temperatures of surface waters at St. Andrews, N.B. have oscillated between  $5.4^{\circ}\text{C}$ . and  $8.5^{\circ}\text{C}$ . The annual means give an overall picture of the average conditions during the calendar year. Several factors contribute to the variations of the annual means. The effects of these factors are more discernible by studying the variations of the annual minima and maxima and consequently of the warming and cooling and their interrelationships.

A study is being made of such variables, their relationship and their contribution to the annual mean, and finally, of the possibilities of foreshadowing the annual means.

The annual maxima, which usually occur in August, were on the upward trend from the early twenties to the middle thirties and from the middle forties to the early fifties with a rapid drop between the two periods. Since 1951 there was a slight drop. From 1946 to 1952 there have been erratic variations not recorded before or since. The annual minima behaved differently. The variations of the minima seemed to be erratic from the beginning of the series to the early forties, and after 1942 there was a steady increase up to the present time with the exception of 1948 and 1951 when the minima deviated somewhat from the general trend.

From year to year the warming may vary in some erratic fashion, it may reach extremes from one year to the next. However, after the middle thirties, it seems that the variations

were more consistent, there were series of decreasing or increasing annual warmings. The variations of cooling through the years seemed to be erratic, the extremes were more widely separated than those of the warming. It is of interest to note that, during the last decade, both the warming and the cooling were on a downward trend.

The variations of annual temperatures and some of its components, the warming and cooling, the minima and maxima, have been briefly described. Two properties of these variables are of particular interest: the dispersion and the persistence. The measure of the dispersion is given by the "standard deviation". The persistence, which indicates the order of occurrence, is a function of the standard deviation of the series as a whole and of the differences from one observation to the next. Persistence in annual temperatures indicate that a warm year is apt to follow a warm year instead of a cold year. The smallest standard deviations of the series were found in the annual means, the annual warming and the maxima (0.73 and 0.81<sup>o</sup>C.), the annual cooling and the minima had the highest standard deviations (0.96 and 1.10<sup>o</sup>C.). The most persistent variables were the annual means and the minima and the least persistent were the warming and cooling.

To continue the work started last year, we have studied the correlation between the variables. The purpose is to find a statistically significant correlation between the annual temperature and one or two variables which would permit

us to foreshadow the annual temperatures at least 9 or 10 months in advance. This prerequisite eliminates correlations like those involving the warming during a year or the maximum during a year and the annual temperature of the same year because it would give predictions only 5 months beforehand.

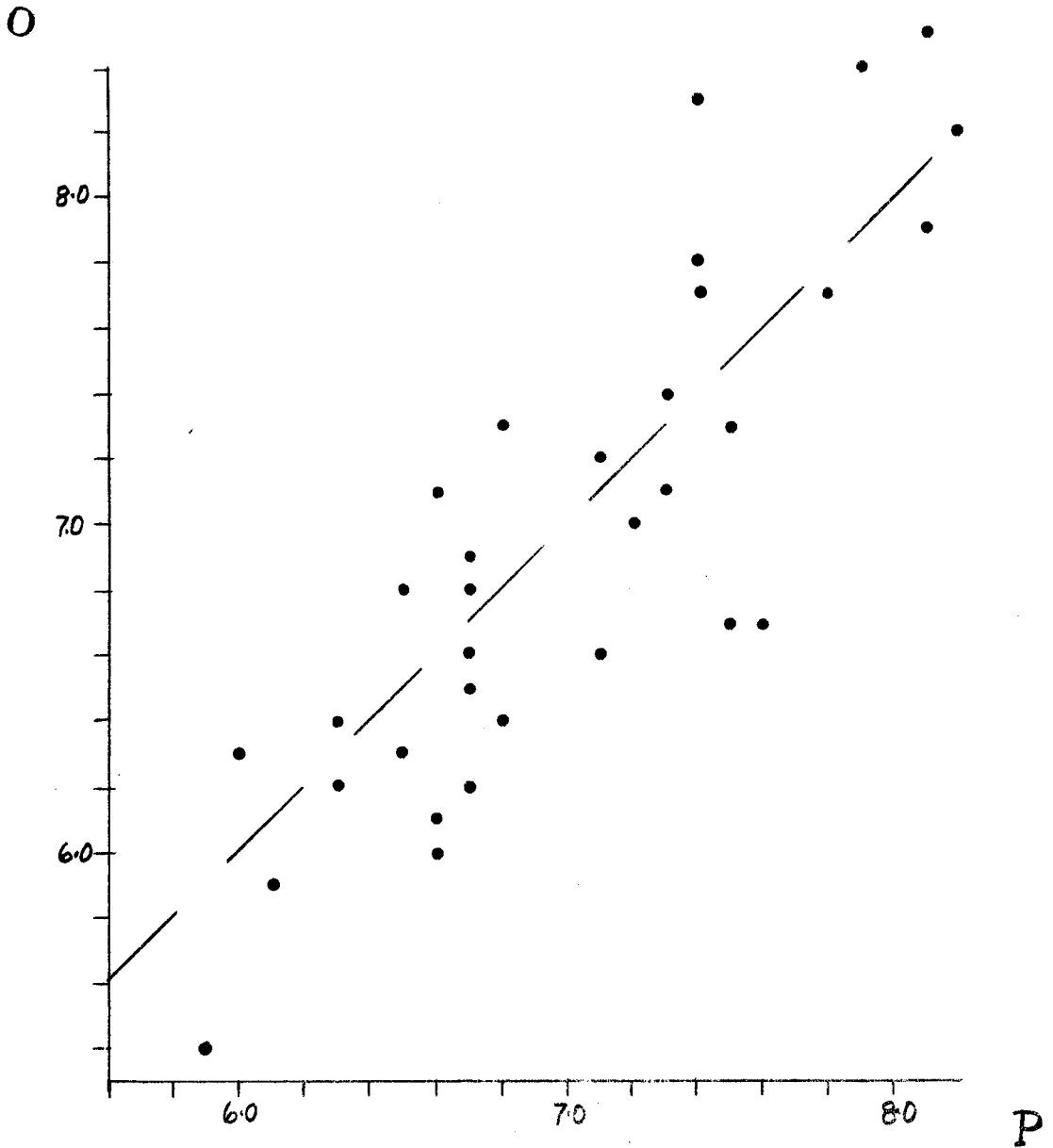
The correlation between the change in annual temperature and the cooling during the previous winter was significant. The equation relating the two series of variables give good results; it was based partly on the persistence of the annual temperature. The other factor involved was the cooling which is not persistent. However, the probable error of the predicted values was  $\pm 0.33^{\circ}\text{C}$ . The most persistent variable after the annual temperature was found to be the minimum. Even if it varies within wide limits over the years (high standard deviation), this factor was the most promising for a short term forecast. A multiple correlation was established between - (a) the annual mean temperature of year N, (b) the annual mean temperature of year N-1, and (c) the minimum temperature of year N. The following equation was established:

$$T_N = 0.49 M_n + 0.20 T_{N-1} + 5.4$$

$T_N$  is the annual mean temperature of year N

$M_n$  is the minimum temperature which occurs normally in February.

$T_{N-1}$  is the annual mean temperature of the previous year (N-1).



Comparison of observed (O) and calculated (P) values of annual mean temperatures at St. Andrews, N. B.

With this equation one can calculate in advance the annual mean temperature with a good degree of accuracy since the probable error of the difference between the calculated and observed values is  $\pm 0.28^{\circ}\text{C}$ . The standard error of the difference between the calculated and observed values is less than the standard error of the change of mean temperature from year to year,  $0.41^{\circ}\text{C}$ . as compared to  $0.65^{\circ}\text{C}$ .

The relationship between observed and calculated values are given in figure 1.

L. Lauzier

## Hydrography of Malpeque Bay Area

Because of an increasing need for a better understanding of the circulation in Malpeque Bay, P.E.I., and of better facilities, the hydrographic observations outside the bay were resumed in 1953 and regular observations at four points in the Bay were initiated at the same time. It is intended to obtain from these observations a backlog of information that will help the planning of a full scale survey of the area as proposed for the summer of 1957.

It is known from previous observations, 1930-1937, and from the 1955 observations, that the salinity cycles of the waters inside and outside the Bay are out of phase. Even if the warming is more intense inside the Bay than outside, there is a period during the summer when the surface waters outside the Bay are less dense than the waters inside. There is a suggestion that, during such a period, the surface residual flow would be into the Bay.

L. Lauzier

Currents and Transport in Cabot Strait

Currents and transport of volume and salt have been calculated by dynamical methods for Cabot Strait in the section extending from Cape North to Cape Ray, making the assumption that the 400 metre depth was a level of no motion. Data from eight crossings of the section were examined, representing spring, summer and autumn conditions through the years 1950-1954.

Features of the current distribution noted were: much variation from cruise to cruise, strongest currents in August and least in April and May, currents outward on the Cape Breton side and most often inward on the Newfoundland side, and reversals with depth with no fixed pattern.

Inward and outward transports through the section were found to be of the order of  $10^6$  cubic metres per second and to vary considerably. Zero net transport could be obtained in each instance by a small velocity adjustment comparable in magnitude to the errors inherent in the method of calculation. Salt balance calculations confirmed these velocity adjustments.

D. G. MacGregor

## Early Summer Survey of the Gulf and Estuary of St. Lawrence

To continue the work done in 1953 the estuarial waters of the St. Lawrence were studied during an extended seasonal cruise of the C.N.A.V. "Sackville" in June and July, 1955. The observations in the Gulf of St. Lawrence and the Estuary were made from June 29 to July 10.

The data collected during this survey will serve to present a synoptic picture of the temperature and salinity distribution over the Laurentian Channel and surrounding waters, one to two months after the spring runoff of the St. Lawrence and its tributaries.

The purpose of these surveys in the estuary and the Gulf is to study the circulation in the area with emphasis given to the Gaspe Current. The behaviour of this current, which makes a major contribution to the circulation in the Gulf, is not satisfactorily known. Among the various aspects of the problem to be considered are: the origin of the current, the volume transport and its seasonal variations, the effect of the spring runoff of the St. Lawrence on the current, the path of the current after it leaves the Gaspe Peninsula, the contribution of the current to the replacement of the waters of the Magdalen Shallows and of the Bay of Chaleurs.

The data from this cruise have been analysed in part and some of the results are as follows:

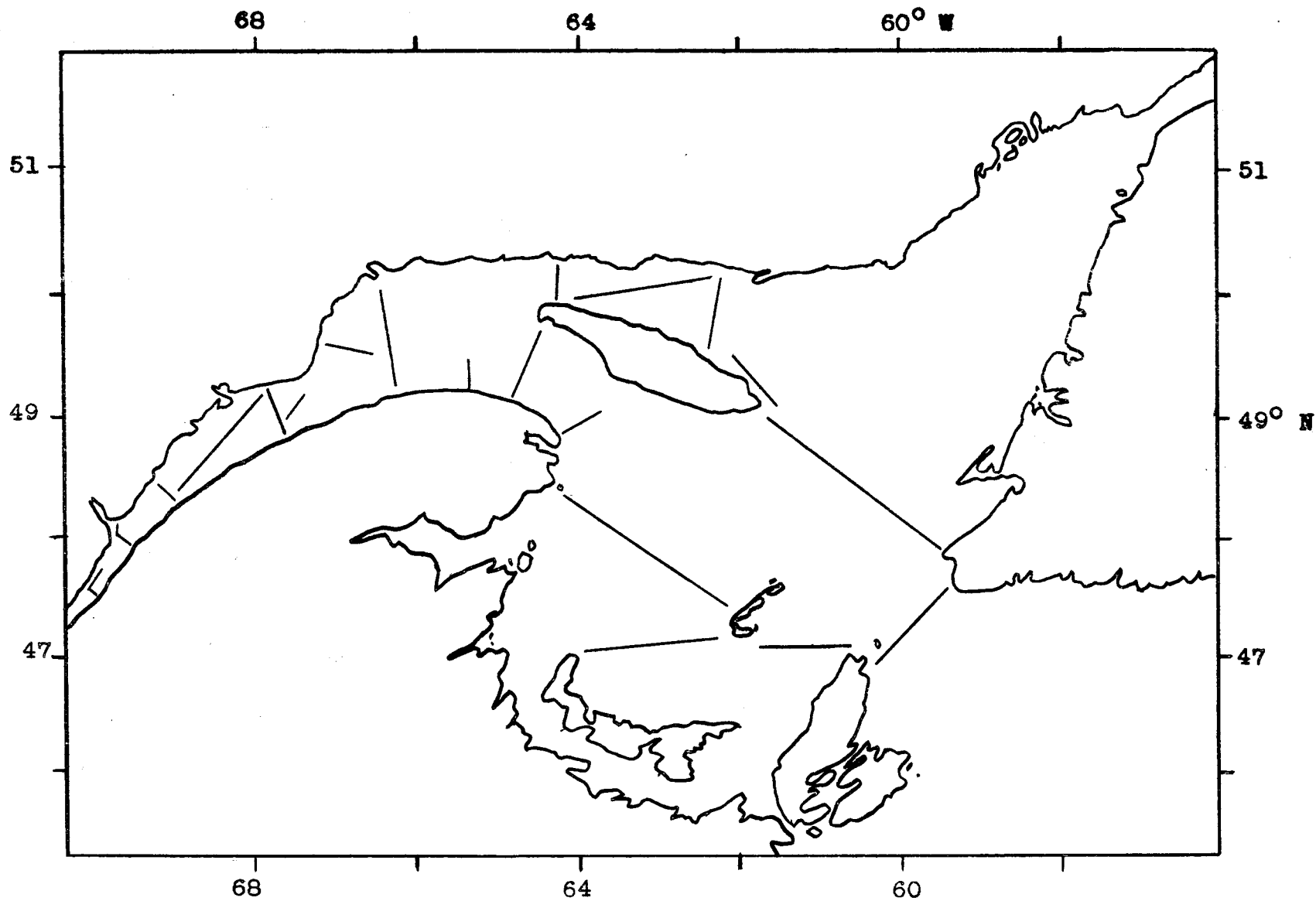
1. The range of surface salinity in the western Gulf was

approximately nine parts per thousand (22.5 - 31.5‰), a large body of low salinity water 22.5 - 23.5‰ was observed along the Gaspé coast.

2. In the estuary, east of the Saguenay, the surface salinity ranged from 24.0 to 28.5‰. Most of the water had a salinity less than 25.0‰ and the body of higher salinity was located along the North Shore between the Saguenay and the Bersimis rivers.
3. The influence of the Bersimis, Outardes and Manicouagan rivers was very noticeable, as in September 1953.
4. West of the Saguenay, the surface salinity dropped rapidly to approximately 20.00‰ contrary to the conditions observed in September 1953.
5. The horizontal salinity gradient over the Magdalen Shallows was very steep in June 1955, the surface salinity ranged from 25.0 to 30.0‰. Over the same section, from the Gaspé Peninsula to the Magdalen Islands, in September 1953, the salinity gradient was very small. This seems to indicate that the Gaspé Current after leaving Cape Gaspé turned towards the south and southwest in June, and to the southeast in September. The current was apparently much stronger in June than in September.
6. The vertical temperature stratification was very intense, a cold water layer with temperature below 0°C. was found in every one of the fourteen sections made from Cabot Strait to the head of the Laurentian Channel east of the Saguenay, including the Magdalen Shallows and Jacques

Cartier Passage. The overall minimum temperature in the cold water layer was  $-0.88^{\circ}\text{C}$ . The below zero water in Cabot Strait was located on the western slopes of the Channel and it had the same properties as those of the cold water layer found over the Magdalen Shallows.

L. Lauzier



St. Lawrence Estuary Survey, 1955

Effect of Bottom Configuration on the Temperature and  
Salinity Distribution near the Entrance of the Saguenay  
River

The Laurentian Channel penetrates into the estuary of the St. Lawrence as far as the mouth of the Saguenay River. Within a few miles the channel shallows from more than 300 metres to less than 50 metres. The funnelling effect of the channel has been detected in the oscillations of the different layers of water between the mouth of the Saguenay and Red Islet.

Our study of the Gaspé Current in the Gulf and the Estuary necessitates an understanding of the processes involved at the head of the Laurentian Channel. The study of data collected in 1934 by the Station biologique du Saint-Laurent, was undertaken. The temperature-salinity relationship of the waters in the area had not previously been studied.

The conservative temperature-salinity relationship of these waters shows that there is little vertical mixing, but horizontal mixing takes place with waters from the Saguenay and the St. Lawrence. The maximum oscillations at the head of the channel, near Red Islet, lead us to believe that the decreasing amplitude away from this point indicates dissipation of energy used for mixing. This mixing seems to occur along a "front" or a boundary which changes position in relation to the tide. The lower temperatures on the south side as compared to the north side indicate same degree of upwelling along

the front. The currents along the south shore in the sector between Basques and Bic Islands are weak and inconsistent. The Red Islet area is the meeting place of the brackish waters of the St. Lawrence and the Saguenay, with the higher salinity waters of the deep Laurentian Channel. This mixing area undoubtedly contributes to the formation and maintenance of the Gaspé Current but its share is still to be determined.

L. Lauzier

Winter Survey of Water and Ice Conditions in the Gulf of St. Lawrence

The full understanding of oceanographic conditions in the Gulf of St. Lawrence has long been seriously hampered by the lack of observations during the winter season. One can only speculate until observations of the water column are available for the coldest part of the year. There is inadequate information concerning the nature and extent of the ice cover in the Gulf during the winter months. Such information would permit an estimate of the effect of freezing in modifying the salinity distribution, horizontally as well as vertically. Observations in winter time are necessary to determine what proportion of the cold water layer, which is found throughout the summer, is caused by winter cooling or comes from outside the Gulf. This additional knowledge would have great bearing in the study of the heat budget of the Gulf and also the formation of ice in winter.

To provide winter observations from this area a survey was undertaken aboard the H.M.C.S. "Labrador" in the Gulf of St. Lawrence from February 22nd to March 6th, 1956. A total of 44 stations were occupied in the Gulf covering the main channels and passages as well as the shallow waters. As shown in the figure, five sections across the Laurentian Channel were made from Cabot Strait to Father Point (in the estuary). Observations were made north of Anticosti Island and in the northeast sector of the Gulf. The shallow waters

between Cape Breton Island and Prince Edward Island and west of Magdalen Islands were also explored. Observations were made at one station south of the Canso Causeway in Chedabucto Bay.

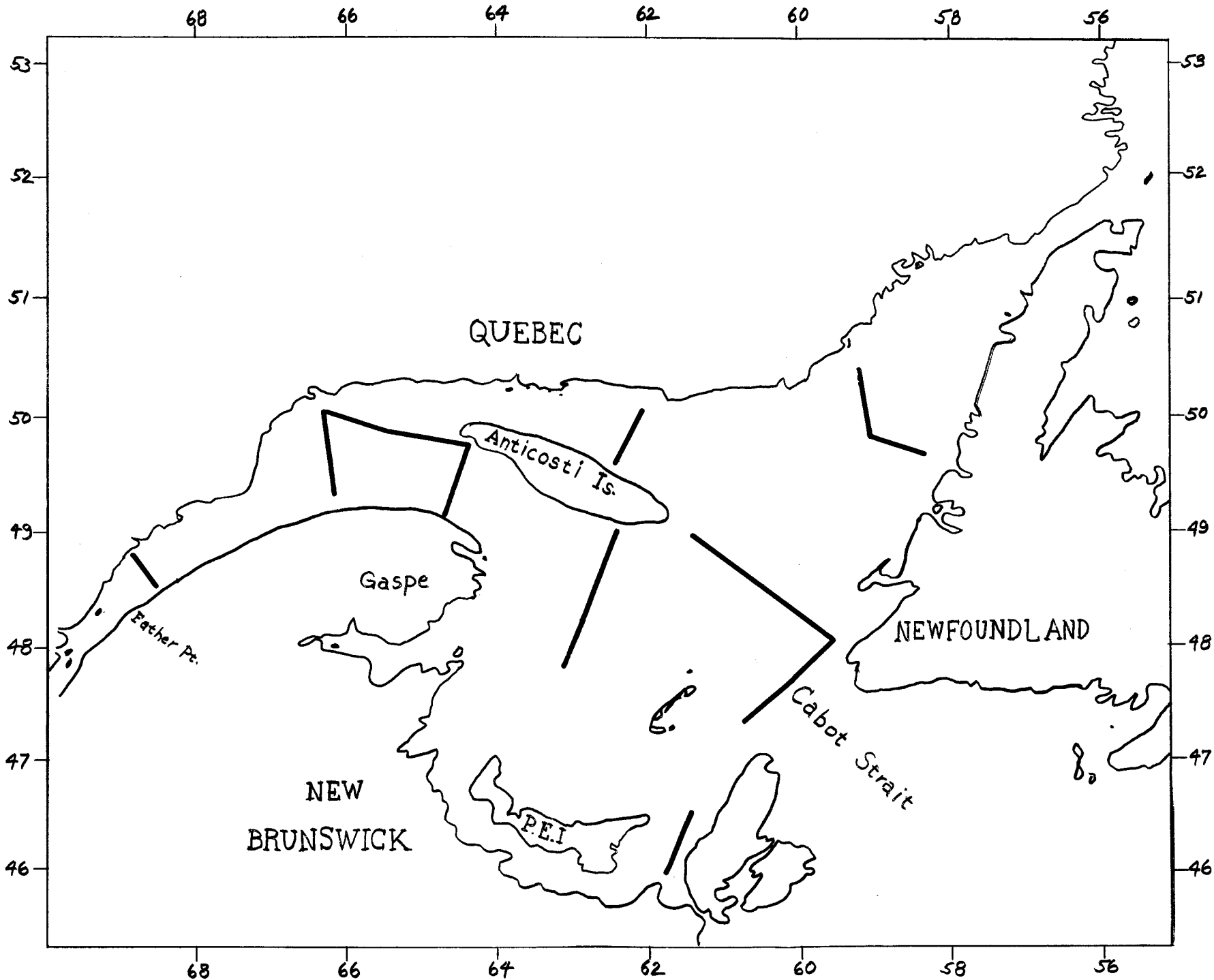
The data obtained during the H.M.C.S. "Labrador" cruise are to be related to the data collected during the winter cruise of C.N.A.V. "Sackville" in the lower Laurentian Channel outside the Gulf.

Observations of temperature and salinity were made at all the stations from the surface to bottom, and observations of dissolved oxygen and phosphate content were added at some key stations.

Ice observations were made from the ship during the cruise and ten air reconnaissance flights were undertaken by the Maritime Squadron of the Royal Canadian Air Force in collaboration with the Royal Canadian Navy. Ice distribution charts for the period of the cruise have been prepared.

Observations of seals were recorded.

L. Lauzier



Winter Survey, Gulf of St. Lawrence

Winter Conditions in the Bay of Fundy (1954)

A full scale survey of the waters of the Bay of Fundy and southwestern Nova Scotia was appended to the winter seasonal cruise in 1954. Preliminary analysis of the data indicates that there is strong movement of waters westward from the edge of the Scotian Shelf through the Fundian Channel into the Bay of Fundy. The water from the Scotian Shelf is progressively mixed with the water from offshore after it rounds the southern tip of Nova Scotia and its identity as a cold low salinity water is soon lost. At the head of the Bay of Fundy the waters are cold and of low salinity. They move westward from Minas Basin to join those from Chignecto Bay and then flow southwestward out of the Bay along the New Brunswick coast.

The horizontal distribution of temperature and salinity are similar at all levels and are strongly influenced by the bottom contours off the southwestern coast of Nova Scotia. Surface temperatures ranged from  $1.7^{\circ}\text{C}$ . near the coast to greater than  $5.0^{\circ}\text{C}$ . on the edge of the shelf. In the Bay of Fundy surface temperatures ranged from  $0.85^{\circ}\text{C}$ . in Chignecto Bay to  $4.0^{\circ}\text{C}$ . in the center of the Bay. On the Nova Scotia side of the Bay all temperatures were above  $3.0^{\circ}\text{C}$ . while in the New Brunswick side, they were lower than  $2.0^{\circ}\text{C}$ .

Temperature-salinity correlation curves show that the waters at all stations are primarily composed of a mixture of inshore coastal water ( $0.8^{\circ}\text{C}$ ., 30.6‰) and intermediate slope water ( $9.8^{\circ}\text{C}$ ., 35.1‰). The deep offshore stations

had, in addition, a mixture of intermediate slope water and deep slope water (5.1°C., 34.9%).

The analysis of this data is continuing and will be presented shortly in conjunction with the data from seasonal cruises since 1952.

W. B. Bailey

On the Origin of the Deep Baffin Bay Waters

In the analysis of the oceanographic data collected during the 1954 cruise of H.M.C.S. "Labrador" to the Canadian Arctic it was noted there were certain marked relationships between the temperature and salinity characteristics of the waters in the Arctic Ocean, Smith Sound and Baffin Bay. These relationships suggest that the water, found at depths greater than 1250 metres, in Baffin Bay originates in the Arctic Ocean.

Previous investigators maintained that deep Baffin Bay water represents a mixture of Labrador deep water with Baffin Bay surface water, the salinity being increased sufficiently by freezing to cause the water to sink.

Our analysis indicates that the deep Baffin Bay waters originates in the Arctic Ocean at a depth of about 250 metres. Soundings on existing charts show that the channel through Smith Sound to the Arctic Ocean is the only one with sufficient depth to admit the heavy Arctic water to Baffin Bay.

W. B. Bailey

Some Features of the Waters of the Canadian Archipelago

In July 1954, personnel from the Atlantic Oceanographic Group sailed in H.M.C.S. "Labrador" to carry out an oceanographic reconnaissance of the waters in the Canadian Archipelago. Observations were made in Davis Strait, Baffin Bay, all of the channels leading from Baffin Bay, Viscount-Melville Sound, and the Beaufort Sea. In addition bathythermograph observations were taken every hour while underway, ice conditions permitting, during the entire cruise.

On completion of the scientific work in the North, H.M.C.S. "Labrador" completed the Northwest Passage and arrived in Esquimalt, B.C. on September 27, 1954. The return trip to Halifax via the Panama Canal was completed on November 21, 1954.

The oceanographic data collected from H.M.C.S. "Labrador" permitted the description of the detailed vertical temperature and salinity structure of the waters found over a large area of the Canadian Archipelago. In addition comparisons were permitted between the water characteristics of the Arctic Ocean, the Archipelago and Baffin Bay.

The more important features noted in the analysis are:

1. The vertical distribution of temperature, salinity and density in section revealed that, in the Baffin Bay area, where depths were sufficient, the water columns were composed of mixtures of four main water masses as follows:

- (a) A thin surface layer with temperatures generally greater than  $2.0^{\circ}\text{C}$ . and as high as  $6.4^{\circ}\text{C}$ . Corresponding salinities ranged from 31.0 to 32.5‰ at the surface.
  - (b) A cold water layer with temperatures less than  $-1.0^{\circ}\text{C}$ . and as low as  $-1.8^{\circ}\text{C}$ . with salinities ranging between 32.5 and 34.0‰. The salinity associated with the minimum temperature was 33.7‰.
  - (c) A warm water layer with maximum temperatures ranging from  $0.5$  to  $1.3^{\circ}\text{C}$ . with salinities of about 34.4‰.
  - (d) Deep Baffin Bay water exhibiting a temperature of  $-0.5^{\circ}\text{C}$ . and a salinity of 34.5‰.
2. In the Western Arctic and the Beaufort Sea, the water columns were composed of mixtures of four main water masses as follows:
- (a) A very thin surface layer with temperatures ranging between  $-1.0$  and  $2.2^{\circ}\text{C}$ . and with salinities between 4.1 and 27.4‰.
  - (b) A cold water layer with temperatures less than  $-1.0^{\circ}\text{C}$ . and as low as  $-1.8^{\circ}\text{C}$ . Salinities in this layer ranged from 31.5 to 33.0‰, with a salinity of 32.3‰ associated with the minimum temperatures.
  - (c) A warm water layer with temperatures as high as  $0.5^{\circ}\text{C}$ . and with a salinity of 34.9‰.
  - (d) Deep water, exhibiting a temperature less than  $-0.4^{\circ}\text{C}$ . and a salinity of 34.96‰.

3. The origin of these waters is described as follows:
  - (a) In Baffin Bay the surface layer is locally formed as is part of the cold water layer. The upper part probably came from the Arctic Ocean. The warm water layer had its origin in the Labrador Sea while the deep Baffin Bay water originated in the upper layers of the Arctic Ocean.
  - (b) In the Western Arctic, the surface and cold water layers are formed locally while the warm water layers and the Arctic deep water had their origins in the Norwegian Sea.
  - (c) In winter the surface and cold water layers are identical to one another in both areas.
4. A comparison of T-S diagrams for stations in the Beaufort Sea and in Baffin Bay shows that:
  - (a) The upper waters of the Arctic are much less saline than those found in Baffin Bay, but minimum temperatures are the same ( $-1.8^{\circ}\text{C}.$ ).
  - (b) The waters of the upper 200 metres in Baffin Bay are denser than those found at corresponding depths in the Arctic Ocean.
  - (c) Below 200 metres, Arctic waters are the denser, and below 500 metres they are denser than any water found in Baffin Bay.
  - (d) Waters found at 250 metres in the Beaufort Sea, at 500 metres in Smith Sound and at 1250 metres in Central Baffin Bay have identical temperature and

and salinity characteristics ( $-0.3^{\circ}\text{C}.$ , 34.4‰).

5. Investigation of a patch of warm water at the entrance to Lancaster Sound, having a temperature greater than  $6.0^{\circ}\text{C}.$  and a salinity of 32.2‰ revealed that it was the same water which is identified as "north water".
6. Dynamic calculations of current velocities in Lancaster, Jones and Smith Sounds gave good agreement with those of previous investigators. Calculations of the net volume transport of waters are not considered reliable due to interference from either tidal or meteorological causes or both.

W. B. Bailey

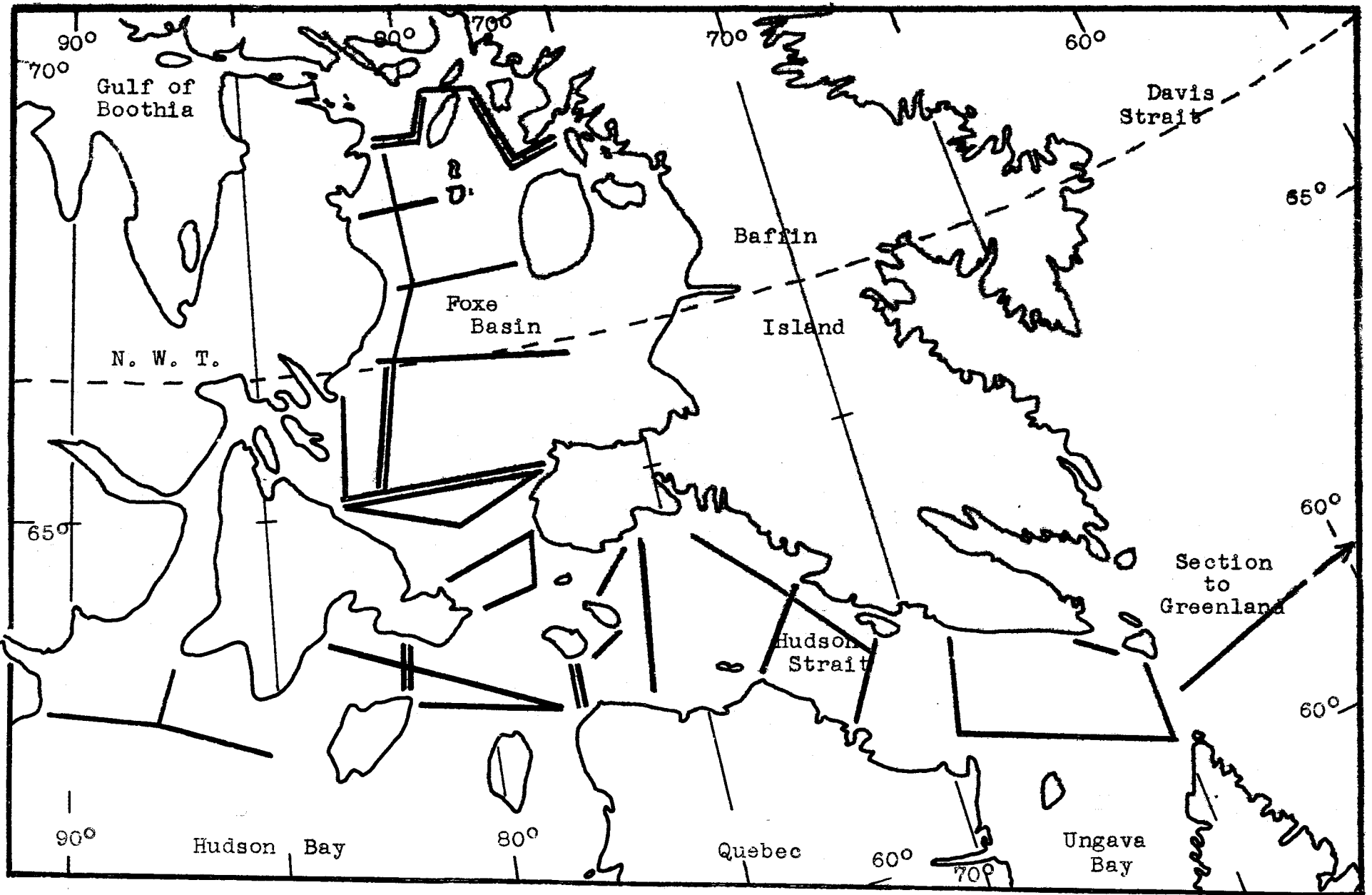
H.M.C.S. "Labrador" 1955 Arctic Cruise

The "Labrador" sailed from Halifax, N.S. on June 1st and returned on November 18th. A party of three from the Atlantic Oceanographic Group was carried and oceanographic observations were made wherever and whenever the military commitments of the ship permitted.

On the way north opportunities were afforded to occupy stations in four sections across the Strait of Belle Isle, one section across Davis Strait, and a section in Hudson Strait. The season's work was carried out chiefly in Foxe Basin, and the oceanographic observations included temperatures, salinities, oxygen, phosphates, silicates, currents and ice observations. Collections of plankton, bottom samples and marine life were made and an extensive record of marine mammal observations kept. On the outward journey a rather complete survey of Hudson Strait was carried out.

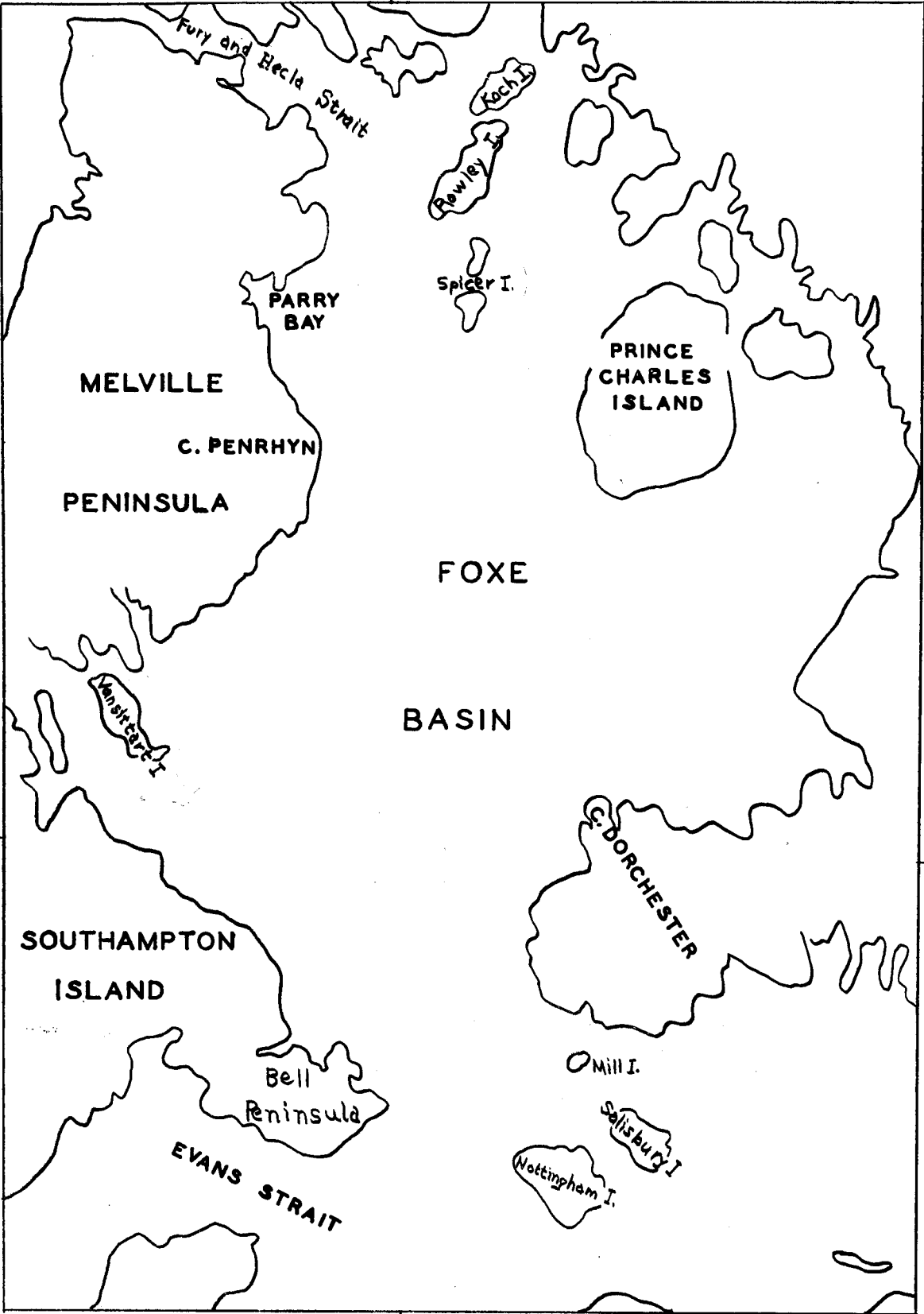
The analysis of the data is being carried out.

N. J. Campbell



ATLANTIC OCEANOGRAPHIC GROUP - ARCTIC SURVEY - 1955

80°W



65°N

65°N

80°W

## Bottom Topography of Foxe Basin and Foxe Channel

The bottom topography of Foxe Channel exhibits several deep channels and basins similar to those found in Hudson Strait. Depths do not exceed 250 fathoms while in Hudson Strait several basins exceed 300 fathoms, the maximum being 400 fathoms at the eastern entrance.

The canyons in Foxe Channel extend from Hudson Strait between Nottingham, Salisbury and Mill Islands and Foxe Peninsula to Frozen Strait. The greatest depths are found on the western half of the channel. Frozen Strait has several small basins of depths of 200 fathoms or more.

North of Vansittart Island and C. Dorchester the bottom shoals to 50 fathoms and less and gradually loses the sharp relief found in the Channel. In many ways the Basin resembles Hudson Bay with its gentle changes in bottom topography although it is not as deep.

Depths exceeding 75 fathoms are not found again in the Basin until the approaches to Fury and Hecla Strait are reached.

Wide ranges of bottom sediments were found throughout the area. Blue and black clays or muds overlain with coarse gravel were found in Foxe Channel while in the Basin itself, buff coloured silts, gravel shells and seaweed were encountered. In contrast to these sediments, sampling east of C. Dorchester showed extensive deposits of shells, barnacles and coral-like growths. In Frozen Strait, fine black deposits of silt were located in one of the deeps.

## Biological Observations Foxe Basin

Biological sampling was carried out at most of the oceanographic stations. The sampling included vertical plankton hauls, micro-plankton, and a few horizontal tows. Whenever the opportunity arose beach collections were made in the intertidal zones and a few brackish water pools. Collections were also made of fossils and arctic flowers.

Throughout the whole voyage a program of marine and bird observations was conducted on board ship with all personnel taking part. Monthly prizes were awarded to the best observer.

A total of approximately 500 observations were logged on the ship with assistance from several U.S. vessels in the area. Of particular interest were observations in November of Greenland Right whales in Hudson Strait, and a beluga migration down the coast of Southampton Island in late August. The most valuable contribution that was made in this connection, was the observations of bearded seals and walrus. Large numbers of walrus were seen off the Spicer Islands and Parry Bay. Walrus were seen in this locale from July until September and it appears that these herds of walrus must calve somewhere near the Spicers. Large numbers of walrus were also seen between Rowley and Roch Islands where their numbers caused considerable difficulty to the ships steaming through this narrow passage.

### Current Measurements in Foxe Basin

Current studies, drift observations and the preliminary analyses of the hydrographic data have revealed some of the gross features of the circulation in Foxe Basin.

The circulation appears to be dominated largely by the tides. Flood currents are northerly and ebb currents southerly. Direct current observations in the northern sections of the Basin show that the average ebb velocities on the western side are 1.8 knots northward, and flood 1.3 knots northward. Maximum flood and ebb speeds ranged from 3.2 to 4.0 knots.

On the western side a net southward set exists which persists from Fury and Hecla Strait to Evans Strait. Part of this southward movement of water passes out of the Basin via Frozen Strait and Roes Welcome Sound. On the eastern side of Foxe Channel there is a compensating northern flow from Hudson Strait and perhaps Hudson Bay. The extent of penetration of this water into Foxe Basin is still uncertain, some of it appears to join the southward flowing waters from the north in Foxe Channel while other branches move northward into the shallows south of Prince Charles Island.

The tidal range increases from west to east from 4 feet on Melville Peninsula to 12 feet on Baffin Island. Average flood velocities are larger, however, on the eastern side, perhaps suggesting a net counterclockwise circulation in the Basin. Both flood and ebb velocities are decreased in magnitude east of Rowley Island.

Attempts to obtain current information as inferred from ice movement were tried by marking floes of ice with fluorescence dyes. These dyes worked successfully in water for short period current studies. The same success was not, however, achieved with the dyes on ice where long term drift experiments were envisaged. The dyes were subject to rapid fading in sunlight and could not be distinguished after 4 hours of exposure. The experiments did yield the means and type of markings that gave best results on the ice. Recently in St. Andrews a successful series of tests were completed with new dyes that have prolonged staying power on ice and snow. It is felt that these dyes will be suitable for marking ice floes.

N. J. Campbell

Ice Conditions Foxe Basin and Foxe Channel

From June until August heavy concentration of ice were encountered in Foxe Basin and Channel. However, north of Cape Penrhyn on the mainland side the thickness and concentration were much less than elsewhere during this whole period of time. The ice was mostly hummocked and appeared to be at least two-year old ice from the extent of weathering. Thicknesses varied from a few feet to twenty feet.

The striking features of the ice encountered were the hummocked appearance and extent of discolouration. The ice was covered with a fine buff coloured silt in such concentrations that the ice had a brown appearance. This contamination could not be confused with the deposits of stones and mud resulting from the ice grounding or overturning, a phenomena which was observed frequently throughout the area. From preliminary observations of the samples collected, it appears that the deposits were of marine origin and probably arise from the late autumn and winter storms stirring up the shoal waters of the Basin. This explanation possibly accounts for the presence of the silt within the ice and the hummocked nature of the fields at large.

Occasionally floe ice was encountered void of deposition. The presence of such ice with the other may be explained on the basis of release of ice from protected bays and channels and discharge of ice through Fury and Hecla Strait.

The distinguishing features of these two types of ice

gives rise to the possibility of using the uncontaminated ice to supplement the dyed ice flow technique of observing ice movement which was tested during the summer's operations.

From June until November, the period that H.M.C.S. "Labrador" operated in these waters, no month was completely ice free. At the time the mainland side of the Basin was clear, extensive fields of ice were observed on the northern side of Prince Charles Island. During September and October a considerable amount of ice was discharged into Foxe Basin through Fury and Hecla Strait and by October lily-pad ice was forming in the turbulent waters north of Parry Bay.

N. J. Campbell

## Very Cold Waters in Foxe Basin Area

One of the most interesting oceanographic features encountered during the Arctic cruise of H.M.C.S. "Labrador" in 1955 was the existence of extremely cold water in Foxe Basin and Foxe Channel.

Temperatures of  $-1.8^{\circ}\text{C}$ . and lower were not uncommon in these waters. The distribution of temperatures  $-1.70^{\circ}\text{C}$ . and lower are shown in the accompanying figure. The area outlined  $-1.70^{\circ}\text{C}$ . and less, lies in the western portion of the Basin and Channel and generally within the limits of a southerly flow of water. Two regions of temperatures  $-1.90^{\circ}\text{C}$ . to  $-1.98^{\circ}\text{C}$ . are marked A and B within the  $-1.70^{\circ}\text{C}$ . boundary. The depths of such temperatures in area A extended from 250 metres to the bottom, 300 metres. The salinities varied from 33.75‰ to 34.04‰. Repeated observations in the northern part of sector A showed that waters of these temperatures and salinities persisted from July to November.

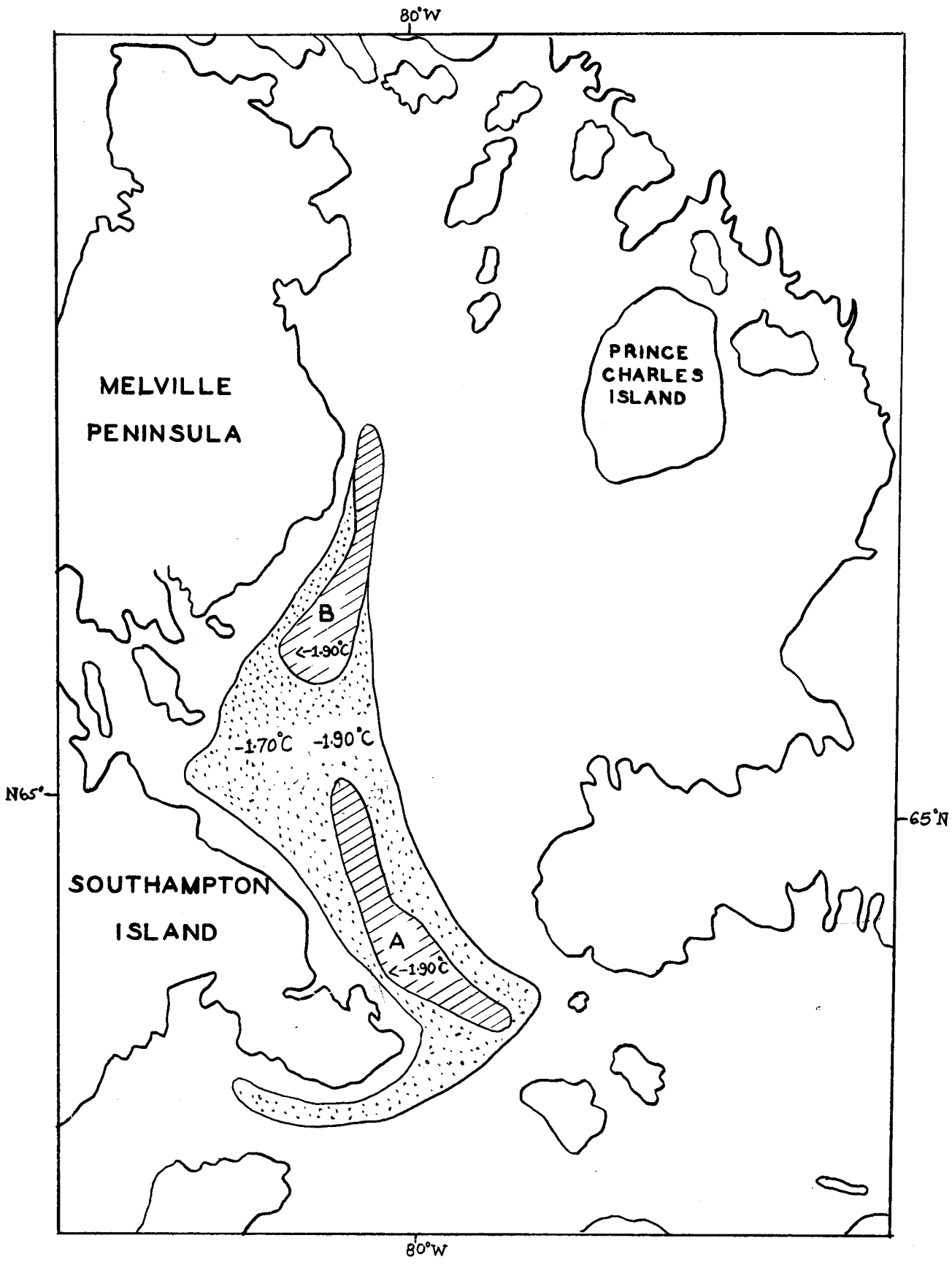
In the northern zone, sector B, a similar body of water was encountered in July and August. Here the bottom does not exceed a depth of 110 metres and these temperatures were found at depths as shoal as 75 metres. The vertical distribution of this cold water ranged from 75 metres to the bottom. Salinities varied from 33.26‰ to 34.07‰. During the month of September this body of water could not be found, the lowest temperatures recorded then were not less than  $-1.50^{\circ}\text{C}$ .

The depths of the cold waters,  $-1.70^{\circ}\text{C}$ . to  $-1.98^{\circ}\text{C}$ .

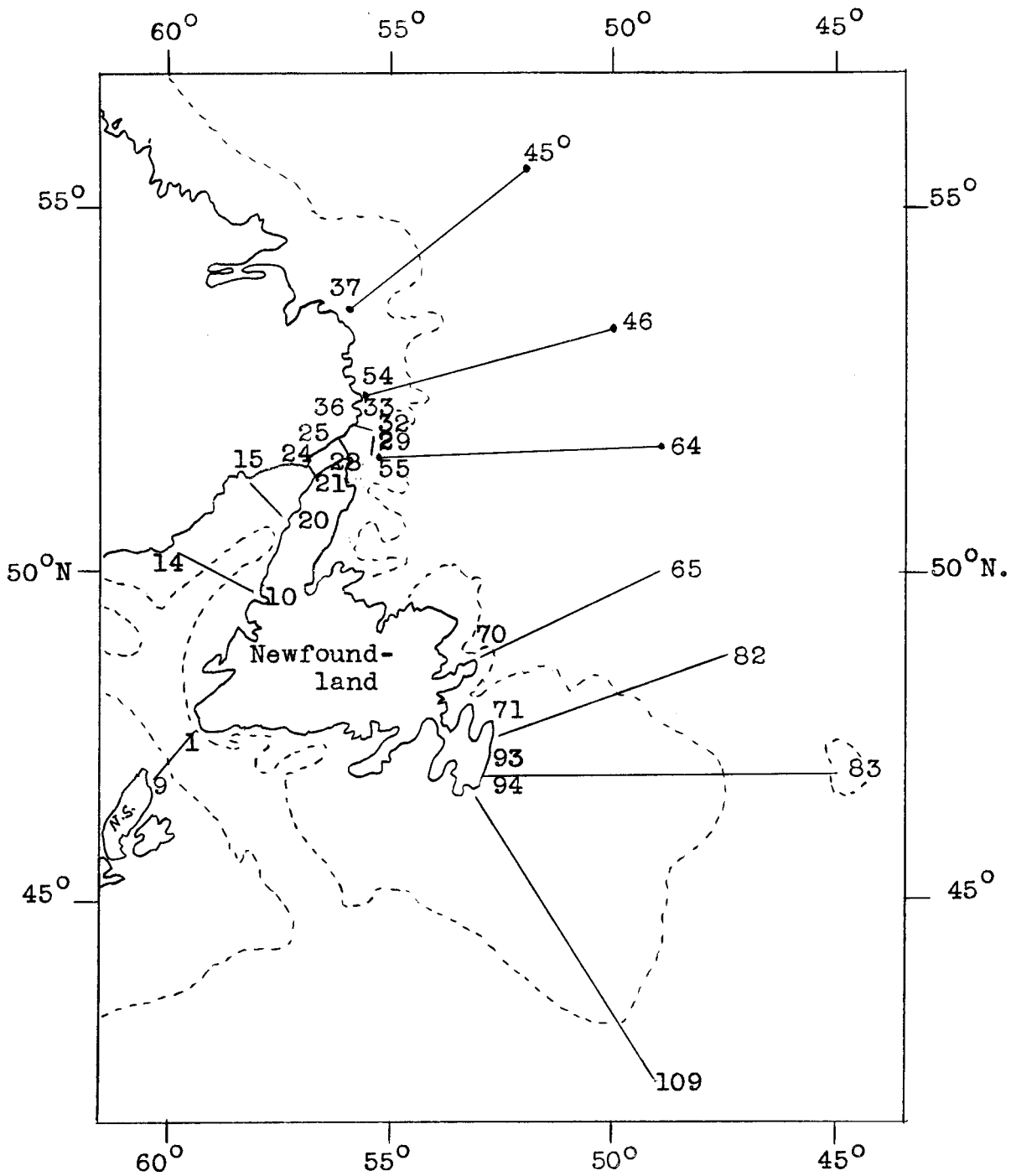
varied from 20 metres to 200 metres. The largest columns were found off the southern part of Southampton Island in Foxe Channel and Evans Strait.

There is still a question as to how such waters form and what is peculiar about their location since the temperatures fall below the freezing point curve for these salinities. Several theories are being considered and it is hoped that some light may be shed on the formation of the water when the area is again visited.

N. J. Campbell



Distribution of very cold water Foxe Basin



Atlantic Oceanographic Group - Survey of Newfoundland Waters,  
September-October, 1955

Autumn Survey of Newfoundland Waters

During the period of September 16 to October 20, 1955 a survey of the waters around Newfoundland was carried out in conjunction with the Fisheries Research Board of Canada, Biological Station, St. John's, Newfoundland. In addition to the standard oceanographic observations, plankton tows were made at selected stations over the entire network. The observational program is shown in the accompanying figure.

The principal object of the cruise was to gather data over the entire Newfoundland area so that the relationship of the different sectors to each other could be understood. In the past the various sectors (e.g. Grand Banks, Gulf of St. Lawrence, etc.) have been treated individually.

In addition to the data collected from this cruise, data will be available from extensive spring surveys in the Gulf of St. Lawrence and Strait of Belle Isle made by H.M.C.S. "Labrador" and from the east coast and Grand Banks of Newfoundland made by the International Ice Patrol.

At the time of writing the data have not been completely processed. It is expected that the analysis of these data will prove to be very interesting and will make a valuable contribution to Atlantic oceanography.

Oceanographic Observations by the Canadian Hydrographic Service  
on the Atlantic Coast

Ships of the Canadian Hydrographic Service, while engaged in cartographic surveying, regularly make a limited number of oceanographic observations. The program was commenced in 1949 with two vessels making observations. In 1952, six ships reported data, and the program has remained at this stage since that time.

Each spring one member of the Atlantic Oceanographic Group, visits the survey vessels and gives a lecture or demonstration in the use and care and maintenance of oceanographic equipment. During this visit, problems are ironed out and advice is tendered on the most practical approach to carrying out an oceanographic program as it concerns individual ships. In addition to the purely technical approach to oceanography, an attempt has been made to engender an interest in the subject through discussion and the distribution of oceanographic literature.

The following table gives the number of oceanographic stations occupied each year, the number of ships operating, totals of bathythermograph observations, oceanographic stations and temperature and salinity samples taken.

T A B L E

Year	1949	1950	1951	1952	1953	1954	1955
Ships	2	5	5	6	6	6	6
Station	46	63	53	97	58	72	89

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	<u>BT</u>	<u>Station</u>	<u>Temp. Obs.</u> <u>Sal. Samples</u>
Total observations	481	469	2483

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The importance of these observations as a contribution to Canadian oceanography cannot be over emphasized because they provide approximately simultaneous observations over the entire Canadian Atlantic seaboard. In addition observations are made in areas that have yet to undergo a full oceanographic survey and in areas seldom or irregularly visited by oceanographic vessels. The value of the oceanographic data collected by the Canadian Hydrographic Service increases many-fold as the numbers of observations made by each ship increases.

W. B. Bailey

## Seismic Survey

In association with the Dominion Observatory, a seismic survey was carried out in the Sable Island region and in the Gulf of St. Lawrence during August. This survey, a project of the Dominion Observatory, was designed to determine the basic structure of Sable Island and to elucidate certain structural features in the Gulf of St. Lawrence. Shock waves were set up by dropping depth charges from the ship at known positions and the transmissions were recorded at strategically located shore stations.

C.N.A.V. "Sackville" was used as the shot vessel, carrying recording equipment and co-ordinating personnel. Recording parties were also landed at the Magdalen Islands. Other agencies co-operating in this survey included the R.C.N., the R.C.A.F., the Hydrographic Service, the Department of Transport, and the Nova Scotia Research Foundation.

While the analysis has not been completed, it is known that the results were satisfactory and that the main structural features of these areas can be outlined.

R. W. Trites

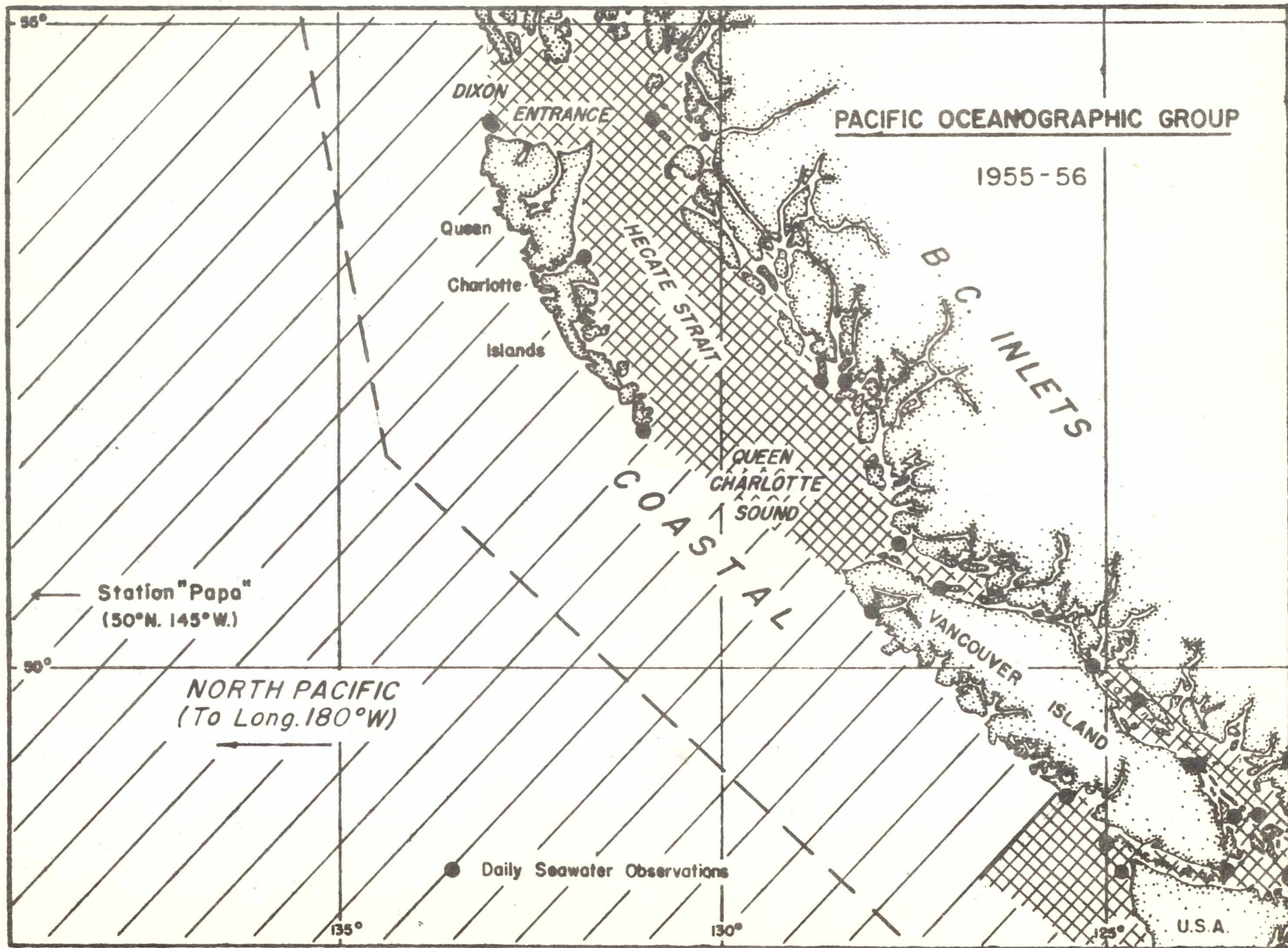
### Technical Services

In 1955, as during the previous years, the processing and filing of bathythermograph data was a major project. All the BT data collected by Canadian agencies in the Canadian Atlantic waters come to A.O.G. where they are processed in a uniform fashion, the complete data for each slide being re-recorded on cards.

An extensive library of oceanographic observations is maintained by the Group. This library serves as a reference and may be used by any interested organization. From November 1954 to January 1956, the library was augmented by 6350 BT cards of which 3975 came from BT slides processed in St. Andrews. Data from approximately 800 hydrographic stations occupied by Canadian agencies were also added to the library. The technicians of the Group made 6680 salinity determinations during the last fourteen months.

The production of the technical services of A.O.G. have increased in 1955, as compared to 1954.

The production of graphic reports this year included unpublished temperature and salinity data of the waters - a) of the Laurentian Channel in 1953 and 1954, b) of the southwestern Gulf of St. Lawrence from 1950 to 1954. These reports are the continuation of a scheme of graphic presentation of data from the waters along the Canadian Atlantic coast.



ANNUAL REPORT  
PACIFIC OCEANOGRAPHIC GROUP

Introduction

1. The Pacific Oceanographic Group under the Canadian Joint Committee on Oceanography is responsible for oceanographic activities in the Pacific approaches to Canada. With the advent of an Arctic Group based on H.M.C.S. "Labrador", this Group has withdrawn from active research in the Western Arctic.

2. The program has been designed primarily to meet the immediate and long-term requirements of the Fisheries Research Board of Canada and the Royal Canadian Navy. The Navy has provided two research vessels, H.M.C.S. "Cedarwood" and C.N.A.V. "Ehkoli" which are used jointly by this Group and the Pacific Naval Laboratory. Additional service vessels have been allocated from time to time as the work demanded. The Fisheries Research Board provides the ordinary expenses, personnel, laboratory space and scientific equipment.

3. This Group undertakes observation of the properties of the water. However the data required for oceanographic study also includes depth, bottom materials, shore line, tides, land drainage, meteorology, and the oceanography of contiguous seas. All these data are gathered by other agencies, domestic and foreign. Hence the Group maintains a close liaison at the working level with the hydrographic, hydrological and meteorological agencies working in the northeast Pacific. The best results have been brought about by data exchange and cooperative observation and use of facilities.

Staff

4. During the past year the staff of the Group consisted of:

J. P. Tully,	Oceanographer-in-Charge
N. J. Campbell,	Associate Oceanographer (transferred to A.O.G., March 31)
F. G. Barber,	Associate Oceanographer
A. J. Dodimead,	Associate Oceanographer
R. A. Pollard,	Assistant Oceanographer (to February 14)
S. Tabata,	Assistant Oceanographer
R. W. Trites,	Junior Oceanographer (on educational leave to May 31. Returned to A.O.G. June 1)
N. P. Fofonoff,	Assistant Oceanographer (Term to April 30)
G. L. Pickard,	Associate Oceanographer (Seasonal May 15 - July 31)
M. Kirsch,	Assistant Oceanographer (Seasonal May 1 - August 31)
H. J. Hollister,	Technician, Gr. 3
R. H. Herlinveaux,	Technician, Gr. 2
A. W. Groll,	Technician, Gr. 2 (to November 15)
L. D. B. Terhune,	Technician, Gr. 2 (Term from April 1)
L. H. McCracken,	Technician, Gr. 1
J. A. Stickland,	Assistant Technician, Gr. 3
M. A. Smith (Mrs.),	Assistant Technician, Gr. 2
B. M. Berisford (Miss),	Stenographer, Gr. 3
E. B. Bennett,	Seasonal Investigator (May 1 - September 15)

C. Sauer,	Seasonal Investigator (May 30 - September 15)
A. E. Filmer,	Seasonal Investigator (June 15 - September 2)
L. M. McKenzie,	Seasonal Investigator (June 15 - September 15) Assistant Technician, Gr. 1 (September 16 - October 31)
Lt. D. A. Still (LTJG) U.S.N.	Volunteer Investigator (from U.S. Naval Postgraduate School, Monterey, California) (June 27 - August 6)

#### General Program - 1955

5. The general program has been centered around the provision of an atlas of oceanographic data in all our Pacific Coast regions. Daily observations of surface sea water temperature and salinity are made at a number of stations to provide marine climatological records. Synoptic surveys of limited areas are undertaken to identify the water masses, their area, depth, and movements. The synoptic surveys define the meaning and domain of the daily sea water observations. These may then be used as indices of the occurrence and duration of the oceanographic states.

6. A pattern of study has evolved from experience. An area is defined and the possible information that may be required is assessed. Observations are undertaken using the accumulated experience of previous studies as guides. These data are reduced to usable values and published (mimeographed) in Data Records. Then study of the data is undertaken to produce general reports describing the major oceanographic features and processes. Specific information for fisheries, naval, industrial or municipal purposes

are then taken from the general reports, the data, or may require additional data. Each step of the process is documented as it is made. This ensures availability of the data and research.

7. This program is well advanced. Most of the coastal seaways have been surveyed. The waters over the continental shelf remain to be observed. The offshore oceanic waters have had preliminary examination. Programs for systematic observation have been proposed (Swiftsure, North Pacific) which will probably be implemented in the near future. The use of hydraulic models to solve oceanographic mechanisms and interpret data has been undertaken.

8. During the year there has been a transition of effort from the gathering of data to the study of data. Study of the Hecate, Strait of Georgia, and Juan de Fuca data is going forward, some conclusions have been published, and many others are in sight. Serious study of the daily sea water data has been initiated in conjunction with these, and it is already evident that they justify the claims and effort made for them.

9. This is a happy situation for the research staff; to have adequate data and leisure to develop it into sound scientific reports. It is hoped that this situation may continue through next year to its warranted conclusion.

#### Particular Program

10. Daily Sea Water Observations: Daily observations of sea water temperature and salinity are being made at seventeen positions (mostly lightstations) along the British Columbia coast. This program started with one station (Departure Bay)

in 1914. Since then stations have been added as the need became apparent, or dropped when their usefulness ceased.

11. This is the most comprehensive time series of observations on the Pacific Ocean and is comparable in scope and application to the daily meteorological observations. It was undertaken to provide a climatological record of coastal waters as background information for oceanographic and fisheries research. It is developing into the principal criteria of oceanographic processes and events.

12. Mr. H. J. Hollister manages this program of observations, and the data records. The salinity of the sea water samples is determined in the titrations laboratory under Mr. L. H. McCracken, and the data are processed and tabulated by Mrs. M. A. Smith.

13. Mr. Hollister has published a series of articles describing the location and operation of the observing stations. Each year he presents a climatological review of the past year's data and compares it with previous years. He also prepares a weekly summary of sea water temperatures from four locations, and a comparison with corresponding data from previous years. This is aired over CBU on the Fishermen's Broadcast every Wednesday morning.

14. Development of the data began a few years ago when Dr. G. L. Pickard and Mr. D. C. McLeod defined the mean annual cycles of temperature and salinity and the principal controlling factors. They showed that there were three types of coastal oceanographic regions, and that each observing station represented a domain within one or other of these.

15. At the present time, Mr. S. Tabata is studying the data from five stations in the Hecate region. He has devised a statistical method of classifying the data to define normal and abnormal states. The method is readily applicable to correlation of oceanographic factors to the fisheries where adequate data exist. He is also examining the contributions of solar radiation, cloud cover, effective back radiation, conduction, and evaporation to the temperature cycle; and the contributions of precipitation, land drainage, and advection of ocean water to the salinity cycle.

16. Dr. J. P. Tully is studying data from three stations in the Strait of Georgia. In addition to the statistical analyses, he is correlating salinity to the Fraser River discharge and is giving particular attention to the phenomena of diurnal and seasonal heating and cooling, and heat exchange with the atmosphere.

17. Mr. R. H. Herlinveaux is studying data from Race Rocks in the Strait of Juan de Fuca where he has revealed a correlation of the daily surface sea water with data from synoptic surveys.

18. Weathership "Papa": The Department of Transport is operating the Weathership on Station "Papa" (Latitude 50° N., Longitude 145° W.). Two ships occupy the station for alternate periods of forty-two days each, observing the weather continuously. Each ship has been equipped with a winch and bathythermograph, and the ships' companies make observations of temperature, from the surface to 450 feet depth, every two hours enroute to and from the station (weather permitting) and twice daily on station. This provides a mid-ocean time series of weather and ocean temperatures.

19. Mr. Hollister has been in charge of this program of oceanographic observations since its inception in July, 1952. The data are regularly processed, bathythermograms photographed, and surface temperatures are reported annually in the Manuscript Series, "Observations of Seawater Temperature and Salinity on the Pacific Coast of Canada". He is now preparing a climatic review of the data, illustrating the seasonal cycle of temperature structure and its variations through the years of observation.

20. Station "Papa" is situated close to the region where the North Pacific Drift Current divides, part turning north into the Gulf of Alaska and part turning south to form the California Current. It is in the region of maximum horizontal temperature gradient as shown by the NorPac survey. Hence any changes in the Drift Current should be indicated by marked changes of temperature levels. Thus the station is an ideal monitor of the ocean waters moving towards the Canadian Coast. It is evident that analyses of these data in conjunction with the NorPac survey should provide a critical assessment of oceanic conditions in this region of the North Pacific which is most important to Canadian interests. Proposals have been made to augment this program and to provide for study of the data.

21. Hecate Project: The Hecate Project undertakes to describe the water masses, properties of the water, and the currents throughout the year in Queen Charlotte Sound, Hecate Strait and Dixon Entrance. A year's series of seven bi-monthly oceanographic surveys on a planned-grid pattern were completed in June. These encompassed all parts of the area in all seasons. Temperature,

salinity and dissolved oxygen were observed at standard depths from surface to bottom on all surveys. During four expeditions, the tidal and non-tidal currents were observed every half-hour through fifty hours, at standard depths. These data have been published in three manuscript Data Records and are being studied by Mr. F. G. Barber.

22. Hecate Model: Currents and water movements in the area are primarily due to wind and tide and density gradients. It became evident in the early analysis of current observations that the tidal currents were complex. They could not be simply related to the tides tabulated for the region. Observations thus far have been inadequate to define the characteristic features of tidal circulation.

23. In view of the difficulties of obtaining reliable current data, and the prohibitive expense of developing a network of current stations for the entire region, alternatives to extensive current surveys were considered. Dr. N. P. Fofonoff analysed this problem and envisioned a hydraulic model to solve the tidal circulation. In addition, the model provides a means of viewing all the features at once and watching the sequence of events. This will certainly facilitate appreciation of the oceanography and interpretation of the data.

24. Construction of the model base was begun early in the year and it is hoped to complete the work under Mr. L. D. B. Terhune during 1956, and to make the observations during 1957.

25. NorPac Project: The NorPac Project was an international joint synoptic oceanographic survey over the whole Pacific Ocean north of the Tropic of Cancer and was carried out during August, 1955. There was one Canadian, seven United States and ten Japanese ships, each surveying a predetermined part of the area.

26. Such a survey has long been needed to determine the properties of the water, the currents and the biological productivity of this area, and to provide the background knowledge for the studies of fisheries problems.

27. To date the data records of all the agencies have been exchanged, the preliminary work has been reviewed and plans are now underway to publish an oceanographic atlas, which will include all the data and charts showing the distribution and properties of the water of interest to fisheries and to oceanography. The date of publication has been set for March 1, 1957.

28. The magnitude of this project clearly demonstrates what can be achieved by international cooperation in oceanographic research. It is hoped that further studies of this kind can be carried out.

29. Preliminary research already has demonstrated the effectiveness of the project. It clearly shows the need for information in the whole oceanic system if any of the parts are to be fully understood. This has shown to be particularly true in our own area.

Mr. A. J. Dodimead's analyses of the data from the surveys and exploratory fishing show that the Pacific salmon occur only in the region where the surface waters have lower salinities than

are normally encountered in oceanic waters. It appears that their distribution is not related to temperature.

30. Strait of Georgia Project: Dr. M. Waldichuk has completed his study of the data, from the synoptic surveys of 1949 through 1951, under the title, "Physical Oceanography of the Strait of Georgia". On the basis of temperature, salinity and current observations, he discussed the circulation, mechanism, and flushing characteristics of the region.

31. Dr. Tully is still working on the treatise "Properties of the Water in the Strait of Georgia" based on data collected prior to World War II, and the daily sea water observations. This study gives particular attention to the distribution of physical and chemical properties in space and time, and to controlling factors. The cycles of Fraser River discharge, insolation, the consequent structures, their relations and probability of occurrence are discussed.

32. These two researches are complementary and when combined with the Data Records form a comprehensive study of this region. It is proposed that the two lengthy papers be published together in a single volume.

33. Juan de Fuca Project: Synoptic surveys and comprehensive current measurements were made in Juan de Fuca Strait during 1951 and 1952. Mr. Herlinveaux has solved the tidal mechanisms and devised a method for predicting the tidal currents in all parts of the area from information in the Tide Tables.

34. As time from other duties allows, he is studying the properties of the water. He has derived the annual cycles of

temperature and salinity and their controlling factors. He has found that temperature bears a simple linear relation to salinity in all parts of the region throughout the year. The cycle of variation is dependent on coastal drainage, insolation and occurrence of coastal upwelling. The material is being arranged in two studies; one dealing with the time sequence of events at representative locations, and the other dealing with the differences from one part to another of the region.

35. Data in the approaches to Juan de Fuca Strait were collected in 1936 through 1938. These have been processed and partially analysed by Dr. Tully. These studies should be continued, utilizing the daily sea water observations at Swiftsure Lightship.

36. British Columbia Inlets Project: During the past few years, Dr. Pickard has made observations of the characteristics of the large inlets on the British Columbia coast. He has been devoting his available time to study of these data. He has made observations of depth, temperature, salinity, oxygen and bottom materials for most (29) of the major inlets. There are observations during two to five years in six of the larger inlets.

37. From a study of the heat budget he has developed a technique for estimating the mean seaward flow out of the inlets (Trites and Pickard) and this also yields an estimate of runoff when the salinity is known. This has been applied in a number of cases.

38. He has made observations of internal waves in the upper layers (0 - 80 feet) and in mid-depth (100 - 400 feet) in Bute

and Knight Inlets, and measurements of current profiles from surface to 1,000 feet in the southern inlets. He has observed that internal waves are large in the inlets and that surge currents as great as one knot occur in the deep waters.

39. He has also made an examination of bottom currents across the central part of Georgia Strait. Here he found reversing tidal currents of the order of 0.2 to 0.6 knots. The corresponding surface currents were of the order of one knot. It was observed that the tidal currents were strongest on the right in accord with the Coriolis force; the north-flowing flood is strongest on the mainland side, and the south-flowing ebb on the Vancouver Island side.

40. Chemistry: Dr. M. Kirsch has studied the ionic ratios in the brackish waters near several estuaries. He found that the magnesium content was higher and the potassium content lower in these regions than in the normally saline (30 ‰) sea water. He attributes the magnesium to the inflowing fresh water. He suggests that potassium is probably adsorbed on the silt.

41. He also found that the alkalinity of these waters was high and that this effect persisted for some distance from the stream. He suggests that this property may be used to trace the movements of water from an individual river.

42. Hydraulics of Salmon Spawning Gravels: A study of the hydraulics of flow through gravel in salmon spawning redds, in conjunction with the Salmon Investigation of the Biological Station, Nanaimo, B. C., was undertaken and the first phase was completed by Mr. R. A. Pollard in 1954. This involved the design

and calibration of equipment with which fisheries biologists could measure the oxygen content and flow of water through the redds, to determine the probability of survival of the eggs. A model spawning bed was established in the Model Laboratory where extensive studies of the flow through uniform and random gravels were made. The conclusions have been reported and implemented in the assessment of spawning areas in British Columbia and in the United States.

43. It has become apparent that modifications of apparatus, extension of the limits of calibration, and measurements of permeability of clutches of salmon roe, and estimation of waste products in the groundwater are also required. Mr. Terhune is carrying out this second phase of the work in cooperation with Mr. W. P. Wickett. It will lead to a further publication on this subject.

44. A number of technical services are required to support the research efforts.

45. Mr. McCracken, with assistance from sea technicians, determines the salinity of all sea water samples from the expeditions and daily observations. During the past year 20,000 titrations have been made. He also prepares standard solutions for use at sea, assembles and calibrates apparatus, and maintains a general laboratory service.

46. Mrs. Smith, and sea technicians when available, carry out routine computations involved in processing data, under direction of the scientist in charge of the project (Hecate, NorPac, etc.) on which they are working. This includes

instrument corrections, conversion of units, dynamic height calculations, and checking. The oceanographic data from each project are published in a manuscript series, "Physical and Chemical Data Records" which are prepared by Mrs. Smith. She also makes photographic enlargements of the bathythermograms, transcribes the auxiliary data on the reverse, and catalogues the cards for ready reference.

47. Mr. Herlinveaux services, stores, and maintains all sea equipment. In addition, he calibrates bathythermographs and prepares standard grids for the Pacific Naval Laboratory, Royal Canadian Navy, and the Institute of Oceanography at the University of British Columbia.

48. All data are catalogued by Mr. Hollister and preserved for use in a fireproof vault. He also maintains a "ready use" library of oceanographic reprints.

49. Mr. Hollister manages procurement and supplies. Miss B. M. Berisford handles all secretarial duties, filing and typing. Dr. Tully directs all research and administration.

#### Liaison

50. Biological Station, Nanaimo, B. C.: There is close contact at the working level between all members of this Group and the biological staff. Equipment and service has been provided for bathythermograph observations in the Young Salmon Program, Mid-Water Trawl Project, and Lake Studies. Plankton has been collected. Oceanographic equipment has been loaned to the Pollution Studies and Juvenile Herring Surveys. Salinity determinations have been made on samples collected by these groups

and bathythermogram prints have been provided. Arrangements have been made for the use of C.N.A.V. "Ehkoli" for several Pollution surveys. Joint studies have been undertaken on salmon spawning gravels and suspected shipworm infestation in the Fraser River Estuary. Daily sea water observations are being made at two stations at the request of the Herring and Groundfish Investigations.

51. Real assistance has been received from the Biological Station in the design and furtherance of research, facilities, direction, and administration. The assistance of Mr. M. Pirart and facilities of the Electronics Laboratory on the Hecate Model Project have been made available; also the art service of Mr. G. D. G. Denbigh in preparation of conceptions of the Hecate Model. All these are appreciated.

52. Pacific Naval Laboratory: There is close contact at the level of work between all members of both Groups. The resources, particularly the ships (C.N.A.V. "Ehkoli" and H.M.C.S. "Cedarwood") are pooled so that either Group may use either or both ships. The Pacific Oceanographic Group provides all oceanographic information to the Pacific Naval Laboratory including an atlas and oceanographic monitoring of P.N.L. operations. The Pacific Naval Laboratory manages the ships, provides all liaisons with the Navy, and provides base facilities in H.M.C. Dockyard.

53. Recently the Pacific Naval Laboratory built and installed equipment for bathythermograph calibration which is operated by the Pacific Oceanographic Group. The Pacific Naval Laboratory

is providing specialized machine design and shop service in the construction of bathythermograph winches for the Weathership Program, and alterations to the deep-recording current meter (bathyrheograph). They also undertook management, and bore the expense of the alterations to H.M.C.S. "Ste. Therese" for the recent NorPac Operation. Without this generous co-operation, it would be impossible for this Group to have operated successfully.

54. Hydrographic Service: Close liaison has been maintained with the survey and tidal work of the Service. C.G.S. "Wm. J. Stewart" made regular oceanographic observations, and a joint tidal current measuring project was carried out with C.G.M.V. "Parry" in the Hecate region. Copies of all current measurements are provided to the Tidal Branch.

55. In this liaison, it has been made clear that the Hydrographic Service is concerned with the prediction of tidal currents for shipping and their conclusions are published on the charts and in the Tide Tables. The Pacific Oceanographic Group is concerned with tidal circulation and transport of water at all depths. The collection of data is often similar but the use and interpretation is different.

56. Meteorological Service: The Port Meteorological Officer at Vancouver collects sea water temperature data from several coastal ships and refers them to the Pacific Oceanographic Group. Copies of the original weather data from meteorological stations at or near the daily sea water sampling stations are provided by Gonzales Observatory in Victoria. Barometric charts and specific data are provided on request from these

agents and from the Air Services Weather Bureau at Sea Island Airport, Vancouver. The Head Office of the Meteorological Service in Toronto has provided a complete set of the Canadian weather records dating from 1889, in addition to copies of all publications and microfilm copies of the ocean weather observations at Station "Papa".

57. Department of Transport: Most of the daily sea water observations are made by lightkeepers of the Department of Transport. For this service they are paid on honorarium. The District Marine Agents at Victoria and Prince Rupert provide liaison with these observers, and arrange transport of most of the samples and supplies in Department of Transport ships. The Agent at Victoria also provides liaison with the ships on Ocean Weather Station "Papa". Their assistance in expediting shipments of equipment, and bathythermograph supplies to the ships is invaluable. The efforts of the officers and men of the ships in maintaining the continuity of the bathythermograph observations is worthy of the highest praise.

58. The Telecommunications Division of the Air Services Branch transmit the weekly reports of daily water temperature observations that are used for the weekly broadcast of sea water temperatures.

59. Department of Public Works: Recently the Department was concerned with the possibility of *Bankia* infestation in the Steveston Harbour Basin in the Fraser River. Mr. Tabata studied the oceanography of the situation, and Mr. R. J. LeBrasseur (of the Biological Station, Nanaimo, B. C.) studied

the biology. A report including their recommendations is appended. From time to time oceanographic data are provided from the files as requested by the Department.

60. Institute of Oceanography: It is recognized that the Institute is the primary source of trained oceanographers in Canada and every effort is made to ensure its survival and healthy growth. Equipment is loaned, and seminars on Oceanographic research are given. Employment has been provided for the professors so that they may be able to continue their researches during the summer recess. Employment is also provided for students. This provides much needed assistance for the Pacific Oceanographic Group, and is a method of recruiting oceanographers.

61. The Institute reciprocates by assigning research problems in our data which has materially helped research production. Examples of such work are McLeod's thesis on daily sea water observations, Trites' thesis on Chatham Sound, and Campbell's thesis on Burrard Inlet.

62. Canadian Broadcasting Corporation: A weekly review of sea water temperatures, and a comparison with previous years is aired every Wednesday morning (7:00 a.m.) from the Vancouver Station, CBU, on the Fishermen's Broadcast. This service was inaugurated March 16, 1955.

63. Several recorded interviews have been given, describing the Hecate and NorPac Projects for broadcast on the Canada Series.

64. Public Service: Requests for information are continually being received from public and commercial bodies. These are met wherever possible from data in the files, or by advice on techniques of observation and interpretation. In the past year, the British Columbia Electric Company has required knowledge of bottom temperatures and currents, chemical companies have consulted on suitable sites for recovery plants. The City of Vancouver has sought information on sewage dispersion from particular outfalls. A Vancouver citizens' committee has asked for information regarding suitable locations for airports. The number of requests and range of interest for oceanographic information is steadily increasing.

#### Publications

65. The following papers have been published during the year (since November 15, 1954) or are presently in press:-

Barber, F. G.

Water Masses in Queen Charlotte Strait. Fish. Res. Bd. Canada, Prog. Rept. Pac., #100, 6-7. October, 1954.  
Seasonal Temperature and Salinity Variations in Queen Charlotte Strait, B.C. Fish. Res. Bd. Canada, Prog. Rept. Pac., #105, 14-15, February, 1956.

and S. Tabata.

The Hecate Oceanographic Project. Fish. Res. Bd. Canada, Prog. Rept. Pac., #101, 20-22. December, 1954.

and A. W. Groll.

Current Observations in Hecate Strait. Fish. Res. Bd. Canada, Prog. Rept. Pac., #103, 23-25, July, 1955.

Doe, L. A. E.

Offshore Waters of the Canadian Pacific Coast. J. Fish. Res. Bd. Canada, 12 (1) 1-34. 1955.

Dodimead, A. J.

Project NorPac. Fish. Res. Bd. Canada, Prog. Rept. Pac., #105, 16-18, February, 1956.

Herlinveaux, R. H.

Tidal Currents in Juan de Fuca Strait. J. Fish. Res. Bd. Canada, 11 (6) 799-815. 1954.

Kirsch, M.

Ionic Ratios of the Major Components in River-Diluted Sea Water in Bute and Knight Inlets, British Columbia. J. Fish. Res. Bd. Canada. In Press.

LaCroix, G. W. and J. P. Tully.

The Anomaly of Mean Sea Level in Seymour Narrows, B. C. J. Fish. Res. Bd. Canada, 11 (6) 853-883. 1954.

McCracken, L. H.

The Salinity of Sea Water. Fish. Res. Bd. Canada, Prog. Rept. Pac., #102, 24-26. March, 1955.  
A Simple Technique for Sealing Sea Water Samples. Journ. Mar. Res. In Press.

Pickard, G. L.

British Columbia Inlets. Trans. Amer. Geophys. Union, 36, 5, 897-901. October, 1955.  
Surface and Bottom Currents in the Strait of Georgia. J. Fish. Res. Bd. Canada. In Press.

Pollard, R. A.

Measuring Seepage Through Salmon Spawning Gravel.

J. Fish. Res. Bd. Canada, 12 (5) 706-741. 1955.

Tabata, S.

Oceanography of British Columbia Mainland Inlets.

V. Salinity and Temperature of Waters of Bute Inlet.

Fish. Res. Bd. Canada, Prog. Rept. Pac., #100, 8-11.

October, 1954.

Oceanographic Conditions in Steveston Harbour During  
Normal Discharge of Fraser River. Fish. Res. Bd.

Canada, Prog. Rept. Pac., #104, 26-29. November, 1955.

A Technique for Classifying Daily Seawater Observations  
of Temperature and Salinity. Trans. Amer. Geophys.

Union. In Press.

Sea Water Intrusion in Steveston Cannery Basin. Fish.

Res. Bd. Canada, Prog. Rept. Pac. In Press.

and A. W. Groll.

Effect of Ship's Roll Upon the Measurements Obtained  
by the Ekman Current Meter and Upon Its Behaviour.

Trans. Amer. Geophys. Union. In Press.

Trites, R. W.

Oceanography of Chatham Sound. J. Fish. Res. Bd.

Canada. In Press.

Tully, J. P.

Conditions for Troll Fishing. Fish. Res. Bd. Canada,

Prog. Rept. Pac., #101, 12-16. December, 1954.

Tully, J. P.

Oceanographic Vessel's Ordeal. Fish. Trade News, 7,  
7, 12-13. January, 1955.

Oceanography Along the Canadian Pacific Coast. Inter.  
North Pac. Fish. Comm., Bull. No. 1, 130-138. 1955.

Pollution Research in Alberni Inlet. Trans. Seventh  
B. C. Natural Resources Conference, 296-300. Feb-  
ruary, 1954.

Recent Advances in Oceanography. Amer. Peoples'  
Encyclopedia, Annual Supplement, Chicago, 799. 1955.

Recent Advances in Marine Biology. Amer. Peoples'  
Encyclopedia, Annual Supplement, Chicago, 682. 1955.

and A. J. Dodimead.

Salmon Water. Fish. Res. Bd. Canada, Prog. Rept. Pac.  
In Press.

#### Manuscript Reports

66. The following manuscript reports have been distributed  
during the past year:-

Anonymous.

Observations of Seawater Temperature and Salinity on  
the Pacific Coast of Canada, Vol. XIV. 1954. July 1,  
1955.

Physical and Chemical Data Record, Hecate Project,  
1954. January 15, 1955.

Data Record. Current Measurements, Hecate Project,  
1954. March 1, 1955.

Anonymous.

Physical and Chemical Data Record, Juan de Fuca Strait Project, 1951-52. With Appendix I, Current Measurements. April 30, 1955.

Physical and Chemical Data Record, Hecate Project. With Appendix I, Current Observations, 1955. August 15, 1955.

Physical, Chemical and Plankton Data Record, Project NorPac, July 26 - September 1, 1955. February 1, 1956.

Saur, J. F. T., J. P. Tully and E. C. LaFond.

Oceanographic Cruise to the Bering and Chukchi Seas, Summer, 1949.

IV. Physical Oceanographic Studies. April 1, 1955.

Tabata, S.

The Problem of Sea Water Intrusion in Steveston Cannery Channel. October 15, 1954.

Studies in Steveston Harbour Basin.

Part 1. Sea Water Intrusion into the Steveston Harbour Basin. February 15, 1955.

Summary Reports

67. The following summary reports are attached:-

- (a) Daily Seawater Observations, 1955. H. J. Hollister.
- (b) Ocean Weather Station "Papa" Bathythermograph Observations. H. J. Hollister.
- (c) Classification of Daily Sea Water Data. S. Tabata.
- (d) Hecate Project - Water Masses in the Hecate Region. F. G. Barber.
- (e) Heat Budget Studies. S. Tabata

- (f) Hecate Project - Current Observations.  
F. G. Barber.
- (g) Hecate Tidal Model. N. P. Fofonoff.
- (h) Project NorPac. A. J. Dodimead.
- (i) Salmon Water. A. J. Dodimead.
- (j) Strait of Georgia. J. P. Tully.
- (k) Juan de Fuca Strait. R. H. Herlinveaux.
- (l) Hydraulics of Salmon Spawning Gravels.  
L. D. B. Terhune.
- (m) Sea Water Intrusion in Steveston Cannery Basin.  
S. Tabata.
- (n) Sea Water Analyses Laboratory. L. H. McCracken.
- (o) Data Records. H. J. Hollister.
- (p) Bathythermograph Calibration. R. H. Herlinveaux.

John P. Tully,  
Oceanographer-in-Charge.

Nanaimo, B.C.  
March 31, 1956.

Daily Seawater Observations, 1955

General: There are seventeen locations on the British Columbia Coast at which a daily water temperature and seawater sample were obtained during 1955.

At eleven of the locations shown in the accompanying Table, the records extend for periods varying from forty-one years (Departure Bay) to fourteen years (Race Rocks).

Station	Commenced Observations	Station	Commenced Observations
Departure Bay (Biological Stn.)	September, 1914	Entrance Island	November, 1936
Cape St. James	July, 1934	Pine Island	January, 1937
Amphitrite Point	August, 1934	Ivory Island	July, 1937
Kains Island	January, 1935	Triple Island	November, 1939
Cape Mudge	November, 1936	Langara Island	March, 1940
		Race Rocks	May, 1941

Observations at Ivory Island lightstation in Milbanke Sound were terminated in December, 1955. Daily seawater observations in this region are now being made from McInnes Island lightstation, which commenced these observations in August, 1954.

At the six other locations:- East Point lightstation, Beaver Point wharf, Texada Mines wharf, Pulteney Point lightstation, McInnes Island lightstation, and Sandspit wharf, observations have been made for periods ranging from thirty months (Texada Mines) to sixteen months (Pulteney Point and McInnes Island).

A daily seawater observations program is also conducted by personnel of the United States Coast Guard on the ships that

occupy the Swiftsure and Umatilla lightship positions in the approaches to the Strait of Juan de Fuca. These include twice-daily bathythermograph lowerings (200 feet). The observations at Swiftsure were commenced in July, 1954; at Umatilla in July, 1955.

Daily water temperatures are observed by Department of Fisheries personnel at the New Westminster wharf, and the records are continuous since 1927.

In March, 1955 the four observing stations of Amphitrite Point, Entrance Island, McInnes Island and Triple Island commenced sending weekly reports of daily seawater temperatures to Nanaimo through the wireless facilities of the Department of Transport. These reports, along with a summarizing analysis, are sent to the Canadian Broadcasting Corporation Station CBU in Vancouver for presentation on the regular Wednesday morning "Broadcast for Fishermen".

Seawater Temperatures: The monthly mean surface seawater temperatures on the British Columbia Coast during 1955 were generally colder than the averages for the past ten-year period (1945-1954), with the exceptions of the months of January and February. At each station these two months were warmer than the 10-year average. January always showed the largest departure from average, the greatest departure being at Langara where the monthly mean temperature of 45.3° F was 3.2 F° warmer than average. In March, the trend at all the eleven stations shifted to colder-than-average, and this trend was more or less continued throughout the remaining months till the end of 1955.

Minor deflections from this colder-than-average trend were remarked for single months at Entrance Island and Departure Bay, where the August monthly means were 0.8 F° warmer than average. Cape Mudge, Ivory Island and Cape St. James had slightly warmer than average (0.3 F°) temperatures in June.

There appeared to be some similarity in the degree of departure from average temperatures between stations of the same oceanic type. For instance, Race Rocks and Pine Island showed a fairly constant colder-than-average departure of 0.8 F° to 1.0 F° during the period March to October, and in November and December at both stations the departure extended to 2.0 F° colder-than-average.

The comparison of 1955 temperatures from all seventeen stations with those for the previous year (1954) showed considerable variation, but the net effect was for 1955 temperatures to be colder than those in 1954. At most stations, the 1955 January and February monthly mean temperatures were warmer. November and December monthly mean temperatures at all stations were definitely colder than in 1954, with November usually showing the largest difference. This amounted to 4.5 F° for both months at Amphitrite Point and McInnes Island, and at many of the other stations it was about 3.0 F°.

Seawater temperatures during 1955 at Swiftsure Lightvessel were at a maximum (52.5° F) in July - August and at a minimum (44.3° F) in March.

Seawater Salinities: The 1955 monthly mean salinity data obtained at the long-term stations showed no common month-to-

month trend of differences when compared with the 10-year (1945-1954) average values. Usually the range of departures from average conformed to the concept of the physical oceanographic characteristics associated with the region in which the station was located. The widest departures from average were shown at those stations that come into the influence of the fresh water runoff from large rivers. At Entrance Island in Georgia Strait the 1955 June mean salinity of 26.30 ‰ was 2.84 ‰ higher than the 10-year average salinity, but the August salinity mean of 21.87 ‰ was 2.70 ‰ lower than the 10-year average. Langara Island's location can be classified as "exposed to open ocean". Here the greatest departure from average, in February, was only 0.45 ‰ and throughout the year the monthly mean salinities were lower than average. Pine Island, which can be classified as a "turbulent seaway", recorded monthly mean salinities during each month of 1955, with the exception of January, that were higher than average, with the maximum departure being 0.5 ‰ in May.

Comparing the 1955 salinities with those for 1954, there was a large amount of variability noted in month-to-month trends of the differences, just as had been noticed in the comparison with the 10-year averages. In the records from six of the stations it was clearly evident that 1955 salinities were generally higher than those for 1954. At Langara all the 1955 monthly mean salinities were average or lower-than-average. The other stations exhibited variable month-to-month differences. A regional similarity in salinity conditions was noted in some

of the stations located in Georgia Strait. At Entrance Island, Departure Bay, Texada Mines and Cape Mudge the 1955 monthly mean salinities are all higher than those for 1954. In general, the monthly fluctuations were proportional to the distance from the Fraser River. Beaver Point and East Point, in the southern regions of Georgia Strait, showed different patterns for the 1955-1954 monthly differences.

There was no definite seasonal pattern of variation in the salinity of the surface water at Swiftsure. It was generally about 31.5 ‰ but it was noticed that it was always higher than at Amhitrite Point, farther north along the Vancouver Island shore.

During the past year several statistical researches have been commenced which interpret these data so that they can be used to delineate normal and abnormal coastal conditions (Tabatathis report). Studies by Herlinveaux (this report) have shown that the observations at Race Rocks can be extended in scope to describe the seasonal variations that can be expected in the surrounding regions of the Strait of Juan de Fuca.

Volume XV, 1955, of the series, "Observations of Seawater Temperature and Salinity on the Pacific Coast of Canada" will be published early in April, 1956. It is planned to supplement the daily records with annual graphs of the temperature and salinity observed at each station.

Coastal Shipping Temperature Observations: A valuable adjunct to the daily seawater observations are the surface seawater temperatures being taken by four Canadian tug-boats

operating in British Columbia coastal waters. This program was commenced in August, 1954 by the Port Meteorological Officer in Vancouver, and the records are collected by him and sent to the Pacific Oceanographic Group. The observers take surface water temperatures every six hours along the route of the ship's tow. The routes extend from Hecate Strait to the Juan de Fuca Strait. No analysis has yet been made of these data but they could, combined with the daily seawater temperature data, provide indices of seasonal and regional changes in British Columbia coastal temperatures.

H. J. Hollister

## Ocean Weather Station "Papa" Bathythermograph Observations

The program of twice-daily bathythermograph soundings to 450 feet depth at Ocean Weather Station "Papa" (50° N., 145° W.) has been continued throughout 1955. There has only been a total of thirty-five days in which observations were missed, and none of these periods were for longer than ten days. The observations were missed because of rough weather, and breakdowns in the worn-out electric sounding winches. It is hoped to install new bathythermograph winches on both ships in the summer of 1956. The excellent observational record of 1955 is due entirely to the commendable efforts of the personnel of the two Department of Transport ships, C.G.S. "Stonetown" and C.G.S. "St. Catharines".

A definite seasonal cycle of temperature has been observed down to a depth of 250 feet. This pattern has been quite similar each year during the 3 1/2 year period of Canadian observations, but the values change from year to year. Below this depth, the water temperature does not vary more than 2 F° the whole year, and the seasons are not readily noticeable. From November to December the ocean to 250 depth is isothermal. In March and April, the coldest period of the year, this isothermal layer deepens to 400 feet. In May, the surface waters commence to warm and this warm layer extends downward in varying amounts as the summer progresses. The maximum temperature at the surface is reached in August; at the 100-foot depth in September; and at the 200-foot depth in October.

In April, the surface temperatures were 0.4 F° colder than the 1953-1954 period. This cold trend continued and increased

until by August the monthly mean temperature of 52.3° F was 5 F° colder than those for 1952, 1953 and 1954 (Canadian observations at "Papa" commenced in July, 1952). The remaining months of the year showed temperatures about 2 or 3 F° colder than in the previous three years. This deficiency in surface heat was reflected in lowered temperatures, to a lesser extent, at the 100-foot depth and 200-foot depth during most of this nine-month cold period. During the first three months of 1955 the temperature at 450 feet depth was slightly (0.5 F°) warmer than it had been in the previous two years. The 1955 water temperatures were very similar to those of 1950 (observed by the U.S. Coast Guard ships that occupied "Papa").

Surface temperatures at Station "Papa" follow a seasonal trend of cooling and warming similar to that in the British Columbia coastal waters. Station "Papa" surface temperatures in 1955 were 4 to 5° F colder than those at Amphitrite Point on the west coast of Vancouver Island for the first six months of the year until July. During the latter half of the year the difference between temperatures at the two locations reduced from 3° to 2 F°.

A synopsis of the daily water temperature data at the four depths of 0, 100, 200 and 400 feet is presented in the annual volumes of the daily seawater data. A specially prepared reproduction of all the twice-daily bathythermograms obtained during the months of August, September and October, 1955, was included in the Canadian NorPac Data Record.

H. J. Hollister

### Classification of Daily Sea Water Data

It is necessary to classify the large amounts of data originating in the daily sea water data if they are to be interpreted. The proposed technique is to assign rank to the observed values depending on their statistical departure from the smoothed annual cycle. This type of classification allows direct comparison of data from any observatory or over any period of time.

In the seasonal or monthly classifications, the grand monthly means of variables (e.g., sea temperature) obtained from fifteen years of observations are considered as representing the average state. The magnitudes of the individual monthly means are then compared statistically to the grand monthly means. Those falling within the limits of the probable errors ( $0.675\sigma$ ) are considered normal and are given the rank  $\pm A$ . Those falling between this limit and the standard deviation  $\pm (0.675\sigma \text{ to } \sigma)$  are above or below normal with rank  $\pm B$ . Between the standard deviation and the fiducial limit  $\pm (\sigma \text{ to } 2\sigma)$  the values are much above normal, ranked  $\pm C$ , and beyond this limit they are regarded as abnormal ( $\pm D$ ).

An example of this classification is shown in Table I using the daily sea water temperature data from Triple Island light-station. The years 1947 and 1948 may be considered as representing average years because of the few extremes in them. The year 1940 is an example of an abnormally warm Summer and 1950 an example of an abnormally cold Winter.

This method can also be used for first order correlation using the ranked deviations of one series with those of another.

TABLE I  
Triple Island Surface Sea Temperatures

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1940	+C	+C	+C	+D	+D	+D	+C	+C	+C	+C	+C	+C
1941	+C	+C	+C	+C	+C	+C	+C	+C	+C	+C	+B	+C
1942	+B	+C	+C	+B	+B	+B	+D	-B	-C			
1943						-B	-C	-C	-C		+B	+B
1944	+B	+B						-C	-C		+C	+C
1945	+C	+B				-B	-B		-C	-C	-C	-B
1946										-B	-C	-C
1947	-C	-B						+C				
1948											-B	-C
1949	-C	-C	-C	-C			-B			-B		-B
1950	-D	-C	-C	-B	-C				+B		-C	
1951				-B	-B			+B		-C		-B
1952						-C		-C		+C	+B	
1953								+B	+C		+B	+B
1954				-B	-B	M I S S I N G			+C	-B		

Note: Months whose values fall within the probable error (rank  $\pm$  A) are omitted from the Table.

With some modification, this method of classification is applied to short-term variations such as those of daily sea temperature and salinity through an individual year. A reference curve is drawn through the monthly mean values. The standard deviation and probable errors are computed from the differences of observed values and those from the reference curves. Deviations are classified in the same manner as before. Examination of temperature and salinity shows that there are about three major deviations occurring every month in both of these variables. At present this method is being applied to the daily sea water observations along the coast of British Columbia.

Hecate Project - Water Masses in the Hecate Region

Seven oceanographic surveys in the Hecate region were scheduled for the period May, 1954 to June, 1955. These surveys (Table I) have been completed and the data reported.

TABLE I

Catalogue of Oceanographic Cruises

Cruise	Period	Ship
H-54-1	May, 1954	H.M.C.S. "Cedarwood"
H-54-2	July, 1954	C.N.A.V. "Ehkoli"
H-54-3	August, 1954	H.M.C.S. "Cedarwood"
H-54-4	December, 1954	H.M.C.S. "Cedarwood"
H-55-1	February, 1955	H.M.C.S. "Jonquiere"
H-55-2	April, 1955	H.M.C.S. "Jonquiere"
H-55-3	June, 1955	H.M.C.S. "Cedarwood"

The data indicate that surface salinities are low, 30 to 32 ‰, over the entire area during all seasons. There is a gradient from oceanic salinities along the seaward side of the area, to lesser values along the mainland shore. In Dixon Entrance, surface salinities are generally less than in either Hecate Strait or Queen Charlotte Sound. Dilution from land drainage and precipitation is evident in all seasons, particularly in the southeast and northeast sectors, and along the mainland coast.

In general the volume of fresh water entering the region exhibits two yearly peaks. One occurs during the late Autumn, generally November, and coincides with the occurrence of the yearly maximum precipitation. The second occurs during the Summer when the rivers and streams are swollen with melt water from the winter snows stored at high elevations, and in the interior.

The two principal rivers, the Skeena and the Nass, which carry off melt water from the interior drainage basins reach a peak volume in late May and early June. Other smaller rivers which drain the immediate coastal region reach a summer maximum in July and occasionally as late as August. This difference in time of occurrence of peak runoff is exhibited by the salinity data obtained from the daily sea water observations made at Triple and Ivory Island. Triple Island, located close to the mouth of the Skeena River, indicates a minimum in June close to the time of peak Skeena runoff. Ivory Island, located farther to the south and removed from large rivers, indicates a minimum summer salinity in July and August in phase with the peak runoff from the coastal regions.

The existence of a halocline as observed in offshore waters is not a marked feature of the Hecate data. There is, in general, no marked transition from an upper layer of low salinity water to the deeper high salinity water. Vertical salinity gradients are larger and shallower in Summer than in Winter.

The annual range of surface temperatures varied between 7° C in the Winter (February) and 14° C in the Summer (August). Little consistent variation normal to the coast was observed. In general, the surface waters of Dixon Entrance were colder than the waters farther south.

A temperature structure does exist and varies seasonally. In the Spring and Summer the surface waters are warmed and a thermocline is developed which becomes more pronounced as the Summer progresses. In the Autumn and Winter the near surface

waters become homogeneous due to cooling and extensive wind mixing.

In any one season both the salinity and temperature structures are dependent to a considerable degree on position.

Another principal feature of the Hecate data is a seasonal variation of temperature and salinity of the deeper waters. This water is warmer and less saline in Winter than in Summer. The effect is most marked in the inshore regions and becomes less with distance to seaward.

During the Autumn and Winter the southeast winds are much stronger than during the Summer. In the Autumn, under the influence of these winds, surface water is moved toward the mainland coast, then northward parallel to it. This lighter surface water is accumulated in the coastwise region causing a compensating offshore movement of the deeper water. The observed variation in temperature and salinity is brought about when this deeper water is replaced with the less saline, summer warmed, surface water.

In the Spring, when the intensity of the southeast winds decrease, a relaxation occurs. The accumulated surface water moves offshore with a compensating inshore movement of the deep, colder, more saline water from the ocean.

The seasonal variation of the prevailing southeast winds is the chief factor causing the Summer and Winter distribution of temperature and salinity of the deeper water. The oceanographic data indicates further that certain variations in the timing and extent of these type water conditions probably occur. The data

of 1954 suggest that Winter conditions were endured until July, while those of 1955 suggest that an abrupt return to Summer conditions took place between February and April. The occurrence of this phenomenon is being related to the occurrence of southeast winds. It is noted that the greatest variability in winds occurs during the Spring and least variability during the Autumn. It would be expected therefore that little variation would occur in the onset of Winter conditions while considerable variation may occur in the return of Summer conditions.

F. G. Barber

## Heat Budget Studies

Various terms of the heat budget equation were examined to understand more fully the processes causing the fluctuation of surface sea temperatures and to gain some idea of the magnitudes involved in such processes.

Pertinent meteorological data and surface sea temperature data from 1947 to 1955 at Triple Island have been used in the analysis. In addition to these, oceanographic data obtained during the Hecate surveys (1954-1955) and bathythermograph data taken at Swiftsure Lightship have been used to compare the heat transfer at the sea surface at Triple Island and the actual loss or gain of heat from the water column in the two general locations, Dixon Entrance and Juan de Fuca Strait.

In Table I are shown the grand monthly means (1947-1954) of the incident solar radiation, cloud cover, reflectivity, solar radiation corrected for cloud cover, absorbed portion of solar energy, effective back radiation, evaporation, conduction, and the total heat transfer across the air-sea boundary at Triple Island.

The amplitude of the annual cycle of solar radiation is the largest of the terms in the heat budget equation and contributes most to the annual variation of heat transfer at the sea surface. Under observed cloud conditions at Triple Island, only one-half of the solar radiation reaches the sea surface and is subsequently absorbed into the sea. The maximum and minimum periods of heating occur in June and December respectively and are in phase with the radiant energy.

Heat lost by effective back radiation is relatively constant (25% variation from the mean). It is a minimum during the Summer and a maximum during the Winter. Since the amplitude is relatively small, it does not contribute much to the annual variation of the heat transfer.

The annual cycle of evaporation is quite marked. It is greatest in the Winter and least in the Summer. The transfer of sensible heat was computed using Bowen Ratios and multiplying with the evaporation values. The annual cycle of this term is in phase with that of evaporation and varies from a maximum loss in the Winter to a small gain in the late Summer. The magnitudes of the combination of evaporation and conduction are almost comparable to those of the amplitudes of solar radiation. Therefore, they are also of major importance in the variation of heat transfer. In Winter these terms are dominant.

The main feature of the total heat transfer across the air-sea boundary is that the greatest loss (more than 300 g.cal./cm.<sup>2</sup>/day) occurs during a short period in the Winter (December, January) whereas the maximum gain (more than 200 g.cal./cm.<sup>2</sup>/day) occurs in a longer period in the Summer (May to August). Periods of no net heat transfer occur in the latter part of March and September.

During the year there was a net loss of 20% of the total heat. However the errors involved in the computation of the heat budget terms are large and may exceed 20%, therefore it is not too easy to make specific conclusions about this net loss. At present it is assumed that it is real to some degree and that

in order to maintain heat balance the deficit must be supplied by advection of warm water.

An examination in the change of heat content of a column of water in Dixon Entrance revealed some interesting features. During the period from July to August, 1954 there was actually a decrease (about  $100 \text{ g.cal./cm.}^2/\text{day}$ ) of total heat content when the net gain at the sea surface was about  $230 \text{ g.cal./cm.}^2/\text{day}$ . In Juan de Fuca Strait a similar drop in the heat content occurred. This implies that a mass of cold water moved into the areas. This was probably due to the intrusion of upwelled water. Between August, 1954 and February, 1955 the decrease of heat content was about  $30 \text{ g.cal./cm.}^2/\text{day}$  in Dixon Entrance and Juan de Fuca Strait, when there was a mean loss of heat at the sea surface of about  $150 \text{ g.cal./cm.}^2/\text{day}$  at Triple Island. This may be due to northerly transport of warm water into the region under the influence of southerly winds that prevailed during this period.

S. Tabata

TABLE I

Rate of Heat Energy as Expressed in g.cal./cm.<sup>2</sup>/day.

(Positive if Heat Received by Sea.)

	Incident Solar Radiation (direct and scattered)	Cloud Cover (tenths)	Reflect- ivity	Incident Solar Radiation (corrected for cloud cover)	Solar Radia- tion Absor- bed by Water	Effective Back Radiation	Evapor- ation	Conduc- tion	Total Heat Transfer Across Air-Sea Boundary
Jan.	132	7.20	0.17	65	54	-105	-171	-118	-341
Feb.	242	7.55	0.13	112	97	-106	-120	- 70	-198
Mar.	420	7.15	0.09	207	188	- 96	-100	- 37	- 49
April	612	6.95	0.08	310	285	- 91	- 74	- 7	+103
May	762	7.55	0.07	354	329	- 84	- 40	+ 5	+214
June	825	7.65	0.07	377	350	- 88	- 58	+ 4	+214
July	770	7.60	0.07	353	328	- 84	- 30	+ 10	+229
Aug.	645	6.95	0.08	327	300	- 86	- 22	+ 10	+201
Sept.	482	6.95	0.09	244	222	- 88	- 35	+ 19	+114
Oct.	295	7.95	0.11	128	114	-102	-112	- 26	-127
Nov.	160	7.95	0.16	70	59	-108	-118	- 53	-219
Dec.	104	8.10	0.19	45	36	-119	-171	-115	-369

Hecate Project - Current Observations

Observations of current speed and direction were made at a number of positions throughout the area. The majority of this work was carried out from H.M.C.S. "Cedarwood" while anchored, generally to one anchor with reduced scope. Observations were made hourly at the surface using a controlled current drag, and at subsurface depths using an Ekman meter.

These data reveal that rotary currents of tidal period are general, with excursions up to eight miles. Maximum streams vary with position and were of the order of 1/2 to 1 1/2 knots. The time of these maximum strengths generally occur about the time of mid-range for the tide along the shore. Similarly, where a time of slack water or minimum tidal stream could be inferred they occur close to the times of high and low water.

Net movements have been calculated for each depth at each station. These indicate that the net movements are small, usually between 5 and 10 miles per day. The largest movements were generally observed in the surface waters, although at a number of positions the net movements occurring at intermediate depths and close to bottom were the greatest.

The data suggest that a seasonal variation of net water movement occurs in Hecate Strait. In May a small but persistent southerly movement was observed, while in early September a northward movement was becoming apparent. It is considered that these seasonal variations of net movement in this region are wind dominated.

In June, seaward of the northern end of Vancouver Island,

a slow movement of the deeper water to the northeast into Queen Charlotte Sound was noted. At shallower depths a slow movement was directed to the southeast, parallel to the shores of Vancouver Island. All the net movements in this region were of the order of 5 miles per day.

In June stations were occupied at several positions in the southeastern sector of Queen Charlotte Sound. At this time the net movements were apparently related to the discharge of fresh water from runoff and it is expected that they will vary seasonally with the discharge. In the region just west of the Virgin Rocks the net movements at all depths were directed to the south and west. They tend to confirm the existence in the summer of a clockwise circulation around the Goose Island banks indicated by the synoptic survey data.

The pattern of net movements with depth observed in Queen Charlotte Strait, off Pine Island, is consistent with the known distribution of water movement in regions where fresh water from land drainage is entering the sea. The fresh water moves persistently seaward entraining sea water from below to form an upper brackish layer; a movement of deep water takes place in the opposite direction toward the source of the fresh water. The observed net movements (Table I) clearly indicate the extent of the seaward movement in the upper layer and the landward movement in the deep layer. A depth of no net motion occurs at about 50 meters.

TABLE I

<u>Depth (m)</u>	<u>Velocity (cm/sec)</u>	<u>Direction of Movement</u>
0	-23.5	Offshore
10	-20.5	"
20	-15.5	"
30	- 9.9	"
50	- 1.3	-
75	+14.3	Onshore
100	+15.6	"
125	+16.4	"

F. G. Barber

### Hecate Tidal Model

A very important part of the Hecate project is to determine the tidal and non-tidal current, the circulation systems, and their controlling factors. Currents in the region are due to winds, tides and density gradients. In nature these components are combined in varying degrees, from time to time and place to place, to produce the resultant currents and circulation patterns. Appreciation of the kinetics requires that the contribution of each component be recognized. Prediction of the system requires that the factors governing each be predictable.

In approaching this problem it was realized that the resultant currents could be observed. Hence if two of the components could be evaluated independently, the third could be determined by differences. The contribution of the density gradients may be computed readily from the oceanographic data. Barber and Tabata (this report) are making intensive studies of these factors.

Direct current observations were undertaken and have been described by Barber in this report - Current Observations. Tidal analyses were undertaken. The cycles of velocity and direction were related to the difference of tidal height from the ocean (Clayoquot) to the mainland side of the region (Prince Rupert). It was planned to complete a grid of such stations. It was anticipated that with the aid of the Tide Tables the currents at all stations could be predicted to a single day. Hourly current charts could be prepared showing the vectors at each station, and these could be resolved to show the circulation. This

procedure was successful in Juan de Fuca Strait and Seymour Narrows. The method failed in the Hecate region because the proportionality and phase differences between the tidal and current cycles was found to be variable. It became evident that the tidal currents had a complex structure and could not be simply related to the tides tabulated for the region. Thus far it has not been possible to define the characteristic features of tidal circulation.

It is probable that the general current systems are fairly stable but it is doubtful if they could be discovered with these sea procedures, even if the observations were indefinitely prolonged.

The current pattern might be solved by simultaneous series of observations at thirty or more positions in the area. This is uncertain, and in any case would require more ships, personnel and equipment than are available.

In view of the difficulties in obtaining reliable current data, and the prohibitive expense of developing a network of current stations for the entire region, alternative approaches were sought. It was concluded that some form of model would be required.

A tidal model of the region can, in principle, be a theoretical model to be analysed by numerical techniques, or it can be a physical analogue based on equations governing circulation.

A theoretical model is preferable because it provides a more satisfactory understanding of the circulation in terms of the fundamental laws of fluid motion. In practice, however, it

is difficult to set up an adequate theoretical model of tidal circulation which can be analysed numerically - even with the aid of the most advanced computing machines.

The region is sufficiently large so that the effects of the Earth's rotation cannot be neglected. If these are considered, the computations required to determine the tidal currents in a body of water with the simplest geometrical boundaries becomes extremely involved. If the Earth's rotation is neglected the task of computing the tidal currents in a region of irregular shape and depth is still a formidable one. Furthermore, the theoretical model cannot be generalized to include vertical velocity structure or friction because of the lack of numerical techniques to analyse such a model.

A more promising approach is offered through the use of a physical analogue; particularly a hydraulic model. The hydraulic model can be constructed to take into account many details of shore line and bottom topography. The effects of bottom roughness, fresh water runoff, and non-tidal currents can be determined by suitable modifications of the model. The observer is able to obtain synoptic pictures of the circulation at any stage of the tide, or a detailed picture over many tidal cycles at any point in the model. This may be done with a minimum expenditure of effort as compared with obtaining similar information from the prototype or a theoretical model. The hydraulic model is of considerable value as a visual aid to the observer and can be used to point out regions of special interest in the prototype.

A disadvantage of the hydraulic model is that geometric

and kinematic similarity cannot be preserved while simulating a region of this size. As a consequence, the model cannot be relied upon to give complete detailed information about the prototype and must be carefully compared with the prototype to ascertain the limits of reliability. Another disadvantage of this model is that its size precludes the possibility of building it on a rotating platform so that the effects of the Earth's rotation could be simulated. However, it is possible to compensate for this by applying numerical corrections to the velocities observed in the model. Simple methods for such corrections are being studied.

A complete analysis has been made of the geographic features, the model laws, and the construction components.

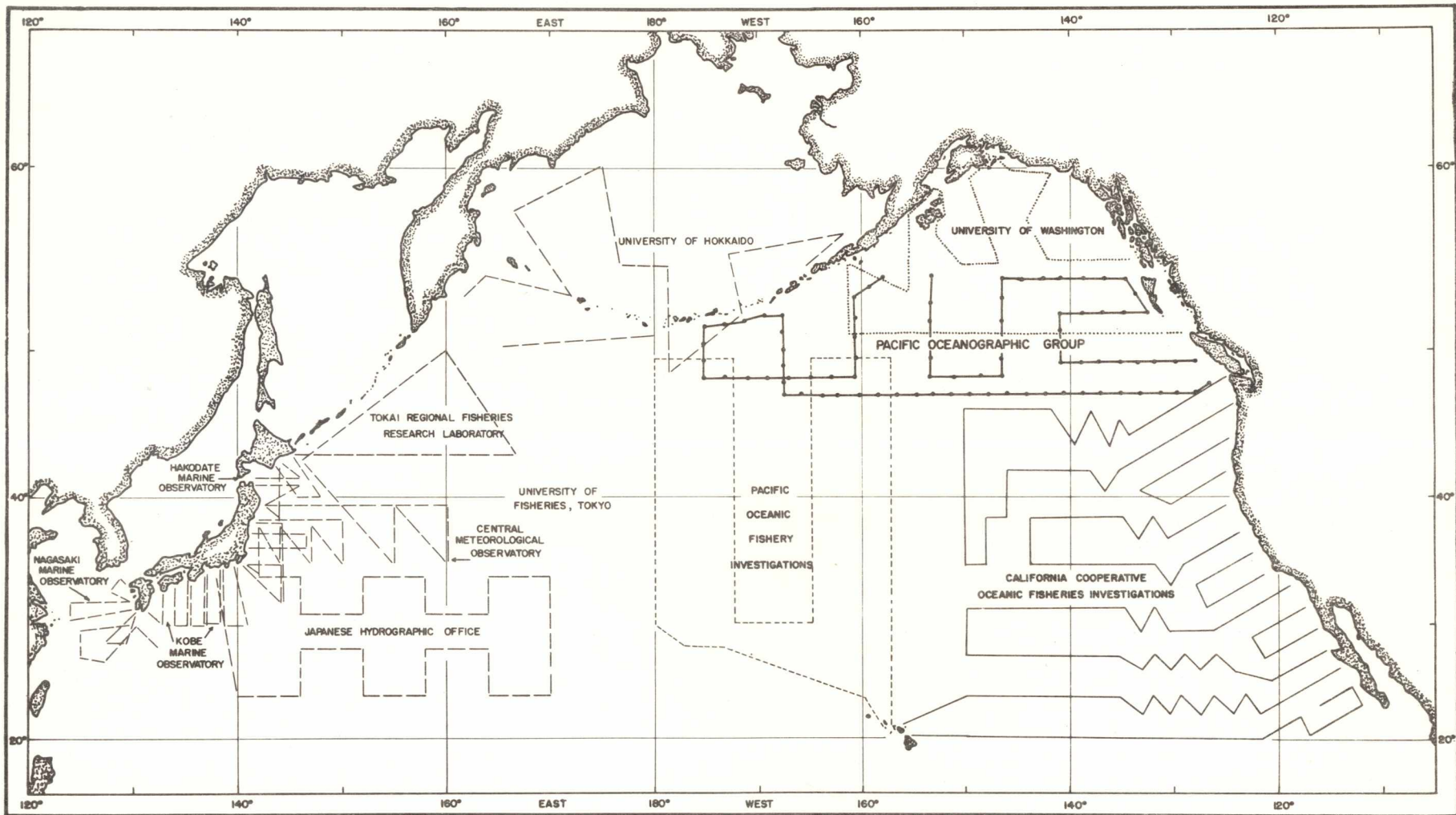
The hydraulic model (104 feet by 45 feet) includes the whole region of the surveys. It is a distorted scale, single-fluid model, using block construction with cement surface. Tides are to be generated across the oceanic approaches by gates hinged along the bottom and controlled by a seven-component Kelvin tide machine. Observation of the movement of dye patches in the water are to be made photographically from a 90-foot tower. This will be comparable to aerial photography, from a height of 360 miles. A tidal day (24 hours, 50 minutes) requires only 62 seconds in the model so that the cumulative effects of tidal circulation over a period of time may be observed quickly.

## Project NorPac

Project NorPac was undertaken as a synoptic survey of the North Pacific Ocean extending from Latitude 20° N., to the Bering Sea and from the North American coast to the east coast of Asia. During July, August and September agencies of Japan, United States and Canada combined their facilities and completed the greatest project of its kind ever undertaken. In all twenty vessels occupied about 1200 oceanographic stations according to an agreed plan, as shown in the accompanying diagram.

The Canadian expedition departed on July 26th in the R.C.N. frigate H.M.C.S. "Ste. Therese" under the command of Lt. Commander W. F. Potter. It returned 37 days later on September 1st after having cruised 7,160 miles and accomplished its mission.

Eighty-five stations were occupied at which observations of temperature and water samples were taken at intervals from the surface to 1,200 metres depth. Aliquots of the samples were analysed on shipboard for dissolved oxygen and inorganic phosphate. Aliquots were taken to the base laboratory for salinity determination. Further aliquots were sent to the United States Atomic Energy Commission and to the Scripps Institution of Oceanography for radio-activity tests. Samples were also collected for "Heavy Water" analyses. Two hundred and sixty-seven bathythermograph lowerings were made, one at each station and an average of two between each station. Plankton was collected to 400 metres depth at each station. Geomagnetic current measurements were made in part of the area. Fishing was not attempted



**NORPAC CRUISE PATTERNS**  
**August 1955**

but sea and bird life was noted. Weather observations were also made four times daily.

Each agency carried out a similar program and processed its own data and prepared data records. These were exchanged at a meeting in February at Honolulu, so that each group has a complete set of records of the entire operation.

The first analysis of the data indicates some important oceanographic features off our coast.

The salinity and temperature structure along with the general circulation has been discussed fully in the following section. However the horizontal surface distribution of temperature, salinity, oxygen and phosphate can be discussed briefly.

South of Latitude  $48^{\circ}$  N. there is a gradient of increasing temperature and salinity toward the sub-tropic waters of the mid ocean. North of this, in the Gulf of Alaska, there is a gradient of salinity which can be associated with land drainage increasing from the shore towards the centre of the region. The temperature distribution is not so definite as the salinity. The waters along the mainland coast were somewhat warmer than those in the centre of the region. Along the Alaskan peninsula and the Aleutian Islands there is a border of cold water.

The principal oceanographic feature is found in the centre of the Gulf. Here, there exists a region of cold saline water. Associated with this are found high dissolved inorganic phosphate concentrations and low dissolved oxygen. The dynamic height shows that there is a cyclonic centre associated with

this cold saline water. Around this there is evidence of a slow cyclonic movement.

A. J. Dodimead

## Salmon Water

The first analysis of the NorPac data indicates its importance in our own area. Here we are primarily concerned with the association of water structure to the distribution of salmon.

The surface sea water temperatures are shown in Figure 1. The coldest waters were observed north of Latitude 48° N. along the Aleutian Islands, and in the Gulf of Alaska. In these regions the temperatures were between 10° and 12° C. These were the maximum Summer temperatures experienced during 1955. In mid-ocean south of Latitude 38° N. the temperatures were generally above 24° C and increased slightly towards the Tropics. Between these warm and cool regions there was a marked gradient of temperature.

In the northern region the temperature structure varies seasonally as shown in Figure 2A, the surface waters being warm in Summer and cold in Winter. In the Summer a warm homogeneous upper zone, 10 to 20 metres in depth is formed. Below this is a thermocline. This is a transition zone in which there is a marked temperature gradient between the warm upper zone and the cold waters of the deep ocean. In the Winter the waters cool. In the Gulf of Alaska the temperatures in the upper 150 metres of depth decrease to about 5° C the same as the deeper ocean water, and the thermocline vanishes.

In the Tropics the upper zone of warm water and the thermocline are present throughout the year.

Figure 3A shows representative Summer and Winter sea water temperatures along the surface. Their difference is the seasonal

temperature range which decreases from north to south. Because of this seasonal range, temperatures greater than  $12.5^{\circ}$  C are found as far north as Latitude  $48^{\circ}$  N. in mid-Summer. By late Winter only the waters south of Latitude  $38^{\circ}$  N. are this warm. Thus any such temperature boundary shifts with the seasons.

The character of the water also depends on its salt content, which is independent of temperature. Figure 3B shows that the surface salinity decreased generally from south to north somewhat similar to the Winter temperatures. Figure 3C shows the distribution of salinity with depth in a longitudinal section from the Tropics to the northernmost part of the Gulf of Alaska on Longitude  $147^{\circ}$  W. (the dashed line in Figure 1). The salinity structure in the northern and southern waters is distinct. In the Gulf of Alaska the salinity increases with depth; in the sub-Tropics it decreases.

South of Latitude  $38^{\circ}$  N., in the sub-Tropics, the surface salinity is high (greater than  $35 \text{ } \text{‰}$ ) and becomes less toward a minimum ( $34.00 \text{ } \text{‰}$ ) at 600 metres depth. This structure occurs at all times of the year.

A typical salinity structure in the gulf is shown in Figure 2B. In the upper 60 to 100 metres of depth the salinity is low; less than  $32.8 \text{ parts } \text{‰}$ . Below this to about 170 metres depth there is a halocline in which the salinity increases by one part per thousand or more. Below this the salinity increases gradually towards the great depths. This structure was observed north of Latitude  $40^{\circ}$  N. all across the Pacific Ocean from Asia to the North American coast, and in the southern part of the Bering

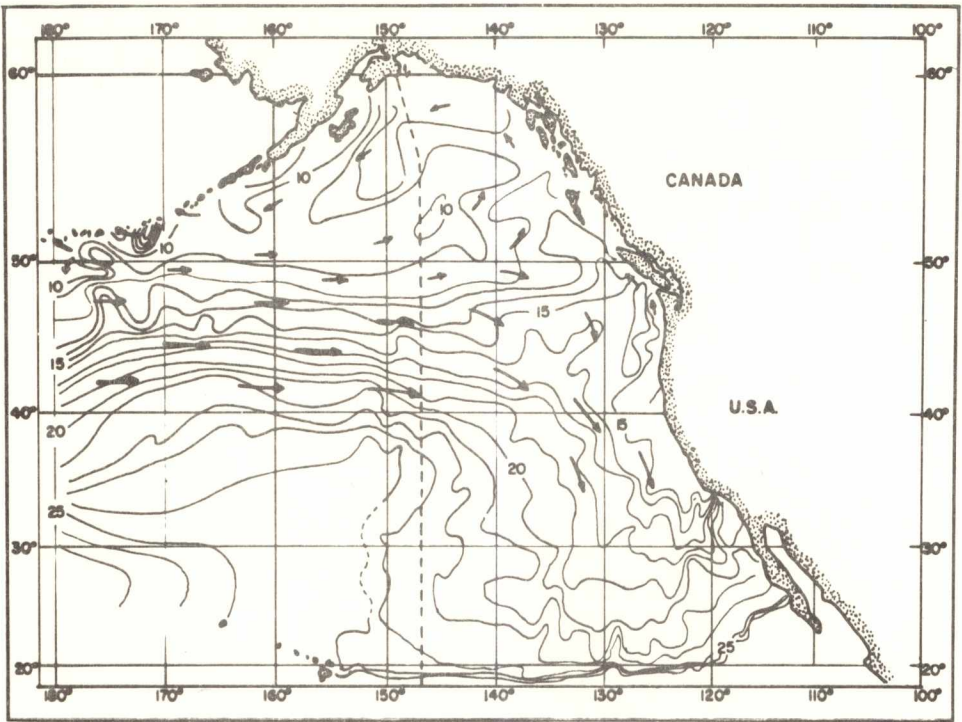


Figure 1.

Surface temperature distribution and currents in the Northeast Pacific Ocean, Project NorPac, 1955

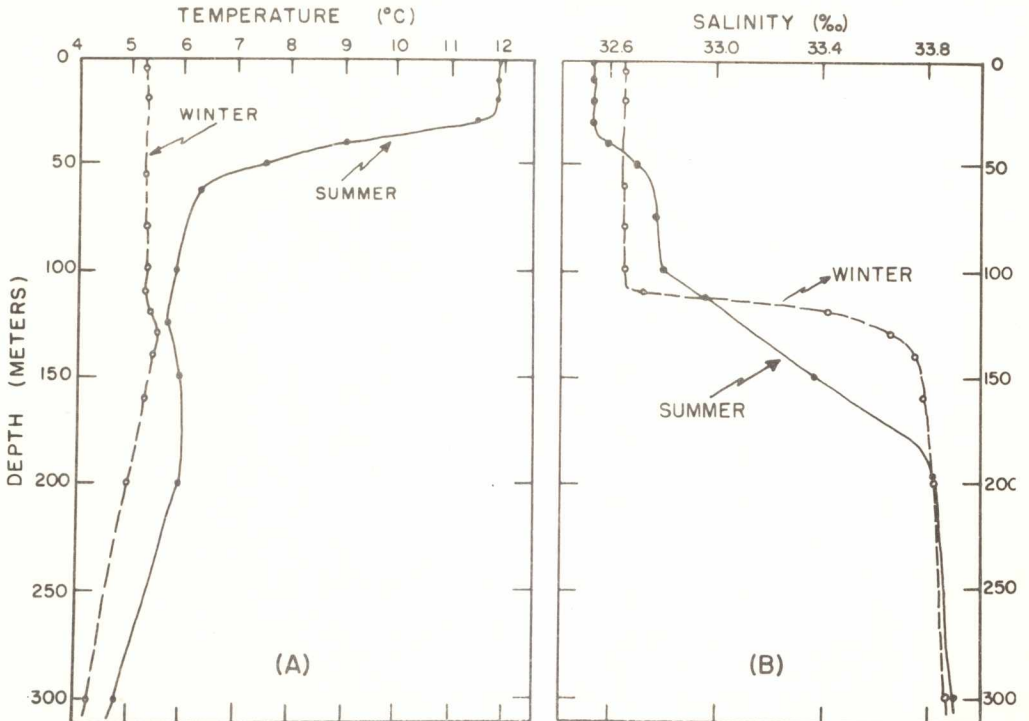


Figure 2.

(A) Representative temperature and (B) salinity structure in the Gulf of Alaska during the summer and winter.

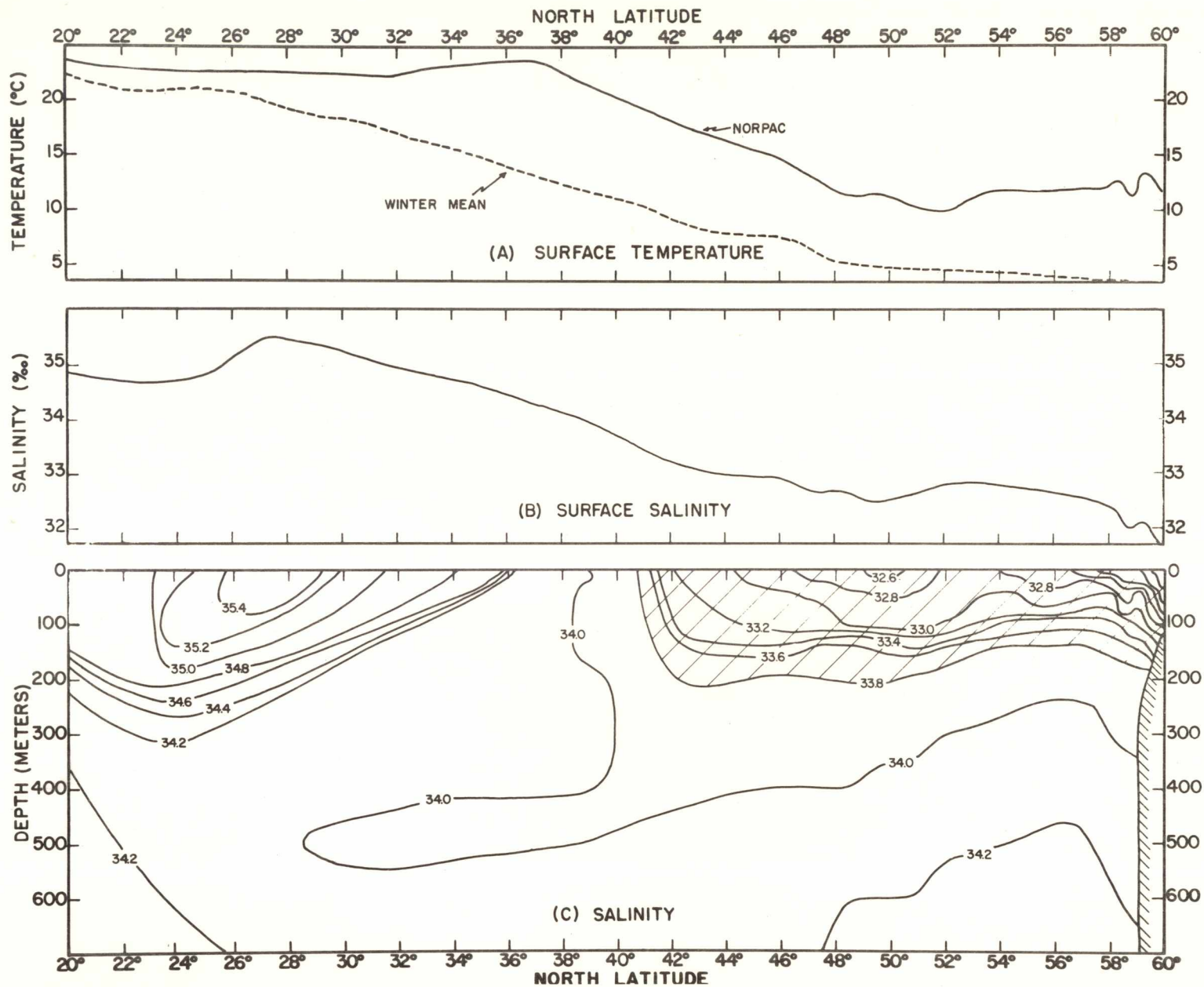


Figure 3.

(A) Surface sea water temperature, (B) surface salinity and  
(C) salinity-depth section along longitude 147° W., NorPac, 1955.

Sea. It is the same structure that is observed in the Canadian and Alaskan coastal waters. Previous surveys show that this surface zone of low salinity occurs throughout the year (Figure 4B). The halocline, unlike the thermocline in these regions, is a permanent feature of this area.

There are three distinct regions. The mid-ocean region south of Latitude  $38^{\circ}$  N. is the sub-Tropics. Here the surface waters are warm and saline in all seasons. Both the temperature and the salinity decrease with depth. North of Latitude  $40^{\circ}$  N. the structure is as shown in Figure 2B and 3C. Between these two regions there is a boundary in which the salinity is constant from surface to 500 metres depth and there is no halocline. Although there are data showing that the northern and southern structures exist throughout the year, there are no data showing the Winter position of this boundary. It is difficult to say whether it shifts with the season, or is more or less fixed.

The fishing experience around the north Pacific shows that salmon occur in all the coastal waters north of Latitude  $42^{\circ}$  N. These have the same temperature and salinity characteristics as the sub-Arctic waters in the Gulf of Alaska. Recent data from exploratory fishing by United States and Japanese agencies during the Summer of 1955 indicates that salmon occur in the waters having these properties, but do not occur outside of them. The temperatures of these waters vary greatly through the year. In the coastal region the salmon tolerate temperatures from less than  $5^{\circ}$  to  $20^{\circ}$  C. Salmon have not been sought on the high seas in Winter, but it is reasonable to assume that they would not

desert the northern seas because of the low Winter temperatures.

The salinity of the upper zone remains low all year round in the coastal waters where salmon are known to occur, and in the northern offshore waters where they may be anticipated. Exploratory fishing for Albacore has not encountered salmon in the region of high salinity, even in the Winter when the temperatures fall within the known range of tolerance. It appears probable that salmon are associated with the northern salinity structure; that is, an upper zone of low salinity bounded by a halocline.

The circulation of these waters is shown in Figure 1. There is a general easterly drift south of Latitude 52° N. The southern side of this drift has its origin in the Kuroshio Current. The water on the northern side of this current originates in the Bering Sea. As this drift approaches the North American continent part turns south flowing toward the Equator. The remainder turns north and moves slowly around the Gulf of Alaska. Most of this water is dissipated through the Aleutian Islands back into the Bering Sea. In these Summer data there was no evidence that any large proportion rejoins the easterly drift to form a gyral in the gulf. These movements are very slow, from 2 to 5 miles a day, so that the water requires a year or more to cross the ocean, or progress around the gulf.

## Strait of Georgia

During the period 1930 to 1938 oceanographic observations were made in the Strait of Georgia. These included a monthly series of serial observations at a central position in the strait through fifteen months; a series of serial observations at positions around the strait, observed on each tidal extreme through one day, and repeated in Spring, Summer and Autumn; thermograph and daily observations of salinity at Departure Bay and several other stations; as well as a number of casual observations. These data include temperature, salinity, dissolved oxygen, phosphates, silicates, nitrates, and nitrites, and the pH.

These observations were limited by equipment, facilities, personnel, and lack of experience. By themselves they are inconclusive. However they can now be interpreted in the light of later experience, and provide an interesting and useful study of the properties of the water, and the mechanisms contributing to these properties.

Analyses of the data was undertaken in 1949 and has continued intermittently ever since. The mechanism of discharge and the dissipation of Fraser River water has been solved. The mechanism of daily heating and cooling, and seasonal cycle of temperature has been explained. The relation of tidal movement to these properties has been described. The relation of dissolved oxygen and pH has been described. The sources of the high phosphates and silicates has been shown. It has been shown that dissolved nitrates vary from zero to high values and may be the limiting factor in plankton growth.

This study deals with the properties of the water and the reasons for the levels rather than the overall physical picture. It has provided a vehicle for discussion and explanation of many of the oceanographic processes observed in the Pacific Coast region.

It is in its final stages of preparation as a companion work to the physical study recently completed by Dr. Waldichuk.

J. P. Tully

## Juan de Fuca Strait

The Juan de Fuca Strait Project was undertaken to define the water masses, the physical properties of the water, and the currents throughout one year. Daily observations of surface sea water temperature and salinity have been made at Race Rocks since 1936. Also periodic observations from surface to bottom have been made at a number of positions.

The waters in the strait oscillate to and fro with the tides. The velocity and direction at any point bear a simple relation to the difference of sea level between the inner and outer ends of the strait. This phenomenon has been discussed in recent papers. In the upper waters, and along the Canadian shore, the ebb movement is stronger than the flood. These waters progress seaward. The flood movement is stronger in the deep waters, particularly along the United States side. These waters progress toward Georgia Strait. The surface and deep waters are mixed to a varying degree enroute, by the turbulence associated with the strong currents.

There is a longitudinal gradient of properties (temperature and salinity) from the inner to the outer end of the strait, from the characteristics of the Strait of Georgia to those of the coastal ocean water. In addition the properties in all parts of the region vary with time. Generally the range of variation is greatest at the inner end. It decreases to seaward as far as a line across the strait from Pillar Point to Glacier Point. From this line seaward the ranges of variation increase.

The surface sea water temperature and salinity vary through a cycle whose period is twelve and one-half hours, closely related to the tidal cycle. As the waters are moved back and forth by the tide, the properties at any point change in accord with the water mass which is advancing.

The surface sea water temperature and salinity oscillate through a cycle of fifteen days which is closely related to the spring and neap tidal current cycle.

The annual surface sea water temperature cycle shows a maximum in August (mean value  $10.7^{\circ}$  C) and a minimum in February (mean value  $7.2^{\circ}$  C). The annual cycle in the deep waters shows a maximum in January and a minimum in August. In consequence, the vertical structure tends to be slightly positive in Winter changing to a negative gradient of about  $5^{\circ}$  C in mid-Summer.

The annual surface salinity cycle shows two minima. One occurs in Winter (February) associated with the maximum precipitation and coastal runoff. The other occurs in the Summer (July) in consequence of the peak discharge of the Fraser River, and drainage from the melting snow at high levels. The intervening maxima occur in Spring and Autumn. The grand monthly mean salinities vary between  $31.00$  ‰ and  $31.50$  ‰. The greatest fluctuations are associated with the periods of lower salinity.

There is also a diurnal cycle in the surface sea water temperature associated with daylight heating and night cooling (afternoon effect).

Relations have been found between the daily observations

of sea water temperature and salinity at Race Rocks, and the values of these properties in all parts of the strait. From this it is possible to recognize the oceanographic state in the region at any time.

R. H. Herlinveaux

## Hydraulics of Salmon Spawning Gravels

During 1954 Messrs. Pollard and Wickett developed a method of measuring the flow of natural waters through the gravels of salmon spawning redds. They designed a 1 1/2 inch diameter standpipe whose lower end contained a perforated chamber. This chamber was sealed by a flat plate through which a 3/8-inch pipe extended to the upper end. The lower end of the standpipe was fitted with a point. In use the standpipe was driven ten inches into the gravel. Methylene blue dye was introduced into the chamber, and its rate of fading measured. This was found to be proportional to the hydraulic gradient (s) of the groundwater flow. The rate at which water must be pumped out of the standpipe, to maintain the level inside one inch below the level on the outside, was found to be proportional to the permeability (k) of the gravel. From these data the velocity of flow can be determined in the relation

$$V = ks$$

The standard standpipes (Mark II) were calibrated in a trough permeameter using a range of random gravels. Properties of the ground waters were determined on samples taken from the standpipe. This work has been published.

After a year's use a number of difficulties have appeared which have necessitated further research and modification of the equipment and procedure.

The points broke off the standpipe when they were being driven into the gravel. This breakage was eliminated by having the inner tube and seal of the lower chamber removeable. An

iron bar is inserted through the pipe so that the driving force is exerted directly on the point. The pipe takes no strain.

The permeability of some natural spawning gravels was greater than the range of calibration of the Mark II standpipe. While extending this range, it was found that water friction in the 3/8-inch inner pipe limited the rate of inflow of water. However when the inner pipe and the seal of the lower chamber were removed there was no difficulty in making the measurements.

Previous measurements showed wide variability. This was partly due to the effect of the narrow inner pipe, and partly due to the fact that earlier calibrations were made in random gravels. Recently calibrations have been made in uniform gravels. In each case the observations are constant within  $\pm 5\%$  of the mean. This is useful because for each level of permeability there is a wide range of composition of random gravels. These can now be referred to the permeability in standard uniform gravels.

The use of methylene blue to measure the hydraulic gradient was questioned because the results continued to be erratic. The dye solution was considerably more dense than the groundwater. It leaked out of the standpipe chamber when there was no groundwater flow. Also the residue formed a lake in the bottom of the standpipe chamber. The original technique required frequent stirring which caused random losses of dye. It was found that methylene blue is readily absorbed on rusty iron, and is bleached by zinc and detritus in the water. It is unsatisfactory for the use in this test.

The dye difficulties were resolved by using a mixture of Tartrazene and Brilliant Blue FCF made up in 15% alcohol so that the specific gravity is 0.99975. This forms a green colour which does not adsorb or fade in use. It diffuses readily in the chamber of the standpipe, requiring no stirring, and does not leak out when there is no flow.

In the earlier standpipe the chamber was open to the inner pipe. The water in this pipe was not flushed in the same manner as the chamber. Its volume was about 40% of that of the chamber and was variable depending on the depth of water in the gravel and the stream. This source of error caused wide fluctuations in the observations. They have been eliminated by fitting a rubber membrane across the bottom of a removeable inner tube, and introducing the dye with a hypodermic needle. Thus the dye is confined to the lower chamber where the flushing characteristics are constant.

The new standpipe (Mark IV) appears to be satisfactory. It is a simple 1 1/2 inch iron pipe, with a point, and perforations around the lower end. It is driven into the gravel with a solid steel rod resting on the point. Permeability is determined by measuring the rate at which water must be removed to maintain the level inside the standpipe one inch below the level on the outside. A lower chamber is formed by introducing a diaphragm into the pipe with access through an inner pipe. The new dye is introduced into this lower chamber with a hypodermic needle. Its rate of fading is determined by sampling. No stirring is required.

It remains to calibrate this new model and prove it in field use.

L. D. B. Terhune

### Sea Water Intrusion in Steveston Cannery Basin

In July, 1954 the Harbours and Rivers Engineering Branch of the Department of Public Works approached the Group for assistance. They wished to know if sea water intrusion occurred in the recently completed Steveston Cannery Basin, and if the unprotected pilings of the various wharves along the waterfront had been infested by shipworms (Bankia setacea).

In August, 1954 a weekly sampling program for salinity was instigated and continued for 15 months till October, 1955. On the basis of the first three months of observations, it was concluded that sea water intrusion occurred in the basin and that the salinity of the water was suitable for shipworm survival. The study was extended to determine if shipworms were present in the basin. After learning that they were, it was necessary to determine how they entered the basin, and whether they would continue to grow and cause serious damage. In addition, it was necessary to learn the extent of sea water intrusion in the adjacent river channel, to see if conditions there were more or less favourable for shipworm survival.

These problems suggested a coordinated oceanographic and biological investigation of the area. The latter was undertaken by Mr. R. J. LeBrasseur of the Biological Station, Nanaimo, B. C. The weekly sampling of sea water and the placement and removal of test blocks for shipworm infestation was made by the staff of the Department of Public Works. Four oceanographic surveys were made in the area, one in December, 1954, aboard C.N.A.V. "Ehkoli". The others were made by the staff of the Department

of Public Works in April and May, 1955, under the direction of the Group.

During normal river discharge (50,000 to 150,000 cubic feet per second) sea water advances into the estuary on the flood tide, forming a salt wedge between the upper layer of fresh water and the river bottom. This sea water intrusion occurs in the mid-channel of the Fraser River outside Steveston Cannery Basin, and in the basin during most of each tidal day. There is no intrusion during the six weeks of freshet period from the time the discharge rises above 250,000 cubic feet per second until it falls to 180,000 cubic feet per second.

During the 10 1/2 months when intrusion occurs, the intruded sea water remains in the basin throughout the tidal day except at times of lowest low of the spring tides, when it is flushed for several hours. The river channel adjacent to the basin is flushed for a few hours during the neap tides and for longer periods during the spring tides. Flushing is more effective in the river channel than in the basin.

The upper ten feet of the water in the basin is relatively fresh but at five feet above the bottom the salinity of about 25 ‰ endures for more than one-half a day, and along the bottom for more than three-quarters of a day. The maximum salinity of the intruded sea water is of the order of 28 ‰.

Sea water remains in the "depressions" along the bottom of the basin throughout the tidal cycle. In these places it also remains during the freshet period even though the tidal intrusion is not occurring.

In view of this it was suggested that the basin be dredged on a uniform slope and all depressions filled. Furthermore, it was recommended that all depressions and cross-channel bars lying seaward of the basin be eliminated.

A two-current system exists in the basin; the currents in the upper layer of fresh water and the currents in the deeper layer of sea water. The maximum strengths of the deep currents occur about three hours after those in the upper layer. The maximum strengths of these currents are about 0.8 knots.

The temperatures of the intruded sea water are the same as those encountered at depths from 10 to 50 feet at the mouth of the river. The temperature of the upper layer is that of the river water.

The decrease in the concentration of dissolved oxygen toward the bottom of the basin is attributed to the demand made by the organic matter (black mud) lying along the bottom of the basin. This organic matter probably originated in the waste products from the canneries and domestic sources.

Sea Water Analyses Laboratory

A specially-designed semi-automatic titrations laboratory comprising five units is available to analyse the great number of sea water samples received annually from the various field expeditions and daily sea water program.

The salinities of these samples are analysed to varying levels of precision. In the case of routine investigations (daily sea water observations, etc.) an accuracy of  $\pm 0.06$  ‰ is required. Where a high degree of precision is required for dynamic calculations (Western Arctic, NorPac) an accuracy of  $\pm 0.02$  ‰ is required. Last year 18,400 samples were titrated.

This service is also extended to analyse samples collected during observations by the Biological Station and the Pacific Naval Laboratory.

L. H. McCracken

## Data Records

In recent years it has been the policy of this Group to publish, as soon as possible after the completion of an oceanographic survey, a record of the observed physical and chemical data. The data are arranged in tabular form with explanations of procedure of observation and analyses, and are published in the manuscript series of the Joint Committee on Oceanography.

During 1955, records of all the oceanographic observations taken during the Hecate Strait Project of 1954-1955 were published. Observations made in Barkley Sound during April, 1950 were published as well as those made in a series of surveys conducted in Steveston Cannery Channel during August to December, 1954. Other important data records published in 1955 include the observations made during the Juan de Fuca Strait Project in 1951-1952, and the recent NorPac oceanographic survey, August, 1955. The latter presents the physical and chemical data at interpolated and observed depths and uses a unique method of reproducing the bathythermograms obtained during the survey.

There remain quite a number of early oceanographic surveys whose data have not been published, but this back-log is steadily being processed. The following Table shows the status of the publication of data from major oceanographic surveys conducted by the Pacific Oceanographic Group since 1930.

Tabulation of data on file at Pacific Oceanographic Group and  
data records published to December 31, 1955.

Period of Obs'v'n	Region	Publication Status
1914 - 1955	Daily seawater observations, B. C. coastal locations	Continuing No. 1
1930-31, 1932	Strait of Georgia	1953, No. 2
July 24-27, 1933	Nootka Sound	Not published
April-July, 1934	Southwest coast, Vancouver Is.	" "
May-July, 1935	West coast, Queen Charlotte Is.	" "
Feb. 14-26, 1936	Southwest coast, Vancouver Is.	" "
June-Sept. 1936	Offshore, W. coast Vancouver Is.	1950, No. 3
Feb.-Oct., 1937	Approaches to Juan de Fuca Str.	Not published
Jan.-May, 1938	Approaches to Juan de Fuca Str.	" "
May-June, 1938	Dixon Entrance	" "
June-Nov., 1938	Swiftsure Bank area	" "
Oct.-Nov., 1939	Alberni Inlet	" "
April-June, 1941	Alberni Inlet and Harbour	Partial publication F.R.B. Bull. 83
1948-1949	Nodales Channel	Not published
May-Sept., 1948	Chatham Sound	" "
July-Aug., 1949	Bering and Chukchi Seas	Restricted U.S. Publication
1949, '51, '52, '53	Strait of Georgia	1954, No. 4
1949, 1950, 1951	Fraser River Estuary	1951, No. 5
April 4-26, 1950	Barkley Sound	1955, No. 6
May-Nov., 1950	Nodales Channel	Not published
Aug.-Nov., 1950	Bute Inlet	" "
1950-1951	Baynes Sound	" "

Period of Obs'v'n	Region	Publication Status
July-Oct., 1950	Offshore, W. coast Canada	Not published
1951	Bute Inlet	" "
1951	Nodales Channel	" "
May-Aug., 1951	Offshore, W. coast Canada	Part. Published 1952, No. 7
1951-1952	Juan de Fuca Strait	1955, No. 8
July 12-17, 1952	Hecate Strait (Current Survey)	Not published
June-Oct., 1952	Nodales Channel	" "
July 15-23, 1953	Inlets of B. C. coast	" "
May-Dec., 1954	Dixon Entrance, Hecate Strait, Queen Charlotte Sound	1955, No. 9 1955, No. 10
1954-1955	Steveston Cannery Channel	1955, No. 11
Aug.-Sept., 1954	Beaufort Sea	Restricted, U.S. Publication
Feb.-June, 1955	Dixon Entrance, Hecate Strait, Queen Charlotte Sound	1955, No. 12
July-Aug., 1955	Northeast Pacific Ocean	1956, No. 13
Jan.-May, 1955	Steveston Cannery Channel	Not published
Jan.-Dec., 1955	Daily seawater observations, B. C. coastal locations	" "

List of Pacific Oceanographic Group Data Record Publications  
Manuscript Report Series of the Joint Committee on Oceanography

- No. 1 Observations of Seawater Temperature and Salinity on the Pacific Coast of Canada, Volumes I to XIV, 1914 through to 1954. 1947-1955.
- No. 2 Physical and Chemical Data Record, Strait of Georgia, 1930, 1931, 1932. July 1, 1953
- No. 3 Pacific Coast Data Record, Offshore Survey, 1936. November 15, 1950.
- No. 4 Physical and Chemical Data Record, Strait of Georgia, 1949-1953, with Appendix I, Current Measurements, March, 1953. May 1, 1954.
- No. 5 Data Record, Fraser River Estuary Project, 1950. December 1, 1951.
- No. 6 Data Record, Barkley Sound, April 4-27, 1950. December 15, 1955.
- No. 7 Pacific Coast Data Record, Offshore Survey, August 1-14, 1951. July 1, 1952.
- No. 8 Physical and Chemical Data Record, Juan de Fuca Strait Project, 1951-1952, with Appendix I, Current Measurements. April 30, 1955.
- No. 9 Physical and Chemical Data Record, Hecate Project, 1954. January 15, 1955.
- No. 10 Data Record, Current Measurements, Hecate Project, 1954. March 1, 1955.
- No. 11 Studies in Steveston Harbour Basin. Part I. Sea Water Intrusion into the Steveston Harbour Basin, by S. Tabata. February 15, 1955.
- No. 12 Physical and Chemical Data Record, Hecate Project, with Appendix I, Current Observations, 1955. August 15, 1955.
- No. 13 Physical, Chemical and Plankton Data Record, Project NorPac, July 26 to September 1, 1955. February 1, 1956.

The oceanographic data files are kept in a concrete fire-proof vault. They are filed in a chronological order, within regional or project subdivisions. Each file folder is numbered and a data catalogue is kept. There is a free exchange of original unpublished oceanic data with the U.S. Navy Hydrographic Office in Washington, D.C. There the data are tabulated on Hollerith punch cards.

The many hundreds of bathythermogram records taken each year from such sources as the Royal Canadian Navy, Pacific Naval Laboratory, Canadian Hydrographic Survey and from the Pacific Oceanographic Group oceanographic surveys are filed chronologically within a geographical classification determined by latitude-longitude designators.

H. J. Hollister

### Bathythermograph Calibration

A bathythermograph calibration unit was built by the Pacific Naval Laboratory and installed in the Model Laboratory in January, 1955. The unit consists of a pressure tank with heating, refrigeration, and pressure controls and recorders. A bathythermograph is sealed in the tank where it records the imposed temperature and pressure conditions on its smoked glass slide. A temperature-pressure (depth) grid is then fitted to this slide and recorded photographically. From this a standard calibration grid is made. These have been compared satisfactorily with grids prepared by the makers, Wallace and Tiernan Limited, and by Naval Research Establishment, Halifax.

With this equipment, calibration service is provided for the Royal Canadian Navy, Pacific Naval Laboratory, Biological Station, Institute of Oceanography, and Pacific Oceanographic Group. Thirty-six instruments have been calibrated during the past year.

The present unit will only accommodate one instrument (two instruments if all excess parts are removed). It would be much more efficient to handle a larger number, and Pacific Naval Laboratory is building a tank to hold five instruments.

R. H. Herlinveaux