

CANADIAN JOINT COMMITTEE ON OCEANOGRAPHY



ANNUAL REPORT, 1956-57

by

H. B. Hachey  
Chief Oceanographer  
Fisheries Research Board of Canada

St. Andrews, N. B.  
March 31st, 1957.

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Canadian Joint Committee on Oceanography

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Canadian Joint Committee on Oceanography

Annual Report - 1956-57

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Chief Oceanographer  
Fisheries Research Board of Canada

The national effort in oceanography in Canada is co-ordinated under the Joint Committee on Oceanography. This committee is a planning and co-ordinating body, comprising as shown on the organization chart, representatives of the Fisheries Research Board, the Royal Canadian Navy, the Defence Research Board, the National Research Council, and the Hydrographic Service. Several advisers assist the Committee with their specialized knowledge relating chiefly to fisheries and defence problems. The requirements in oceanography for fisheries, naval and other national interests are incorporated into programs, which are carried out on a co-operative basis.

The scientific study of the sea has many implications of national import, not the least of which is fisheries. It is therefore not surprising to find the Fisheries Research Board playing a leading role in the national effort in oceanography. From the fisheries point of view, in order to deal with many of the problems of the sea, a knowledge of the environment in which the fisheries exist is of basic interest. Contributing to the national effort in oceanography, the Fisheries Research Board provides the personnel, administrative facilities and shore laboratories for the Atlantic and Pacific Oceanographic Groups located respectively at the Biological Stations at St. Andrews, N. B. and Nanaimo, B. C.

The modern implements and methods of naval warfare involved in the defence of Canadian territory have made imperative a detailed knowledge of the waters over which the Canadian Navy would operate in case of hostilities. This gives substance to the sustained effort by the Royal Canadian Navy and the Defence Research Board in supporting all phases of scientific studies pertaining to the sea. The national effort is, in part, supported by the provision, maintenance, and operation of two oceanographic vessels, one on the east coast and one on the west coast which are assigned as required for the oceanographic programs co-ordinated under the Joint Committee. In addition, facilities for research in Arctic waters are provided on the modern icebreaker H.M.C.S. "Labrador". Ships and specialized equipment are also provided on occasion for extended programs beyond the scope of the more general facilities. Two naval research establishments under the Defence Research Board are also actively engaged in oceanographic activities, some of which are carried forward in co-operation with the Oceanographic Groups of the Fisheries Research Board.

The Canadian Hydrographic Service, whose main function is concerned with problems of navigation, involving charting and tidal and current work is happily conscious of their ability to co-operate in certain phases of the oceanographic program drawn up under the Joint Committee. Their co-operation has included the collection of oceanographic data in the areas where they are actively engaged in charting operations, and also the active participation in investigations of problems of the sea

which are of mutual interest.

The activities of the National Research Council in oceanography are based on its responsibility for the national development of science generally. While it holds membership on the Joint Committee, its greatest contribution is probably through the Associate Committee on Geodesy and Geophysics, which is the national Committee for Canada, giving support and encouragement to all scientific endeavours in the field of oceanography.

The Meteorological Service of Canada has long been interested in problems of marine meteorology, a subject that became of increasing practical importance, with the development and expansion of trans-ocean flying. Recently the Service has extended its activities into sea-ice forecasting, and in this field a study of oceanographic factors is a most important one.

The Royal Society Committee on Oceanography has been active in organizing symposia on various aspects of oceanography. The Nova Scotia Research Foundation has also been active in this field.

#### Programs of the Oceanographic Groups

The program of the Atlantic Oceanographic Group involves both the Atlantic and Arctic. This program, which is coordinated through the Joint Committee on Oceanography, and carried out by the Atlantic Oceanographic Group of the Fisheries Research Board of Canada, is designed chiefly to meet the immediate and long term requirements of the Fisheries Research Board and the Royal Canadian Navy. Both organizations have

need of a general knowledge of the physical and chemical properties of the waters and the processes which maintain or modify existing conditions. Both have specific problems related to particular regions within the larger areas of interest. While the Group carries out its own program of researches, the broad requirements can only be met by stimulating interest within other organizations and by encouraging co-operation in the collection of oceanographic information. The co-operation of the Biological Stations of the Fisheries Research Board at St. Andrews, N. B. and St. John's, Newfoundland, the Canadian Hydrographic Service, the Naval Research Establishment of the Defence Research Board, the Quebec Marine Biological Station, and other organizations, materially assist 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. Navy Hydrographic Office, and there is an exchange of all data collected in waters of common interest.

The general program has involved the Group in nine oceanographic surveys involving two ships, the H.M.C.S. "Labrador", and the C.N.A.V. "Sackville". A total of more than 47,500 miles were covered, 666 oceanographic stations were occupied, 1283 bathythermograph observations taken, and 5192 water samples collected for analysis. Special attention has been given to the Gulf of St. Lawrence, with winter surveys carried out in February-March of 1956 and 1957. To make best use of these first available data on winter conditions, complementary surveys through the remainder of the year were considered

necessary. A special attempt was made to gather detailed information relative to the summer circulation in the central Gulf. A survey in Newfoundland waters was carried out in September with observations in the Laurentian Channel, southern Grand Banks and Trinity Bay. Personnel from the Biological Station, St. John's, Newfoundland, co-operated, and plankton collections were made in addition to the observations in physical oceanography. H.M.C.S. "Labrador" again operated in Foxe Basin, repeating stations occupied in 1955 and increasing the area of coverage. Opportunity was found for an excellent survey of Hudson Strait and, following the work in Foxe Basin, surveys were made in the Gulf of Boothia, Committee Bay and Lancaster Sound.

Considerable attention has been given to Passamaquoddy Bay and the Bay of Fundy in anticipation of work to be done in connection with the International Passamaquoddy Fisheries Board. The problems associated with model studies of the area have been investigated and preliminary scaling calculations have been made. Much of the accumulated data from the area have been worked up so as to provide a more advanced starting point for the investigation of this Board. A study of the energy considerations in the Bay of Fundy which had been commenced some time ago was brought to completion as having some pertinence to the problems. Studies of the circulation on the Scotian Shelf as shown by data from seasonal surveys has continued as time was available. On request from naval

authorities, a study of pertinent literature and other data was made and a report submitted on the occurrence of ice and icebergs in and around the entrances to the Gulf of St. Lawrence.

The Group was also active in the associated programs of other phases of oceanography. A number of vessels operated by the Biological Station, St. Andrews, N. B. made oceanographic observations in association with fisheries investigations. Ships of the Canadian Hydrographic Service again made oceanographic observations on passage to and from survey areas. The data and water samples are turned over for processing on completion of the season's work. The Naval Research Establishment, Dartmouth, N.S. 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 analyses. A bathythermograph is maintained on Sambro Lightship for twice daily observations and the plotted results made available to A.O.G. A close liaison is maintained with N.R.E., and there is exchange of personnel, equipment and services as required from time to time.

The general program of the Pacific Oceanographic Group, which is co-ordinated through the Joint Committee on Oceanography, has been specifically designed to provide a broad knowledge of the waters of the Pacific Coast regions, to provide general or specific information required by fisheries or defence projects,

and to study the fundamental processes in the ocean which contribute to an understanding of the phenomena involved. Earlier preliminary examination of the offshore oceanic waters has been augmented by the far-ranging synoptic surveys of the North Pacific, and by the inauguration of a comprehensive program of observations at Weather Station PAPA. A program of fundamental research in the physics and chemistry of the sea has been undertaken, with particular emphasis on physical processes, and productivity. In carrying forward this program, close co-operation is maintained with the Biological Station of the Fisheries Research Board, the Pacific Naval Laboratory, the Canadian Hydrographic Service, the Institute of Oceanography at U.B.C., and the Meteorological Service. On an international basis, co-operation is maintained with the University of Washington and the Scripps Institute of Oceanography. The program has involved the Group in two major surveys of the North Pacific during the past year, and two ships, H.M.C.S. "New Glasgow" and H.M.C.S. "Oshawa" carried out the summer and winter cruises. Personnel of the Group also furnished the oceanographic staff on the Weathership C.G.S. "St. Catherines" and on the exploratory fishing vessels operated by the Biological Station.

The general climate of the sea is followed by daily observations of water temperatures and salinities, made at eighteen locations along the British Columbia coast. A statistical method of classifying the observations has been

devised, and a heat budget study embodying the sea water data and meteorological observations is in progress.

Studies of the waters of the Strait of Georgia and Juan de Fuca Strait are being brought to a conclusion, and reports on various aspects of these waters have been either completed or are in progress. One phase of an intensive study of the waters of Hecate Strait, which also encompassed those of Queen Charlotte Sound and Dixon Entrance, was brought to a conclusion one year ago upon completion of a series of seven bi-monthly oceanographic surveys. 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 cruises, the tidal and non-tidal currents were observed at  $\frac{1}{2}$ -hour intervals throughout a 50-hour period.

During the past year, the observational program on Weathership PAPA was enlarged. It is anticipated that this new program of observations, which involve the physical and chemical characteristics of the waters, will serve as an index of conditions in the northeastern Pacific, and provide an opportunity for study of ocean productivity. The enlarged program also includes specific studies of such features as internal waves and diurnal plankton movements.

Fundamental studies in marine physics and chemistry are progressing. A comprehensive analysis is being made of the energy transformations accompanying the displacement and mixing of a water mass in the ocean. Such analyses offer some

insight into the transport of the deep water masses in the North Pacific Ocean. Ionic ratios in the brackish waters of several estuaries have been studied, and it was found that the magnesium content was higher, and the potassium content lower, than in normal sea water. The increased magnesium content was attributed to the inflowing fresh water, while the decrease of potassium is possibly due to the absorption by the silt. Studies of methods of analysis for nutrient and respiratory factors in sea water, as well as the significance of the observed distribution of nutrients are in progress.

#### Atlantic Oceanography

Observations of surface water temperatures at St. Andrews, N.B., beginning in 1921, give the longest continuous water temperature records for Canadian Atlantic waters. A remarkable trend towards higher temperatures has persisted since the mid-twenties, in spite of a period of decreasing temperatures in the early forties. It has been shown that these St. Andrews temperatures are indicative of water conditions over the Canadian Atlantic Coast. A comparison with air temperatures, from longer records taken at Sable Island, N.S., has shown a close relationship between trends in the air at Sable Island and in the water at St. Andrews. It is to be expected that such changes in the water conditions would influence some of the fisheries. Fish populations are, however, difficult to estimate, and landing statistics often reflect economic factors as well as concentration of fish. The ratio of species caught in a fishing

operation would perhaps be somewhat free from most economic factors. The Canadian and U.S. catch statistics for ICNAF Subarea 4, have been used for computing the ratio of haddock landings versus cod landings for a number of years. It has been shown that relatively more haddock are caught in the warm periods and relatively more cod in the cold periods. This is in good agreement with the known temperature preference of the fish, haddock favouring a somewhat higher range than do cod.

One of the characteristics of the water mass in the Gulf of St. Lawrence is the cold water layer, which in summer is found at intermediate depths. It has been defined as the body of water of temperatures less than  $0.0^{\circ}\text{C}$ . The volume of this intermediate cold water layer undergoes seasonal variations from a maximum in spring to a minimum in the autumn. From a study of the salinity distributions within this layer and the seasonal variations, it had been concluded that at least one-third of the cold water layer found in the spring was formed "in situ" as a result of winter chilling. The other two-thirds, of outside origin presumably entered the Gulf through Cabot and Belle Isle Straits, and probably during the winter months as a surface layer. The opportunity for studying the processes involved were afforded during the winters of 1956 and 1957, when the H.M.C.S. "Labrador" was made available for winter cruises into the Gulf of St. Lawrence. As a result of these winter studies, it has been determined that at least half of the cold water layer is formed in the Gulf, and that the year to year variations in the volume and extent of the cold

water layer are related to the severity of the ice conditions during the previous winter.

A method of forecasting the severity of ice conditions has evolved from these winter studies. The "ice potential" is calculated on the basis of the amount of heat contained in the water mass in the late fall. The resulting figures, when related to subsequent weather, provide the data for forecasting ice conditions. Light ice conditions found in the winter of 1956 and heavy ice conditions prevailing in 1957 were forecast on this basis.

#### Arctic Oceanography

A considerable effort has been expended by the Atlantic Oceanographic Group in the H.M.C.S. "Labrador" over a period of three years, in studying the oceanography of the waters of the Canadian Arctic. This effort was supplemented by the Canadian-United States Expedition to the Beaufort Sea in 1954 which involved the Defence Research Board, the Pacific Oceanographic Group, and the United States Navy. On a smaller scale, oceanographic observations were made by the Arctic Unit of the Fisheries Research Board in the M.V. "Calanus" in Hudson Bay and Strait, and in Foxe Basin. The Hydrographic Service in the M.V. "Theron" and the M.V. "Algerine" made observations during this three-year period in Ungava Bay and Hudson Bay.

In 1954, the H.M.C.S. "Labrador" centered its northern operations at Resolute on Cornwallis Island, and made various cruises to cover northern Baffin Bay and the various Sounds,

Straits, and Passages to the north and east. In the late summer, the H.M.C.S. "Labrador" made the east to west passage from the Atlantic to the Pacific through Lancaster Sound, Barrow Strait, Viscount-Melville Sound, and Prince of Wales Strait. The Canadian-United States Expedition to the Beaufort Sea in the U.S.S. "Burton Island" and the U.S.C.G.C. "Northwind" made the west to east passage through McClure Strait, and joined up with the "Labrador" in passing through Prince of Wales Strait to the Beaufort Sea. Observations from these combined efforts included measurements of temperature, salinity, oxygen, phosphate and silicate. Bathythermograph recordings and bottom samples were also obtained. Current measurements were made at all available opportunities. Several long series of current profiles at anchored stations were obtained, and two ships occupied stations in Bering Strait simultaneously over a period of eight hours. In 1955, the "Labrador" made an extensive coverage of the waters of Hudson Strait and Foxe Channel and Basin. The M.V. "Calanus" arrived in Foxe Basin in late summer and wintered there, maintaining an oceanographic station for a complete year near Igloolik Island. In 1956, the "Labrador" again made an extensive coverage of Hudson Strait and Foxe Basin. Towards the end of the season, the ship passed northward through Fury and Hecla Strait. Oceanographic sections were made in Committee Bay, Gulf of Boothia, Prince Regent Inlet, and Lancaster Sound. Ice studies were made in association with the McGill Group under the auspices of the Defence Research Board. The work in Foxe Basin was supplemented by

those of the M.V. "Calanus".

As a result of the past two seasons' work, the dynamics of Hudson Strait, Foxe Channel and Basin are now fairly well known for the summer and autumn months. The circulation of Hudson Strait is dominated by a steady outflow of water from Hudson Bay which is confined largely to the south shore. The main outflow from Hudson Bay appears to be between Cape Wolstenholme and Nottingham Island. The stream parallels the coast as far as Ungava Bay and is approximately 20-30 miles in width. The inflowing waters around Resolution Island appear to be more variable. A definite movement of water along the Baffin coast extends into the Strait. This water turns into the main outflowing stream between Akpotak and Big Island. Part of the exchange of water in the eastern section of the Strait occurs directly between the eastern passages and Ungava Bay. The westward flow along the north side of the Strait practically ceases at Big Island, where an eastward flow from Hudson Bay also appears to terminate. A return circulation westward along the north coast to Foxe Channel exists. This current must carry some of the water, which originally entered the Strait off Resolution Island, into Foxe Channel and Hudson Bay.

Two main current features appear in Foxe Basin, a strong southerly movement of water along the western side extending from Fury and Hecla Strait to the southeast tip of Southampton Island and a northerly flow up the central part of Foxe Channel. The southerly flow also maintains an outflow of water through Frozen Strait and a large back eddy in the central part of the Basin. The northerly movement of water appears to originate

in Hudson Bay and Hudson Strait and extends well into the Basin turning eastward around Foxe Peninsula.

The movements of Foxe Basin ice in relation to navigation in Hudson Strait has always been a matter of some concern. The break-up in Foxe Basin begins about mid-June with formation of leads off Foxe Peninsula and relatively open water at the eastern end of Fury and Hecla Strait. By late July, the northern open water has extended south into Parry Bay, and the Foxe Peninsula lead has expanded into the shallows south of Prince Charles Island. About this time, break-up begins along the northeast coast of Southampton Island and continues northward along the western shore in the form of leads running parallel to the coast. Most of the ice passes out of the Basin during the latter half of August and the first two weeks of September. However, the open water in the north becomes congested with winter ice passing through Fury and Hecla Strait from the Gulf of Boothia and Committee Bay. This ice moves south in the main channel along the western shore passing out through the western section of Foxe Channel into Hudson Strait. By mid-September, Foxe Basin is free of ice except for remnants of shore ice, and occasional flows of winter ice which drift in through Fury and Hecla Strait. This condition remains from approximately mid-September to the middle of November by which time young ice is forming rapidly throughout the Basin and Strait.

#### Pacific Oceanography

The establishment, in recent years, of the International

North Pacific Fisheries Commission, embracing Canada, the United States, and Japan, and their subsequent investigations of fisheries problems, has resulted in co-operative oceanographic and fisheries investigations of North Pacific waters. During 1955, a joint synoptic oceanographic survey over the Pacific Ocean north of the Tropic of Cancer was carried out during August. One Canadian, seven United States, and twenty Japanese ships, each surveyed a selected part of the area. This oceanographic survey of an ocean, the largest co-operative oceanographic operation ever attempted on an ocean-wide basis, was followed in 1956 and February 1957 by intensive surveys, by the Pacific Oceanographic Group, of the area north of Latitude  $40^{\circ}\text{N}$ . and east of Longitude  $180^{\circ}\text{W}$ . The Pacific Oceanographic Group were ably assisted in these ocean surveys by H.M.C. ships, "St. Therese", "New Glasgow" and "Oshawa".

Prior to this survey, the circulation of the North Pacific had been deduced from statistical analyses of reports from ships during the past one hundred years, from intermittent localized observations, and from theoretical considerations. Preliminary analysis of the results of the recent surveys during the late summer months shows that there is a boundary gradient between the sub-tropical water ( $22^{\circ}\text{C}$ . and warmer) and the sub-Arctic water ( $14^{\circ}\text{C}$ . and colder). This gradient lies principally between Latitudes  $40^{\circ}\text{N}$ . and  $45^{\circ}\text{N}$ . and extends from the meridian of  $180^{\circ}\text{W}$ . to the North American coast, where it turns southward. This gradient probably outlines the North Pacific Drift Current. The distribution of surface salinities during the late summer

months re-emphasizes the boundary gradient between the subtropical water (34.0‰ and higher) and the sub-Arctic water (32.8‰ and lower). North of this temperature-salinity gradient, and bounded on the east, north and west by the North American continent and the Aleutian Chain, is the body of water which has been given priority in the initial analysis of the collected data.

In the summer, in this sub-Arctic region, there is an upper zone of relatively homogeneous low salinity water, less than 33.0‰, extending to a depth of about 100 metres. This depth is also the lower limit of the thermocline which outlines an upper comparatively homogeneous warm layer of about 50 metres in thickness. In the approximate center of this region, the colder surface temperatures and the higher surface salinities of the region are found, indicating upward vertical transport of water from greater depths. This sub-Arctic body of water is contained within the Alaska Gyral to which we have referred to earlier. The horizontal surface gradients of both temperature and salinity which form the periphery, and the evidence of upward vertical transport of waters in the central portion, indicate that this body is, or has been, involved in anti-clockwise rotation. A study of the dynamics of this body of water by the Pacific Oceanographic Group has suggested that the Gyral is wind accelerated during the prevalence of the winter-type wind circulation, which persists throughout the period, October-April. Such winter acceleration on the system causes transport of surface ocean waters towards the periphery and gives rise to upwelling towards the center. This system of

circulation persists throughout the summer months by virtue of its winter generated momentum although it is obviously weakened by the summer wind system.

The preliminary results of other phases of the investigations have shown high concentration of nutrients and plankton in the central portion of this Gyral, and concentrations of feeding fish on the periphery. This program, on an ocean-wide scale, promises well to offer the final solution to an international fishery problem in the North Pacific.

#### Sea Ice Research in Canada

Since 1950, the United States has been committed to military and naval activities in northern areas, which theoretically involves all the seas and channels of northern Canada. The construction of the Distant Early Warning Line involving both Canada and the United States required a very large sea lift. This sea lift, as well as the re-supply of various northern Canadian posts placed emphasis on the need for sea ice reporting and forecasting programs. Further south, in the Ungava Bay, Hudson Bay and Hudson Strait areas, problems of summer navigation have arisen in connection with the increased shipping through Port Churchill, and the shipping of iron ore from the newly found deposits of northern Quebec and Labrador. The development of the St. Lawrence Deep Sea Waterway and the ever increasing industrialization around the shores of the Gulf of St. Lawrence has brought about an interest in the possibility of lengthening the navigation season in the

Gulf and River St. Lawrence.

The Defence Research Board, through its Geophysics Section, has made a study of the problems involved, and have put forward the minimum national requirements. To supply the information required for military and commercial organizations, the minimum data required are:

- (a) the date of the onset of ice in ports and bays,
- (b) the thickness, distribution, and movement of floating ice,
- (c) the method and rate of growth and degeneration of ice in ports, bays, and seas, and
- (d) reasonable forecasts for the above.

This, it is thought will require two organizations, the operational group, and the research group. The function of the operational group is to collect and disseminate the information in such a manner that it will assist in obtaining the maximum period of safe operation of commercial shipping in the St. Lawrence in the winter, and in northern Canada in the summer. The function of the research group is to carry forward fundamental studies on the climatic and oceanographic factors that affect the growth, distribution, and degeneration of sea ice.

In 1955, the Defence Research Board initiated a sea ice research program at McGill University. Part of this program is directed towards a study of the physical properties of the sea ice. Field studies have also been initiated, by the Meteorological Service and by the Atlantic Oceanographic Group

of the Fisheries Research Board. Other government agencies have been active in other aspects of the ice problem, and it is hoped that shortly these will all be co-ordinated under a working group of the Joint Committee on Oceanography.

Institute of Oceanography of U.B.C.

The prime function of the Institute of Oceanography at the University of British Columbia is to provide instruction at the graduate level in the field of oceanography. The instruction includes both the presentation of lecture courses in biological, chemical, geological, and physical oceanography, and also the organization of research programs for the students to give them training in field and laboratory procedures and in reporting their work.

The research program of the Institute is presently centered on the inlets and coastal waters of British Columbia. The basic study of the water characteristics of the fjord-like inlets of the British Columbia coast has been carried out during the summer seasons, and the following projects have been furthered:

(a) correlations between benthonic organisms and the water properties and circulation,

(b) the estuarial and tidal components of flow in deep inlets,

(c) problems of fluid turbulence,

(d) lateral and vertical mixing,

- (e) internal waves,
- (f) the processes of silt deposition,
- (g) bottom topography and sediments, and
- (h) ionic ratios.

### The Canadian Hydrographic Service

The Hydrographic Service carries out an intensive survey and charting program in Canadian waters, where its chief responsibility is concerned with navigational problems. As one of the organizations co-operating under the Joint Committee on Oceanography, the survey fleet has carried out a regular program of collecting oceanographic data while enroute to and from the various survey grounds. The areas so covered include the various straits and passages along the British Columbia coast, the Gulf of St. Lawrence, the south coast of Nova Scotia and Newfoundland, the coast of Labrador, Hudson Strait and Ungava Bay. The Hydrographic Service was also involved in difficult charting programs relating to the DEW Line Sea Lift in the far North. The new and modern survey ship "Baffin" is being readied for her first survey work in the northern regions in 1957.

Under the Hydrographic Service, the Tides and Currents Survey has been re-organized into the Tidal and Inland Water Section. Tidal, current and wave surveys have been carried out in several areas where detailed information has been required for harbour installations, causeway construction, and tidal power projects. The principal harmonic constituents

of the tide at some seventy ports, in eastern and northern waters, have recently been analysed. Cotidal charts have been prepared from some of these data showing the propagation of the diurnal and semi-diurnal oscillations from the ocean into and around the Gulf of St. Lawrence.

### Naval Research Laboratories

The Defence Research Board maintains the Naval Research Establishment at Dartmouth, N.S. and the Pacific Naval Laboratory at Esquimalt, B.C. These naval laboratories co-operate with the Oceanographic Groups of the Fisheries Research Board in furthering a general oceanographic program in coastal waters, wherein studies are made of the physical and chemical characteristics, the circulation pattern, and the nature and configuration of the sea floor. The Pacific Naval Laboratory has been especially interested in problems of turbulence and in the thermal microstructure in the sea. To aid in these studies, equipment has been developed to measure rapidly the temperature of the water to .001°C. Of special interest to the Naval Research Establishment are the problems of sound transmission in the sea.

### Physical Limnology

The Great Lakes, comprising Ontario, Erie, Huron, Superior, and Michigan, constitute large inland fresh water seas, and a study of the physical and chemical characteristics of their waters properly falls under the subject of physical

and chemical limnology. These lakes vary in size from Lake Ontario, the smallest with a length of approximately 150 miles and a width of 50 miles, to Lake Superior with a length of approximately 400 miles and a maximum width of about 150 miles. In depth, these lakes vary from the shallow Lake Erie, of depths less than 60 metres, to the deep Lake Superior, with depths as great as 400 metres. Surrounded in part by the ever-expanding great industrial areas of Canada and the United States, it is not difficult to appreciate that great changes have occurred in certain environmental factors of these waters, over the past fifty years. So, too, have great changes occurred in the fisheries. The developing situation has finally resulted in the establishment in 1955, by the United States and Canada of a Great Lakes Fisheries Commission, which has the responsibility of making a study of the various fishery problems of these lakes. This will involve limnological studies which will introduce the equipment and methods developed for physical and chemical studies of ocean waters.

The interest will develop in the contrasting characteristics of the various lakes. In the shallower lakes, the waters are readily overturned by wind action and/or seasonal chilling, while the deeper lakes have either a permanent thermocline, or at least a minimum bottom temperature of approximately 4°C. Differences in physical characteristics will prevail due to the varied alignment of lakes with prevailing winds, and contrasts in chemical constituents vary with geological structures, and the degree and kind of pollution.

There are contrasts in the circulation system, the height, length and frequency of waves, the magnitude and frequency of seiches, the amount and kind of sedimentation, and the general vertical and horizontal distribution of physical and chemical characteristics such as temperature, oxygen, nutrient materials, and pollutants.

### The International Geophysical Year

The International Geophysical Year was organized under the authority of the International Council of Scientific Unions. This IGY, as it is called, will bring into being a co-ordinated effort by some forty-six nations of the world, to study some world-wide problems of geophysics. Included in this effort, is a program of oceanography. The Canadian program has been organized under a Canadian Committee for IGY. The details of the oceanographic phases have been co-ordinated under the Joint Committee on Oceanography and will be carried out by the Canadian Hydrographic Service and the Oceanographic Groups of the Fisheries Research Board of Canada.

The oceanographic program, which will be carried out within the period September, 1957 - December, 1958, consists of five projects: (a) Sea Level Recording, (b) Deep Water Circulation, (c) Polar Front Survey, (d) Multiple Ship Surveys, and (e) Observations from Weatherships.

### General

The detailed reports of the Oceanographic Groups are

appended. Thirty-five scientific papers have either been published during 1956-57, or are presently in press. Nineteen manuscript reports were issued.

## Annual Report

### Atlantic Oceanographic Group

#### Introduction

1. The Atlantic Oceanographic Group is responsible for the furthering of oceanographic activities related to the waters contiguous to the Atlantic and Arctic coasts of Canada.

2. The program, which is co-ordinated through the Canadian Joint Committee on Oceanography, is designed to meet the immediate and long term requirements of the Fisheries Research Board of Canada and of the Royal Canadian Navy.

3. 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 existing conditions. Both have specific problems related to particular regions within the larger area of interest. To fulfill these needs the program of studies is aimed at the creation of a file of recorded data from which the answers to most inquiries can be obtained, the detailed investigation of specified regions or problems, and the study of processes fundamental to the understanding of water conditions within the area.

4. The Fisheries Research Board provides personnel to man the Group, laboratory and office space, administrative facilities and certain classes of equipment. The Royal Canadian Navy makes a major contribution in the provision, equipping, manning and administration of a research vessel. Facilities are also provided on board H.M.C.S. "Labrador" for Arctic and winter field work. The Defence Research Board of Canada provides funds

for the acquisition of certain equipment, especially that required for Arctic studies, and will provide specialized part-time personnel.

5. While the Group carries out its own program of researches, its aim can only be met by stimulating interest within other organizations and by encouraging co-operation in the collection of oceanographic information. The co-operation of the Fisheries Research Board of Canada's Biological Station at St. Andrews, N. B. and St. John's, Newfoundland, the Canadian Hydrographic Service, the Naval Research Establishment of Defence Research Board, the Quebec Marine Biological Station, and other organizations, materially assists towards the attainment of the oceanographic objectives.

6. On an international basis, co-operation is maintained with the Woods Hole Oceanographic Institution and the U.S. Navy Hydrographic Office, and there is an exchange of all data collected in waters of common interest.

### Personnel

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

Dr. H. J. McLellan	Oceanographer-in-Charge (Senior Scientist)
Dr. L. M. Lauzier	Senior Scientist
Dr. N. J. Campbell	Associate Scientist
Mr. W. B. Bailey	Assistant Scientist
Dr. R. W. Trites	Assistant Scientist

Mr. A. E. Collin	Assistant Scientist
Mr. J. G. Clark	Technician II
Mr. J. A. Sullivan	Technician I (on leave until May 14, resigned, effective October 3, 1956)
Mr. J. H. Hull	Technician I
Mr. G. B. Taylor	Assistant Technician III
Mr. N. A. Clarke	Assistant Technician III (term to August 17th)
Mr. C. C. Cunningham	Assistant Technician III
Mr. T. A. Grant	Assistant Technician II (from February 1, 1957)
Mr. R. K. Robicheau	Assistant Technician I (from October 1, 1956)
Mrs. M. M. Irwin	Stenographer 2B
Professor D. G. MacGregor	- Associate Scientist (Seasonal)
Mr. R. D. Graham	Student Assistant (Seasonal)
Mr. W. D. Harrison	Student Assistant (Seasonal)
Mr. W. V. Carson	Technician I (From January 21 to February 20, 1957)

8. Dr. McLellan completed the degree of Doctor of Philosophy in Physical Oceanography at the University of California during the year.

9. Dr. Trites was on loan to Naval Research Establishment, Dartmouth, N. S. up to July 1, 1956.

10. Mr. Collin completed the requirements for an M.Sc. degree in geography at the University of Western Ontario in

January 1957. The degree will be conferred at the spring convocation.

### General Program

11. Personnel of the Group have, since February 1956, taken part in 9 oceanographic surveys involving two ships. A total of over 47,500 miles have been steamed, 666 oceanographic stations occupied, 1283 bathythermograph observations taken and 5192 water samples collected for analysis.

12. Special attention has been given to the Gulf of St. Lawrence, with winter surveys carried out in February-March of 1956 and 1957. To make best use of these first available data on winter conditions, complementary surveys through the remainder of the year were considered necessary. A special attempt was made to gather detailed information relative to the summer circulation in the central Gulf.

13. A survey in Newfoundland waters was carried out in September with observations in the Laurentian Channel, southern Grand Banks and Trinity Bay. Personnel from the Biological Station, St. John's, Newfoundland, co-operated and plankton collections were made in addition to the observations in physical oceanography.

14. H.M.C.S. "Labrador" again operated in Foxe Basin, repeating stations occupied in 1955 and increasing the area coverage. Opportunity was found for an excellent survey of Hudson Strait, and, following the work in Foxe Basin, surveys were made in the Gulf of Boothia, Committee Bay and Lancaster Sound.

15. Considerable attention has been given to Passamaquoddy Bay and the Bay of Fundy in anticipation of work to be done in connection with the International Passamaquoddy Fisheries Board. The problems associated with model studies of the area have been investigated and preliminary scaling calculations have been made. Much of the accumulated data from the area have been worked up so as to provide a more advanced starting point for the investigation of this Board. A study of the energy considerations in the Bay of Fundy which had been commenced some time ago was brought to completion as having some pertinence to the problems.

16. Studies of the circulation on the Scotian Shelf as shown by data from seasonal surveys has continued as time was available. The calculations are laborious and time consuming, and the interpretation of results difficult. These studies should evaluate the survey pattern as a tool for observing circulation and point the way for further investigations in this region.

17. On request from naval authorities, a study of pertinent literature and other data was made and a report submitted on the occurrence of ice and icebergs in and around the entrances to the Gulf of St. Lawrence.

18. 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 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 oceanographic stations occupied by all

agencies within the areas of interest.

### Associated Programs

19. A number of vessels operated by the Biological Station, St. Andrews, N. B. made oceanographic observations in association with fisheries investigations. Serial sampling of the water column in Northumberland Strait was carried out regularly in connection with lobster larvae studies, and monthly surveys of the Passamaquoddy Bay area were made in connection with herring studies. The Group processes bathythermograph slides from these investigations, analyzes water samples collected, and offers assistance when desired in the interpretation of results.

20. Ships of the Canadian Hydrographic Service again made oceanographic observations on passage to and from survey areas. As in other years, a member of the Group visited ships before sailing to ensure that they were completely prepared for the observations. The data and water samples are turned over for processing on completion of the season's work.

21. The Naval Research Establishment, Dartmouth, N. S. 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 analyses.

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 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.

### Facilities

22. The laboratory for salinity titrations was completed in the year. There is now adequate provision for two technicians to work simultaneously in a temperature controlled work space.

### General Liaison

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

24. One of the most fruitful liaisons is that with fisheries scientists at the Biological Station, St. Andrews, N.B. All members of the Group take part in this liaison and an attempt is made to keep a major part of the oceanographic program integrated with biological activities related to national fisheries problems.

25. Liaison is maintained with U.S. organizations active in fields of common interest. Data are regularly exchanged with the U.S. Navy Hydrographic Office and the Woods Hole Oceanographic Institution.

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

### Some General Results

27. The results of winter surveys in the Gulf of St. Lawrence have shown that reasonable forecasts of ice conditions

can be made from consideration of the oceanographic parameter "ice potential", as calculated from late autumn surveys, and subsequent meteorological records. It would appear that at least half of the cold intermediate layer in the Gulf is locally formed by winter cooling "in situ". There is a year to year variation in the volume and extent of this cold water which can be related to the severity of ice conditions in the winter.

28. Observations in the central Gulf of St. Lawrence have shown that the Gaspé Current is in part continuous along the southern edge of the Laurentian Channel as far as Cabot Strait. Another portion spreads out over the Magdalen Shallows. There is entrainment of higher salinity waters along the left side of the current in the central Gulf.

29. Deep water in the Laurentian Channel has salinities higher than 34‰ and maximum temperatures at about 250 metres. The maximum temperature shows no seasonal variation but varies year to year by as much as 3 Centigrade degrees. Higher temperatures are associated with greater volumes of the deep layer and these changes are related to temperature changes in the "Labrador" waters.

30. There are certain persistent features shown in the circulation on the Scotian Shelf. The net flow is always found to be southwesterly around Cape Breton and along the Atlantic coast of Nova Scotia, with a minimum transport in early spring and a maximum in the summer. A zone of divergence near Cape Sable varies in position and in the partition of flow between the Bay of Fundy and the Gulf of Maine circulation. There are

indications of a large cyclonic eddy in the central part of the Scotian Shelf at certain times of the year but this is apparently not persistent.

31. A reasonable correlation has been found between the ratio of cod and haddock landings in I.C.N.A.F. subarea 4 and a reliable index of water temperatures over the area. This is in agreement with the known difference in temperature preferences of the two species. This relationship may be of use in forecasting groundfish landings on the basis of temperature trends.

32. Two main currents are found in Foxe Basin, a strong southerly movement along the western side from Fury and Hecla Strait to the southeast tip of Southampton Island, and a northward flow up the central part of Foxe Channel. The southerly flow maintains an outflow through Frozen Strait and a large eddy in the central part of the Basin. The northerly movement appears to originate in Hudson Bay and Hudson Strait and extends well into the Basin, turning eastward around Foxe Peninsula.

#### Incidental Activities

33. The Oceanographer-in-Charge took part in a discussion recorded for the CBC program "Canadian Science".

34. Dr. Trites presented a paper at the annual meeting of the American Geophysical Union.

35. Dr. McLellan and Dr. Lauzier collaborated in preparing a paper for presentation at a meeting of representatives of the fishing industry at St. Andrews, and also on a short lecture to a course for Fisheries Officers.

36. Dr. Lauzier attended the annual meeting of the International Commission for the Northwest Atlantic Fisheries in the capacity of adviser to the Canadian commissioners.

Publications

37. The following papers have been published within the year or are in press:

Bailey, W. B. Water temperatures around North America.

Fish. Res. Bd. Can. Prog. Rept. (Atl.) No. 64, p. 16-18.

Bailey, W. B. On the origin of the deep Baffin Bay water.

J. Fish. Res. Bd. Canada, 13(3), 303-308, 1956.

Hachey, H. B., L. M. Lauzier and W. B. Bailey. Oceanographic features of submarine topography. Trans. Roy. Soc. Can. 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 the 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. Canada 13(3), 435-448, 1956.

McLellan, H. J. and L. Lauzier. Predicting water temperatures.

Canadian Fisherman, 43(9): 11-12, September, 1956.

McLellan, H. J. On the sharpness of oceanographic boundaries

south of Nova Scotia. J. Fish. Res. Bd. Canada, 13(3),  
297-301, 1956.

McLellan, H. J. On the distinctness and origin of the slope  
water off the Scotian Shelf and its eastward flow south of  
the Grand Banks. J. Fish. Res. Bd. Can. - IN PRESS.

McLellan, H. J. Energy considerations in the Bay of Fundy  
system. J. Fish. Res. Bd. Canada - Submitted.

Trites, R. W. The oceanography of Chatham Sound, British  
Columbia. J. Fish. Res. Bd. Canada, 13(3), 385-434, 1956.

Trites, R. W. The ocean floor and water movements. Trans.  
Roy. Soc. Can. - IN PRESS.

#### Manuscript Reports

38. The following manuscript reports have been distributed:

Bailey, W. B. and L. Lauzier. Incidence of ice and icebergs  
in the entrances to the Gulf of St. Lawrence and along the  
south coast of Newfoundland. MSS Rept. Joint Committee on  
Oceanography, 26 pp. November 1956.

Campbell, N. J. and A. E. Collin. A preliminary report on some of the oceanographic features of Foxe Basin 1955.

MSS Rept. Joint Committee on Oceanography, 42 pp. May 1956.

MacGregor, D. G. Calculation of geostrophic currents. MSS.

Rept. Joint Committee on Oceanography, 11 pp. October, 1956.

McLellan, H. J. Studies of the slope water east of Georges Bank. MSS Rept. Joint Committee on Oceanography, 125 pp. October, 1956.

Trites, R. W. A study of the oceanographic structure in British Columbia inlets and some of the determining factors. MSS Rept. Joint Committee on Oceanography, 125 pp. March 1956.

39. The following summary reports are attached:

(a) Seasonal Cruises - R. W. Trites

(b) Energy considerations in the Bay of Fundy system -

H. J. McLellan

(c) Flushing times in the Bay of Fundy - W. B. Bailey

(d) Passamaquoddy Model Project - R. W. Trites

(e) Coastal and slope waters in the Bay of Fundy - W. B. Bailey

(f) Surface water temperatures in 1956 - L. M. Lauzier

(g) Circulation on the Scotian Shelf - R. W. Trites

(h) Water temperature and groundfish landings - L. M. Lauzier

(i) Slope water studies - H. J. McLellan

(j) Oceanographic survey in Newfoundland waters - W. B. Bailey

(k) Summer survey of the Gulf of St. Lawrence - L. M. Lauzier

(l) The deep waters in the Laurentian Channel - R. W. Trites

and L. M. Lauzier

- (m) Winter oceanography in the Gulf of St. Lawrence -  
L. M. Lauzier
- (n) H.M.C.S. "Labrador" 1956 Arctic Field Program -  
N. J. Campbell
- (o) Oceanographic surveys and ice conditions - Hudson Strait  
N. J. Campbell
- (p) General oceanography of Hudson Strait - N. J. Campbell
- (q) Oceanography of Foxe Basin - N. J. Campbell
- (r) Oceanographic survey of the Gulf of Boothia, Prince Regent  
Inlet - 1956 - A. E. Collin
- (s) Oceanographic observations by the Canadian Hydrographic  
Service - W. B. Bailey
- (t) Technical services - L. M. Lauzier

H. J. McLellan  
Oceanographer-in-Charge.

St. Andrews, N. B.  
March 15th, 1957.

## Seasonal Cruises

The long term program of seasonal surveys, initiated in 1950, covering a network on the Scotian Shelf, the entrance to the Bay of Fundy, and the Gulf of St. Lawrence, has been continued. This year, in addition to observing temperature and salinity, oxygen and phosphate determinations have been made for a large percentage of the stations. Normally an attempt is made to cover the area four times a year with the exception of the Gulf of St. Lawrence, where winter ice conditions may prevent observations from being made in some areas. However, with the use of the icebreaker H.M.C.S. "Labrador" as an oceanographic vessel, winter surveys of the Gulf of St. Lawrence in both 1956 and 1957 have been successfully carried out.

During the past year particular emphasis has been given to surveys of the Gulf of St. Lawrence. These more intensive surveys are designed to shed further light on the seasonal variations in the circulation pattern and distribution of properties. In particular, the nature of the cold water layer and its fluctuations seasonally and from year to year is being examined more closely.

During the spring and summer surveys, particular attention was given to the Gulf of St. Lawrence, with observations on the Scotian Shelf being limited to certain stations serving to monitor conditions for the entire Shelf area. In the autumn, the entire network of stations was occupied as well as stations between Seven Islands and the Gaspé Coast and through the Strait of Canso. The winter survey of the Bay of Fundy and

Scotian Shelf was not implemented due to the refitting of the research vessel C.N.A.V. "Sackville".

R. W. Trites

Energy Considerations in the Bay of Fundy System

Calculations have been made of the power involved in various processes in the Bay of Fundy. The results are tabulated below:

	<u>Power (millions of Kilowatts)</u>	
Transmitted into Bay of Fundy	31.4	
"          "    Passamaquoddy Bay		1.33
Work done on the moon		0.60
Dissipated in tidal friction		21.1
Used to maintain mixed state		0.03
Not accounted for in calculations		8.3
	<hr/>	<hr/>
	31.4	31.4

The unaccounted for  $8.3 \times 10^6$  kilowatts is probably dissipated by tidal friction but did not show in the calculations since specific attention could not be given to shallow areas with high velocities.

The effect which the extraction of additional power from the system would have on tidal ranges was evaluated. The range at the head of the Bay would decrease at the rate of 0.84 feet for each million kilowatts. The proposed Passamaquoddy Power Project would probably increase the mean tidal range at Hopewell Cape by 0.6 feet.

A paper has been submitted for publication.

## Flushing Times of the Bay of Fundy

The average length of time required to remove one day's contribution of river water is equal to the ratio of the quantity of river water accumulated within an estuary to the quantity introduced daily by the river. This has been called the flushing time.

Calculations of the flushing times from data obtained from two synoptic surveys of the Bay of Fundy gave values which were significantly different from the published values of 76 and 74 days.

Twenty-one determinations of the flushing time were made using river discharges averaged over varying periods and using different base salinities. From these it is apparent that: (a) a difference of 0.10 parts per mille in the choice of a base salinity may vary the resulting flushing times by as much as 26 days; and (b) the choice of values selected to determine the runoff may vary the resulting flushing times by as much as 80 days. The runoff values for April or May are much greater than those for other months of the year. The inclusion of these peak runoff data will significantly distort the flushing time calculations if they are not strictly applicable to the case under consideration. Thus the discharge data should include only those runoff data which directly contribute to the accumulated river water in the Bay.

In considering the above, it is apparent that large differences in the flushing times do exist. Flushing times

in the spring during peak runoff are short (about 80 days), while during the winter they are long (about 200 days).

W. B. Bailey

### Passamaquoddy Model Project

In the Passamaquoddy power project, it is proposed to place dams across the entrances to Passamaquoddy Bay and also Cobscook Bay, and thereby restrict the flow through the passages leading to these Bays. There have been various schemes proposed, but in any event, whether Passamaquoddy Bay is to be a "high level" basin or a "low level" basin, the tidal amplitude will be reduced to roughly 25% of its present value.

Both the area inside and outside Passamaquoddy Bay has a rich sardine fishery, and hence it is important to know beforehand what effects the power project is likely to have on the fishery. While it is not known specifically what factors determine the sardine abundance and movements, it is suspected that the physical oceanographic features of the area play a major role in this respect.

The degree and extent to which the proposed dams will alter the circulation and mixing in the surrounding areas cannot be determined with a very high degree of confidence, on theoretical grounds alone. It has been suggested that an hydraulic model of the area will serve as a valuable aid in removing this difficulty. With this in mind, some preliminary thought has been directed towards the design and scale of an hydraulic model of the area.

Since one has little notion as to how extensive the influence of the dams may be, it is advisable to study the possible effects for the region from Point Lepreau to West Quoddy

Head. If the model represents an area extending from the south end of Grand Manan Channel to Cape Spencer, this would facilitate the study of the influence of the Saint John river outflow on the area, and also should assure the elimination of any "edge" effects from the tide generating basins. The maximum dimensions of the prototype covering the area is 60 by 40 nautical miles. To reproduce the tidal currents of the prototype, it is necessary to have water entering one end of the model and simultaneously being removed from the other end at about one-half the entrance rate on the flooding tide; the reverse situation being requisite on the ebbing tide. On a relative basis, the residual flow through the model would be small. Preliminary calculations suggest that a horizontal scale ratio of 1:7300, and a vertical scale of 1:146 are in the vicinity of what will be required. These appear to be about the smallest scales permissible, if useful results are to be obtained regarding the distribution of salinity. With these scale ratios, the model will have turbulent flow in most places (depth exceeding 20 ft. and velocity exceeding 0.8 knots in prototype), although the intensity of mixing may not be adequate.

Ideally one would hope that an hydraulic model of the area would successfully reproduce the circulation and distribution of properties as observed in the prototype. It seems highly probable that a model can be built to satisfactorily reproduce the circulation but it is doubtful if one can determine beforehand the degree to which the model will simulate the mixing, and therefore the distribution of properties.

Coastal and Slope Waters in the Bay of Fundy

Observations in the Bay of Fundy and in adjacent areas have indicated that the waters of the Bay of Fundy are primarily a mixture of coastal waters whose salinity may be taken as 30.8‰ and of slope water which has a salinity of 35.2‰.

Calculations of the percentages of coastal, or slope water, at stations in the Bay of Fundy, Fundian Channel, and on the Scotian Shelf indicate that:

(a) there is a relationship between the percentages of slope water in the Fundian Channel and in the Bay of Fundy,

(b) there is no relationship between the percentage of slope water off the Scotian Shelf and that in the Fundian Channel, and,

(c) the percentage of slope water in the Bay of Fundy is primarily controlled by the local processes, and to a lesser extent, by the availability of slope water from the Gulf of Maine.

Comparisons of the percentages of coastal or slope waters with river discharges and excess of SW-NE wind mileages indicates that these have considerable influences in controlling the time, duration and amount of slope water entering the mixing mechanism of the Bay of Fundy.

Surface Water Temperatures in 1956

Observations of water temperatures, taken twice daily, were continued through 1956 at six points along the Canadian Atlantic coast. These observations of temperature revealed a general decrease in 1956 as compared to the previous year. It is to be noticed that the year 1956 is the third consecutive year of general cooling.

The accompanying table gives the monthly averages of temperatures at various points in 1956. The observations were taken at St. Andrews, N.B., Lurcher Lightship, N.S., Halifax, Harbour, N.S., Sambro Lightship, N.S., Entry Island, P.Q., and Port Borden, P.E.I.

The decrease in temperature was general during the first three quarters of the year resulting in a decrease in the annual mean temperatures at all stations. The table shows also that more than half of the monthly temperatures are below normal.

L. M. Lauzier

Monthly Surface Water Temperatures along the Canadian  
Atlantic Coast

Month	St. Andrews N.B.	Lurcher Light- ship, N.S.	Halifax Harbour N.S.	Sambro Light ship, N.S.	Entry Island Que.	Port Borden, P.E.I.
Jan.	1.8 -	3.7 --	2.7 -	1.6 --	-0.2 -	-0.7 -
Feb.	1.3 -	2.8 --	1.2	1.6 --	-	-1.3 -
Mar.	1.3 -	2.5 --	0.8 -	-	-1.7	-1.3 --
Apr.	3.5 --	2.4 --	2.6 -	1.1 --	0.3 --	1.5 --
May	5.9 --	4.5 --	4.1 -	3.9 --	5.2 -	6.8 --
June	9.0 --	4.7 --	9.3 --	7.9 --	9.5 --	13.1 +
July	11.0 --	9.0 --	12.4 -	13.5 --	15.1 +	17.0 +
Aug.	12.3 --	10.1 --	15.0 --	15.9 --	16.5 --	18.0 --
Sept.	12.0 --	-	15.2 +	15.6	14.6 --	15.9 --
Oct.	10.3 --	-	11.7 +	12.7 --	9.7 --	11.2 -
Nov.	8.2 -	10.4 +	9.3 +	-	5.6 +	6.4 +
Dec.	4.8 +	7.9 +	6.0 +	5.7 --	-	0.2 +

- Decrease as compared to the previous year

-- Lower than normal

+ Increase as compared to previous year

## Circulation on the Scotian Shelf

An analysis of the temperature and salinity data gathered on the seasonal surveys over the Scotian Shelf is being undertaken. Since 1950, cruises have covered the network of 31 stations, 23 times.

The first step has been to determine the mass field and then the dynamic topography of the sea surface. Dynamic heights have been plotted with reference to various assumed levels of no net motion. However, the calculation of currents in shallow areas with widely variable depths is always a difficult problem involving assumptions and uncertainties. Various methods have been proposed, but all require the plotting of the isosteres for a section and their extrapolation through the sloping bottom into a fictitious water mass. The method used here is that suggested by Groen.

The results obtained to date do, however, indicate certain persistent features of the circulation. The net flow is always found to be southwesterly around Cape Breton, varying in magnitude seasonally, from a minimum in the early spring to a maximum during the summer months. The flow is normally to the southwest all along the Atlantic coast of Nova Scotia, until it reaches Cape Sable. Here the flow is evidently divergent, with part moving northward into the Bay of Fundy and part moving southward and eventually eastward. The region of divergence appears to fluctuate somewhat in position with volume transport proportions in each branch varying markedly. Over the large central portion of the Shelf, net currents are found to be small and the

circulation pattern varies widely both seasonally and from year to year. There are indications that at certain times of the year a large cyclonic eddy exists, centered in the Sable Island Bank region, while at other times, no such eddy can be identified.

Further analysis of the data is being directed towards determining heat and salt transports. It is felt that these will aid in shedding further light on the nature of the circulation patterns, since both of these quantities must be consistent with the volume transports. However, despite the success that may ensue in this direction, it is becoming increasingly apparent that in this area, which covers one whose depth is so variable, and where effect of bottom topography is a conceivably important factor in determining the circulation patterns, the confidence that can be placed on indirect computation will be limited, until supported by direct current measurements.

R. W. Trites

## Water Temperatures and Groundfish Landings

Observations of surface temperatures at St. Andrews, N.B. beginning in 1921 gave the longest continuous water temperature records for the Canadian Atlantic waters. Short period variations, of the order of 3 to 15 years, are exhibited in the data, but long-term variations show up if the first ones have been smoothed out by means of running averages.

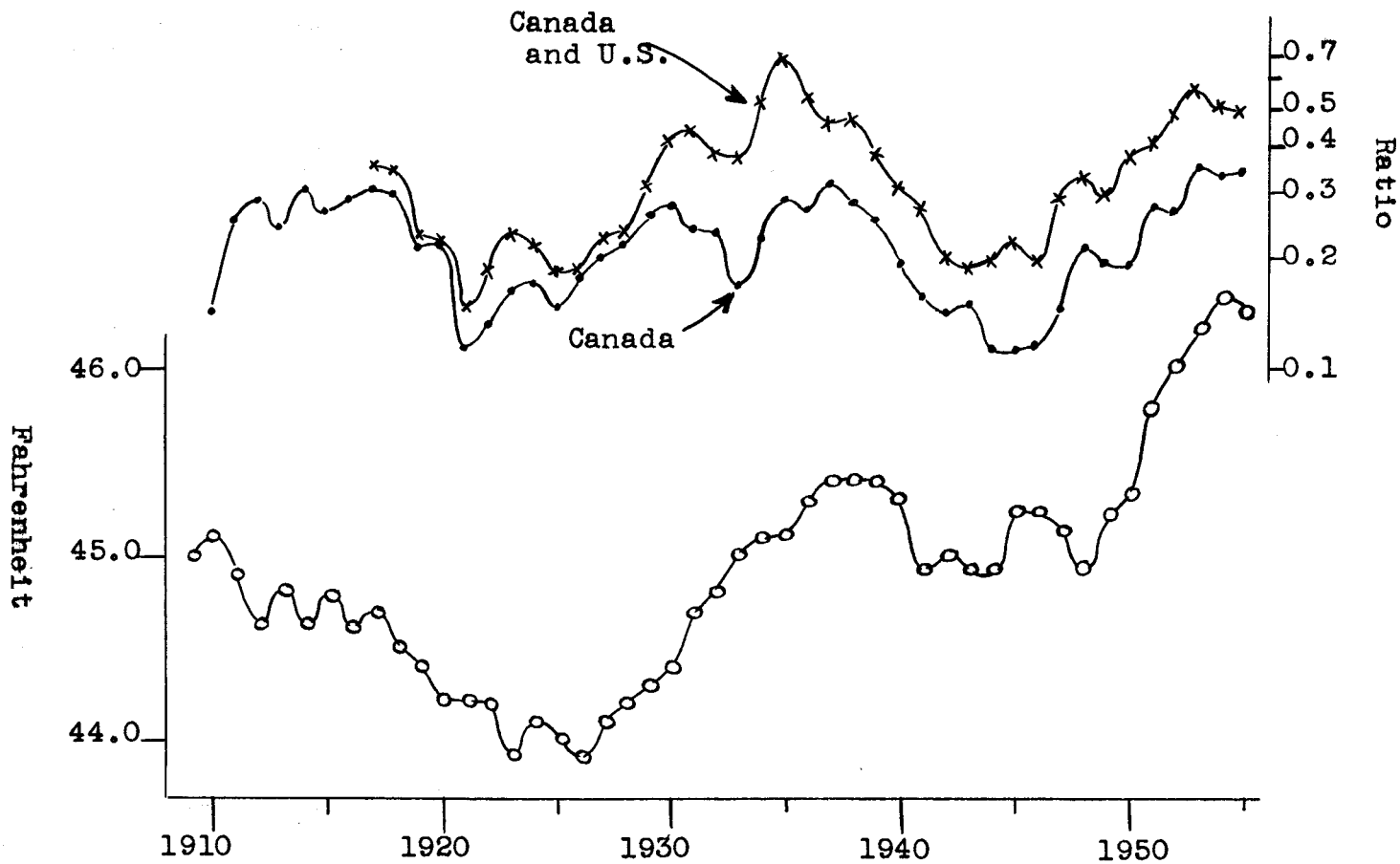
A remarkable trend towards higher temperatures have persisted since the mid-twenties in spite of a period of falling temperatures in the early forties. These St. Andrews temperatures are typical of temperatures all around the Maritimes as can be shown by comparison to shorter period records from a number of locations. A comparison with air temperatures from longer records taken at Sable Island, N.S. has shown a close relationship between trends in the air at Sable Island and in the water at St. Andrews. It could be assumed then that the longest air temperature records from Sable Island are showing approximately what the water temperatures were in the period before the St. Andrews records began. The ten-year moving average of the air temperature at Sable Island is given in the accompanying figure (lower curve) as an index of temperature variations over the Scotian Shelf.

It is expected that such changes in the water conditions would affect some of the fisheries. However, fish populations are difficult to estimate, and landing statistics often reflect economic factors as well as concentration of fish. The ratio

of species caught in a fishing operation would perhaps be somewhat free from most economic factors. The Canadian and U.S. catch statistics for ICNAF Subarea 4, have been used for computing the ratio  $\frac{\text{Haddock landings}}{\text{Cod landings}}$  for a number of years. The computed ratios are plotted along with the index of water temperature variations on the Scotian Shelf. While the correlation is not perfect there is a marked similarity in the curves indicating that relatively more haddock are caught in the warm periods and relatively more cod in the cold periods. This is in good agreement with the known temperature preference of the fish, haddock favouring a somewhat higher range than do cod.

The relationship between the index of temperature variations and the ratio of landings,  $\frac{\text{haddock}}{\text{cod}}$  becomes important in the case of prognostication of groundfish operations as based on long-term temperature variations.

L. M. Lauzier



Ratio of haddock to cod annual landings in Subarea 4: upper two curves. Index of temperature variations over the Scotian Shelf: lower curve.

## Slope Water Studies

Seasonal surveys on the Scotian Shelf continued to intersect the Slope Water Boundary at at least three longitudes so as to follow variations in the shoreward limits of this water mass.

A report on the results of several years of slope water investigations has been prepared and circulated and a paper is in press. A major ocean current originates in the Slope Water south of Nova Scotia and forms part of the Gulf Stream complex. Within a rather limited area, two important water masses, the "Slope Water" and "Coastal Water" are formed from the parent waters "Atlantic" and "Labrador" waters.

The results of a 1954 survey have also been reported upon. This survey covered the area immediately west of the Grand Banks at a time when the flow of "Labrador Water" around the Tail of the Banks had been reduced to negligible proportions for several months.

H. J. McLellan

## Oceanographic Survey in Newfoundland Waters

In co-operation with the Biological Station, St. John's, Newfoundland, a two part oceanographic cruise was carried out from the C.N.A.V. "Sackville", in late September. Observations included the regular ones for temperature and salinity at standard serial depths, bathythermograms, plankton tows, and dissolved oxygen analyses at selected stations. In the first part of the cruise, observations were taken in six sections running from Cabot Strait to the Tail of the Grand Banks. In the second part, sixty-six stations were occupied in a network of 10 sections in Trinity Bay and in the waters immediately adjacent to it.

Analyses of these data have not been undertaken, but some points of interest regarding the waters of Trinity Bay were revealed during survey on September 27-29.

Trinity Bay has a maximum depth of 560 metres and a sill of 280 metres depth, which is located 30 miles outside the mouth of the Bay.

The waters in the area may be divided into three layers on the basis of the temperature and salinity distribution, they are:

(a) a well mixed surface layer with temperatures between  $8^{\circ}$  and  $10^{\circ}\text{C}$ . and with salinities less than 31.5‰, and

(b) an intermediate cold water layer with temperatures less than  $0.0^{\circ}\text{C}$ . with a minimum observed temperature of  $-1.48^{\circ}\text{C}$ . Salinities in this layer are between 32.5‰ and 33.5‰, and

(c) a warm bottom layer with temperatures greater than 1.0°C. and salinities greater than 34.0‰.

The two upper layers were in direct communication with the open ocean. The bottom layer was confined to depths greater than 300 metres. The dissolved oxygen content indicates that the deeper waters are cut off from exchange with the surface layer throughout the summer months. The dissolved oxygen content at a depth of 550 metres was 2.1 ml/l.

W. B. Bailey

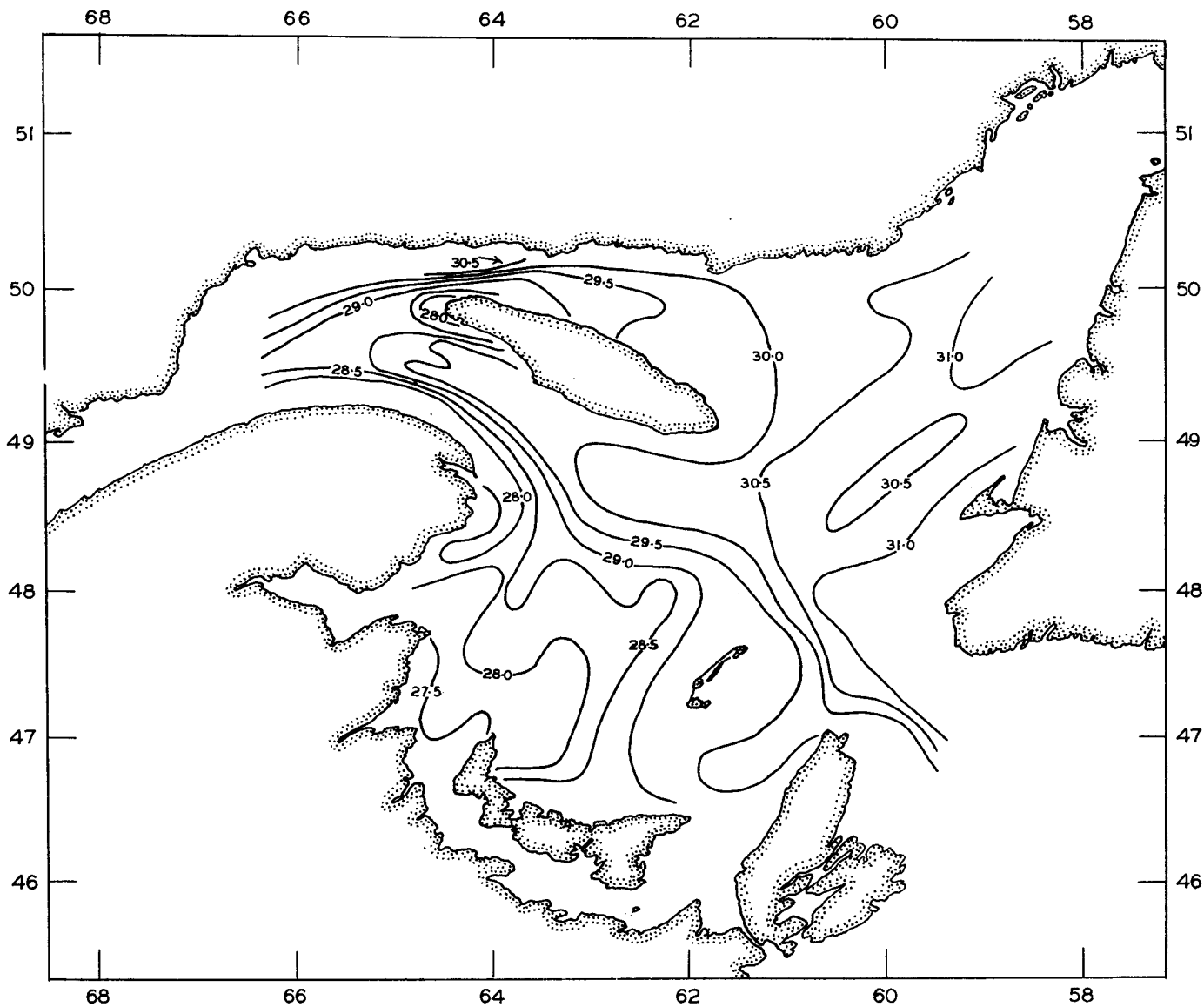
Summer Survey of the Gulf of St. Lawrence

The seasonal surveys in the Gulf of St. Lawrence were undertaken with the purpose of studying the seasonal as well as the year-to-year changes in the oceanographic conditions of the Gulf. Special attention has been given to the northwest sector of the Gulf and to the Estuary of the St. Lawrence in 1953 and 1955. The central sector of the Gulf from Gaspé Passage to Cabot Strait and from the Magdalen Shallows to Esquiman Channel had not yet been explored thoroughly. From August 10th to 17th, 1956, the C.N.A.V. "Sackville" was engaged in a quasi-synoptic survey of the Magdalen Shallows, the Esquiman Channel, the Laurentian Channel and Jacques Cartier Passage.

The data from this survey of the central sector of the Gulf will supplement the data collected previously in the northwestern Gulf and the Estuary, regarding the study of the Gaspé Current. The interrelated aspects of the problem to be considered in the light of the results of the last cruise are: the path of the Gaspé Current after it leaves the Gaspé Peninsula, the contribution of the current to the replacement of the waters of the Magdalen Shallows and of the Bay of Chaleur and the relationship between the Gaspé Current and the Cape Breton Current.

A small proportion of the data has been analysed and the distribution of surface salinity is shown in the accompanying figure. Some of the results are as follows:

1. The range of surface salinity was less than four parts per



**Figure** Surface salinity in the Gulf of St. Lawrence  
August 10 - 17, 1956.

thousand (27.5-31.0‰). The minimum salinity was located on the Magdalen Shallows near the northern tip of Prince Edward Island which is in accordance with previous work describing the time variations of the salinity along the north coast of Prince Edward Island.

2. A steep horizontal gradient of salinity was observed along the southern edge of the Laurentian Channel. Such a distribution indicates some continuity between the Gaspé Current and the Cape Breton Current. It also suggests the entrainment of higher salinity waters from the left hand side of the current in a southeasterly direction.

3. The higher salinity waters along the west coast of Newfoundland are related to the incoming current on the eastern side of Cabot Strait, around Cape Ray.

4. The volume of the cold-water layer, of temperature below zero, was small in the Laurentian Channel, with a minimum temperature of  $-0.33^{\circ}\text{C}$ ., in the Gaspé Passage area, but it was much larger along the North Shore of the Gulf with a minimum temperature of  $-1.14^{\circ}\text{C}$ .

L. M. Lauzier

## The Deep Waters in the Laurentian Channel

Data pertinent to the deep warm water of a stratified three layer system in the Cabot Strait area of the Laurentian Channel, have been collected since 1915. Scattered observations were made up to the mid 1930's followed by more or less regular seasonal observations during the last decade. A study of these data is underway to determine the time variations in temperature, salinity, and volume of the deep layer, and the factors controlling or relating to them.

For analytical purposes, the deep layer is taken to be that whose salinity exceeds 34.0‰. Typical temperature-depth curves indicate that the temperature of the deep layer reaches a maximum at about 250 metres. This maximum shows little or no seasonal changes but year to year variations may exceed 3 C°. Observations show warming of the deep layer from the 1920's to the 1950's, and to a lesser degree, a warming of the upper boundary zone as defined by the 33.0‰ and 34.0 isopleths. The upward trend of temperatures is accompanied by a greater volume of the deep layer and a shallowing and reduction in volume of the boundary zone. Salinity at the maximum temperature varies by less than 0.10‰.

The deep layer consists of a mixture of "Labrador" and "Slope" water in which the mixing ratio of the components remains constant from year to year. Fluctuations in temperature of "Labrador" water are reflected by corresponding changes in temperature of the deep layer in the Laurentian Channel.

The volume of the deep layer is related to its temperature and salinity and to the thickness of the upper boundary zone.

R. W. Trites and L. M. Lauzier

Winter Oceanography in the Gulf of St. Lawrence

1. 1956

Winter oceanographic observations in the Gulf of St. Lawrence were made for the first time in February-March, 1956 when the H.M.C.S. "Labrador" was engaged in an oceanographic survey of the area. The formation of ice in the Gulf as an oceanographic phenomena and the origin of the cold water layer of the Gulf are the two main problems studied in the light of winter observations. Observations made during the previous autumn and the following spring and summer cruises were also considered.

The ice observed in 1956 was mostly young and very young ice with a thickness of less than twelve inches. Light ice conditions in 1956 resulted from abnormally high air temperatures which prevailed up to the month of March. By the end of February, the freezing season was 6 weeks late along the North Shore of the Gulf. According to ice potential calculations, from autumn observations, it was found that in 1956 the ice would form at first along the Gaspé Coast. The calculations also indicated that it would take a much longer period to form in the northern half of the Laurentian Channel, in Cabot Strait and along the west coast of Newfoundland. These were fair estimates since the open water area, at the end of February, included a large area from the northern half of the Laurentian Channel to the west coast of Newfoundland. The calculations indicated that ice formation over the Magdalen

Shallows would occur late, but the presence of ice in the area suggests that the ice had drifted from another area. This is in agreement with the conclusions drawn from surface temperature distribution in the winter. Ice potential calculations also indicate that, along the Gaspé Coast, as the ice will start to form early, the thickness of the mixed layer will be between 12 and 25 metres. In February, the mixed layer was found to have a thickness of 125 to 150 metres. Such an increase in the thickness of the mixed layer along the Gaspé Coast suggests that ice was continually formed there and carried away by the current and the wind towards the Magdalen Shallows.

The distribution of temperature and salinity in the mixed layer during the winter indicates that at least half of the cold-water layer is formed in the Gulf. It was believed previously that at least one-third was formed "in situ". The volume of the cold-water layer varies from year to year. In the summer, 1956, the volume of the cold-water layer was small across the Gaspé Passage. Previous observations also indicate that during the summers of 1952 and 1954, the cold-water layer had a smaller volume than during the summers of 1946, 1947 and 1950. The year-to-year variations in the volume and extent of the cold-water layer seem to be related to the severity of ice conditions during the previous winter. The 1956 observations show that ice conditions were light in the Gulf. Ice conditions were considered moderate to light in 1952, but moderate to heavy in 1946, 1947 and 1950. It is apparent, then, that small volumes of the cold-water layer in the summer

are associated with light to moderate ice conditions in the previous winter and that large volumes of the cold-water layer in the summer are associated with moderate to heavy ice conditions in the winter.

## 2. 1957

A second winter survey was undertaken aboard the H.M.C.S. "Labrador" in the Gulf of St. Lawrence from February 22nd to March 3rd, 1957. Observations were made along sections across the main channels and passages. Special attention was given to the Laurentian Channel from Cabot Strait up to the mouth of the Saguenay River. Observations were also made west of the Saguenay River and in the Esquiman Channel as far as Bay of Islands, Newfoundland. One station was occupied over the Magdalen Shallows.

Ice observations were made during the cruise from the ship and more than ten air reconnaissance flights were undertaken by the Maritime Squadron of the Royal Canadian Air Force in collaboration with the Royal Canadian Navy. The ice distributions were very different in 1956 and 1957. Ice conditions were light in 1956 and heavy in 1957. The heavy ice conditions just experienced are related to abnormally low air temperatures at the beginning of the winter and relatively high ice potentials.

H.M.C.S. "Labrador" 1956 Arctic Field Program

H.M.C.S. "Labrador" sailed from Halifax, N.S. on July 3rd to commence her Arctic operations for the summer of 1956. She was committed to assist the sea-lift operations to carry out hydrographic, oceanographic and ice surveys, and investigate certain areas north of Foxe Basin. She returned to Halifax on October 15th having steamed 18,606 miles and completing all her major tasks.

Three members of the Atlantic Oceanographic Group and one from the Arctic Unit, Montreal, made up the oceanographic team. Ice physics and problems of the sea ice navigability were investigated by Drs. E. M. Little, McGill University and U.S.N.E.L. and C. W. Swithinbank, D.R.B., respectively.

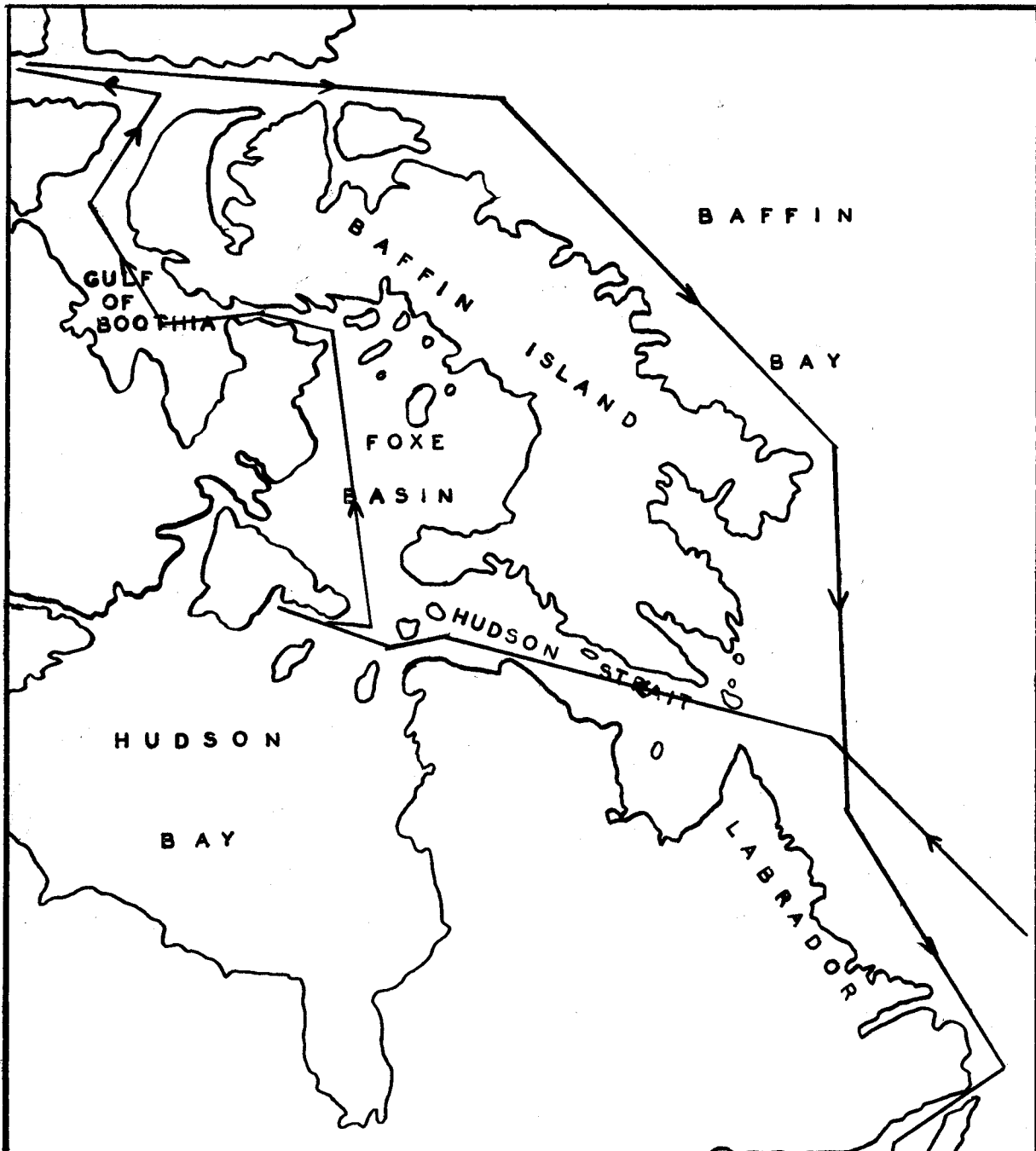
The oceanographic work was integrated into the operational requirements of the ship and it was possible to make observations in all areas of operation. Oceanographic surveys were conducted in Hudson Strait, Foxe Channel, Foxe Basin, Gulf of Boothia, Prince Regent Inlet, Lancaster Sound, Baffin Bay and the Labrador Sea. A total of 200 stations were occupied during the summer and observations included temperatures, salinities, oxygen, phosphate and current measurements. Special attention was devoted to phytoplankton by Mr. A. Bursa, who examined plankton tows aboard ship. Taxinomic examinations of the hauls were made with a phase microscope and approximately 40 species of dinoflagellates were studied besides many other forms of life.

Seventy-five bottom snaps were made enroute, mostly in Foxe Basin, in an effort to complete the existing collections. Sampling was continued through the Gulf of Boothia and Prince Regent Inlet for a northern extension of sediment collections.

Dr. E. M. Little conducted physical experiments on ice in situ for hardness, conductivity and friction. Samples of ice were collected for measurements of shear strength, tensile strength and compressibility aboard, while other samples were melted down for tritium age determinations.

On the completion of the national commitments within the Archipelago, assistance was rendered to the U.S. Hydro programme of oceanographic stations for the 1957 prognostic ice reports.

N. J. Campbell



**OPERATIONAL AREAS**  
**HMCS LABRADOR**  
**JULY - OCT 1956**  
**DAYS AT SEA 102**  
**DISTANCE STEAMED 18600 MILES**



Oceanographic Surveys and Ice Conditions - Hudson Strait

In 1955 H.M.C.S. "Labrador" conducted two oceanographic surveys of Hudson Strait, a small survey in June and a much more comprehensive one in November. Altogether 53 stations were occupied in the Strait. In 1956 a similar study was undertaken in July, reoccupying many of the previous stations and sections of the year before. These data are currently being analysed for the pertinent oceanographic features.

In June 1955, the only sizeable open water region in the Strait was a long narrow polyna extending from almost the southeastern tip of Baffin Island to Big Island. Elsewhere the Strait was covered with heavy close pack ice. These conditions made it practically impossible to obtain cross-sections in the Strait and only 17 stations were completed.

The persistence of an unseasonably warm spell in October and November permitted a survey consisting of 36 stations to be undertaken in November under ice-free conditions.

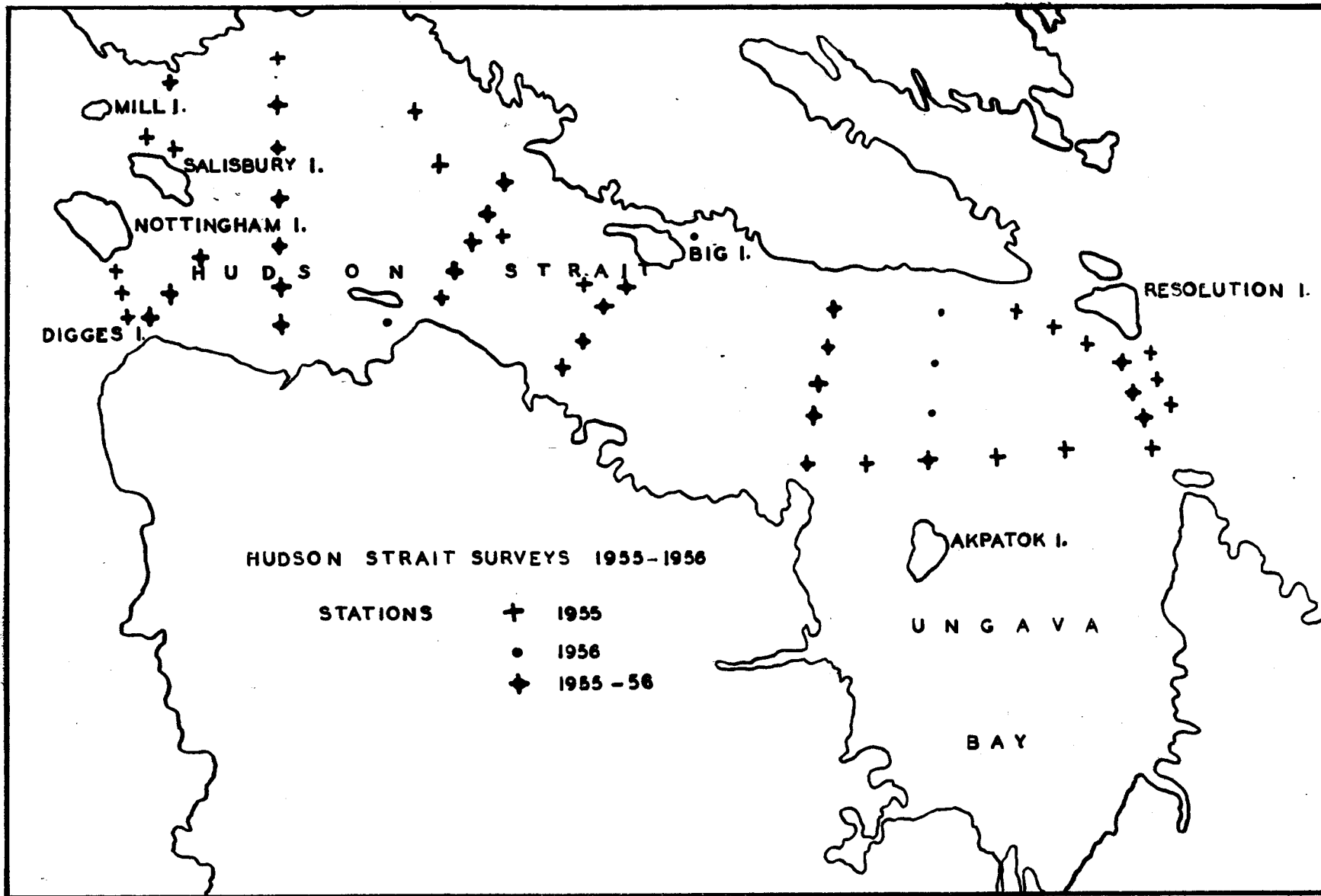
It was the intention to reoccupy these stations in July 1956, but ice conditions were so severe that the first section between Resolution Island and the Button's was abandoned after three stations. The section across Ungava Bay did not offer any improvement for ice conditions and the next section to the west was attempted. It was found that the heaviest concentrations of ice were again along the south shore but not as extensive as first anticipated. Icebergs, however, were far more numerous than during the previous year.

After breaking through the eastern belt of ice, all the remaining sections were occupied, 36 stations being taken enroute.

Generally the ice outlook improves in the Strait by mid-July, particularly in the north central section where the ice disappears first. Both the eastern and western entrances open up by late July but large floes of ice will still be seen in the Strait as ice from Foxe Channel moves eastward.

Freeze-up in the Strait was predicted for November 1955 but at that time no indications of ice were seen even along the shore edge. However, given normal weather conditions, ice will be forming along the south shore and in Ungava Bay by mid-November.

N. J. Campbell



## General Oceanography of Hudson Strait

The circulation of Hudson Strait is dominated by a steady outflow of water from Hudson Bay which is confined largely to the south shore. This flow is particularly evident off C. Wolstenholme and Digges Is. where a continuous outward flow of water exists which is weakened only by flood effect. The main outflow from Hudson Bay appears to be between C. Wolstenholme and Nottingham Island. The stream parallels the coast as far as Ungava Bay and is approximately 20-30 miles in width. A large part of the water sweeps into Ungava Bay off C. Hopes Advance and perhaps east of Akpotok Island. The discharge from the Strait appears to be very close to the southern entrance off the Button Islands.

The inflowing waters around Resolution Island appear to be more variable, however, a definite westward movement of water along the Baffin Coast extends into the Strait. This water turns into the main outflowing stream between Akpotok and Big Islands. The data also indicate that part of the exchange of water in the eastern section of the Strait occurs directly between the eastern passages and Ungava Bay.

The westward flow along the north side of the Strait practically ceases at Big Island where an eastward flow from Hudson Bay also appears to terminate. A return circulation westward along the north coast to Foxe Channel exists which must carry some of the water which originally entered the Strait off Resolution Island into Foxe Channel and Hudson Bay.

Tidal currents play an important role in the Strait, particularly at the eastern and western entrances where currents from 3 to 5 knots are known to exist. South of Resolution Island strong overfalls and tide rips occur which move the ice or a small ship about in frightening fashion. The channels at the western end and along the coast from Big Island to Dorset also exhibit marked turbulence, eddies, and tide rips.

The major characteristics of the salinity distribution found in the fall cruise of 1955 appeared again in the summer of 1956. These features are clearly related to the dynamics of the Strait which are dominated by the outflow from Hudson Bay. At stations occupied along the southern coast, the lowest average salinities were found to exist for both years 30.78‰ in 1955, and 31.03‰ in 1956. Across the Strait higher average salinities were found, 32.61‰ and 32.20‰, for 1955 and 1956 respectively.

Cross-sectional plots of salinity exhibit downward slopes of the isohalines from north to south, while horizontal plots show that the isohalines parallel the coast. Salinity values increase from Hudson Bay through the Strait to the Atlantic with marked variations of the distribution of salinity appearing from C. Hopes Advance east to the Button's. These variations occur from intense mixing of waters and cross channel movements.

Extreme high salinities of 34.00‰ to 34.49‰ were located at the eastern entrance of Hudson Strait and across Ungava Bay,

but not elsewhere in the Strait. These salinities suggest that perhaps much of the deep water exchange in and out of Ungava Bay occurs directly between the eastern entrances and the Bay itself, rather than from the western section of Hudson Strait.

The major features of the temperature distribution are similar to those of the salinity. November, 1955 temperatures in the outflowing current ranged from  $1.00^{\circ}\text{C}$ . to  $4.90^{\circ}\text{C}$ . along the south coast with the warmest water being located on the shoreward side. Temperatures on the northern side of the Strait were less on the whole not exceeding  $1.10^{\circ}\text{C}$ . July temperatures were lower with extremes of  $-0.40^{\circ}\text{C}$ . and  $2.80^{\circ}\text{C}$ . recorded in the outflowing stream, while along the Baffin coast low temperatures were observed west of Big Island,  $-0.70^{\circ}\text{C}$ . and high temperatures,  $3.00^{\circ}\text{C}$ . east of the Island.

Minimum temperatures in the deep water were approximately  $-1.04^{\circ}\text{C}$ . in 1955. A few sections exhibited warming at the greatest sampled depths, particularly east of C. Hopes Advance. However, this phenomenon was more common in June 1955 and July 1956. In 1956, a temperature minimum layer or core,  $-1.40^{\circ}\text{C}$ . to  $-1.50^{\circ}\text{C}$ . extended through the Strait between 50 and 200 m., below this layer the temperatures increased slightly to  $-1.00^{\circ}\text{C}$ . and  $-0.50^{\circ}\text{C}$ .

The oxygen data show very little evidence of a uniform trend in the Strait. Slightly lower oxygen values appear along the south shore than on the other side of the Strait. Surface and subsurface values of oxygen were lower in November than

in July ranging from approximately 8.30 ml/l to 7.40 ml/l at 50 m. July values fell between 9.50 ml/l at the surface to 7.58 ml/l at 50 m. The oxygen value for the deep water was approximately 7.40 ml/l. Percent saturation for the two cruises was the same being about 110% for the surface, and 95% at 50 m.

In 1955 a clearly defined oxygen maximum layer was observed between 10 and 30 m. throughout the Strait. Evidence of such a layer existing in July 1956 was only spotty.

Phosphate analyses were conducted in June 1955 and July 1956; similar values and distribution were found for both years. Phosphate values were low, 0.45 to 0.90 ug. atoms in the sub-surface waters where a minimum layer appeared at about 10 and 20 metres. Concentrations increased with depth to a maximum of 1.20 ug. atoms. Slightly lower values of phosphate were observed along the south shore.

N. J. Campbell

## Oceanography of Foxe Basin

The major part of the Arctic oceanographic studies undertaken in 1956 were in Foxe Basin, where 104 stations were occupied. It was intended that the 1956 survey should repeat as many stations as possible and fill in the areas which were not examined in 1955. To fulfill the latter requirement, it was necessary to complete a number of east-west sections in unchartered waters. This survey was left as late as possible to ensure optimum ice conditions. While proceeding north from Hudson Strait, a section was repeated across Foxe Channel through the typical hummocked dirty ice of Foxe Basin. No further stations were occupied in steaming north as a maximum effort had to be made to reach our destination and begin other work. Long range studies of temperature and salinity were made in northern Foxe Basin and, as the ship sounded out new passages, oceanographic stations were taken enroute.

The motor sound boat "Pogo" was fitted out for current measurements and oceanographic stations. Two current observing stations were occupied in northern Foxe Basin on a detached duty basis. One in particular was interesting since four stations were occupied by "Pogo" across the channel between Rowley and Bray Island. Current measurements were made in this same channel.

The oceanographic field programme for the Basin and Channel was divided into two areas, Foxe Channel and the central part of the Basin. The Foxe Channel work was undertaken before

the sea lift for two reasons, to determine ice conditions for the convoy and to complete all southern obligations as the ship moved north. Eight sections totalling 31 stations were completed in approximately 84 hours. After assisting the convoy north, the central part of the Basin survey was completed with seven remaining sections of 23 stations.

During periods when active oceanographic work was not underway, assistance was given to Dr. E. M. Little with the ice research programme. Further observations and collections of ice contaminants were made in an attempt to complete this phase of investigation.

The data from this season's operations will be analysed in conjunction with those gathered in 1955 on which a preliminary report has already been submitted.

Break-up in Foxe Basin begins about mid-June with formation of leads off Foxe Peninsula and relatively open water at the eastern end of Fury and Hecla Strait. By late July, the northern open water has extended south into Parry Bay and the Foxe Peninsula lead has expanded into the shallows south of Prince Charles Island. About this time, break-up begins along the northeast coast of Southampton Island and continues northward along the western shore in the form of leads running parallel to the coast. Most of the ice passes out of the Basin during the latter half of August and the first two weeks of September, however, the open water in the north becomes congested with winter ice passing through Fury and Hecla Strait from the Gulf of Boothia and Committee Bay. This ice moves

south in the main channel along the western shore passing out through the western section of Foxe Channel into Hudson Strait. By mid-September, Foxe Basin is free of ice except for remnants of shore ice and occasional flows of winter ice which drift in through Fury and Hecla Strait.

This condition remains from approximately mid-September to the middle of November by which time young ice is forming rapidly throughout the Basin and Strait.

Foxe Basin ice is characteristically dirty causing it to be easily identified even as far east as Resolution Island in Hudson Strait. This unique characteristic of the Basin ice is thought to be due to a high content of beach sediments being trapped in the ice during its formation and subsequent concentration on the ice surface.

Two main current features appear in Foxe Basin, a strong southerly movement of water along the western side extending from Fury and Hecla Strait to the southeast tip of Southampton Island and a northerly flow up the central part of Foxe Channel. The southerly flow also maintains an outflow of water through Frozen Strait and a large back eddy in the central part of the Basin. The northerly movement of water appears to originate in Hudson Bay and Hudson Strait and extends well into the Basin turning eastwards around Foxe Peninsula.

Surface salinities reflect the melting of ice and the average surface salinities for the summer of 1955 were 25.89‰ in July and 31.49‰ in October. Subsurface salinities averaged 33.00‰ for southern Foxe Basin and approximately 32.00‰

for northern Foxe Basin.

Temperatures recorded in Foxe Basin in 1955 were generally very low ranging on the average from  $-1.10^{\circ}\text{C}$ . to  $1.88^{\circ}\text{C}$ . The highest recorded temperature was only  $2.60^{\circ}\text{C}$ . Unusually low temperatures  $-1.70^{\circ}\text{C}$ . to  $-1.90^{\circ}\text{C}$ . were observed over extensive regions of Foxe Basin and Foxe Channel in 1955 and it was hoped that these same phenomena would appear again in 1956. However, the lowest temperature recorded in Foxe Basin in 1956 just approached  $-1.65^{\circ}\text{C}$ .

Surface oxygen concentrations were greatest in August, 8.61 ml/l falling off to a value of 7.24 ml/l in October. Sub-surface values followed a similar distribution but maximum values were not attained in the deep water until October, 7.40 ml/l. The average percent saturation varied from about 106% in August to 86% in October.

No phosphate determinations were made in 1955 but analyses were carried out at approximately 60 stations in 1956.

One hundred and four bottom samples were taken in Foxe Basin in 1955 and 45 during the summer of 1956. Extensive mud deposits are located in the northern section of Foxe Basin, off the northeast coast of Southampton Island and around the Foxe Peninsula shoreline. A belt-like deposit of clay extends from the vicinity of Parry Bay southward through the Basin and Foxe Channel. Clay samples were also found in Coral Harbour and at all stations in Hudson Bay. Two areas of gravel bottom were charted from the 1955 samples, one bordering

the Foxe Channel, coast of Southampton Island, the other extending south of Prince Charles Island into Foxe Channel.

Further analyses were conducted on ten samples from various locations in Foxe Basin using the Bouyoucos hydrometer method of particle size determination. These results have shown that at all the locations sampled, over 40% of the bottom sediments are composed of particles within the silt size range, 30% are sand, and the remainder falls within the clay classification.

N. J. Campbell

Oceanographic Survey of the Gulf of Boothia, Prince Regent  
Inlet - 1956

After completing her commitments in Foxe Basin, H.M.C.S. "Labrador" proceeded north to conduct an oceanographic reconnaissance of Committee Bay, the Gulf of Boothia, and Prince Regent Inlet.

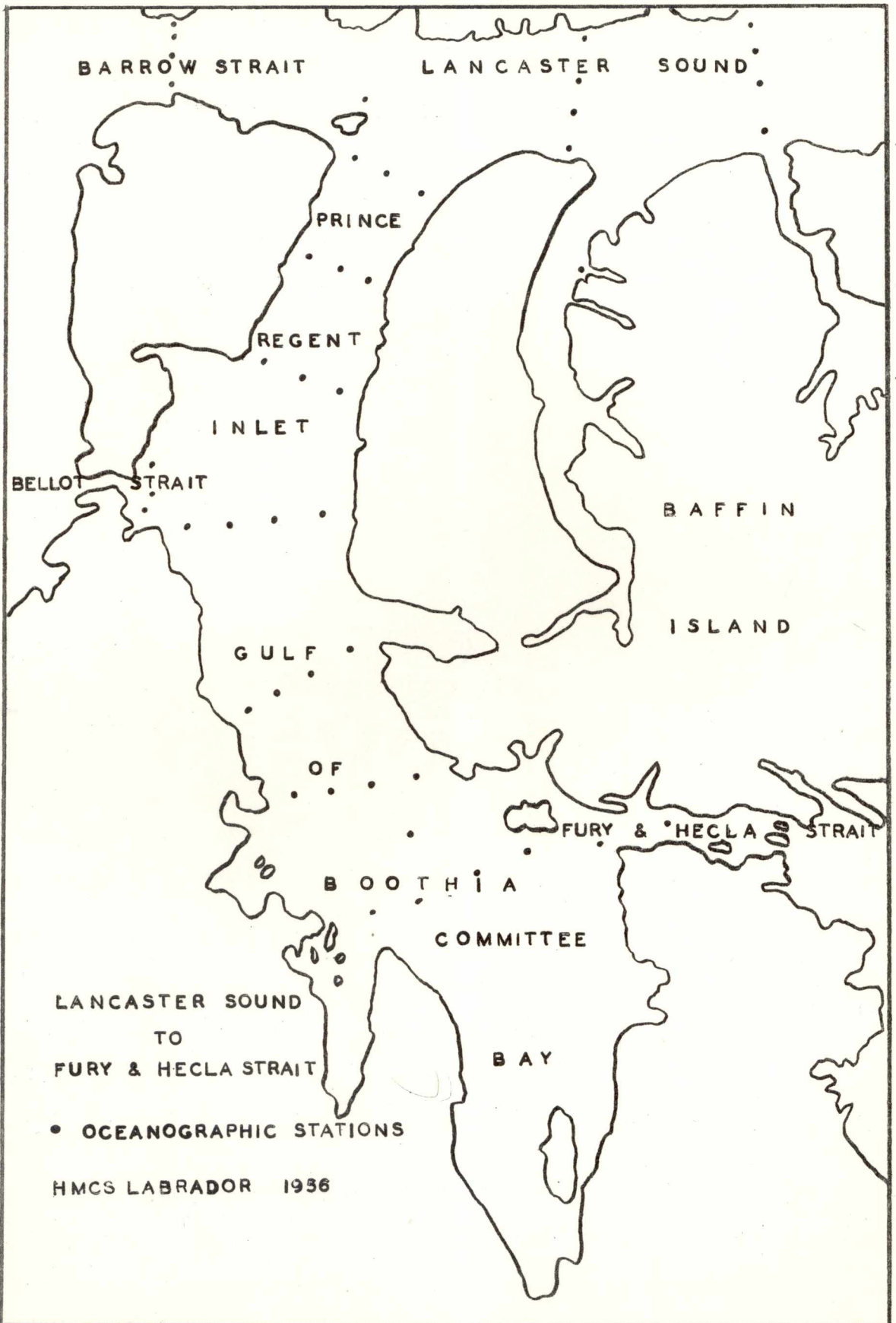
Thirty oceanographic stations were occupied in the Gulf of Boothia, and Prince Regent Inlet. Oxygen and phosphate content were determined at 21 of these positions and 29 plankton samples were collected in the area and examined on board.

It appears that a heavy concentration of winter and polar ice remains in Committee Bay throughout the year. Experience in 1956 proved that this ice was extremely hard in comparison to ice encountered in Foxe Basin and of much heavier concentration.

In the Gulf of Boothia and Prince Regent Inlet, no ice was encountered which in any way hindered navigation through the passage. On no occasion was dirty ice, comparable to that encountered in Foxe Basin, found west of Fury and Hecla Strait.

The channel through Prince Regent Inlet and the Gulf of Boothia has a moderately sloping "u" shaped valley form with slight local relief. Mid-channel depth of 200 fathoms or more extends through Prince Regent Inlet while in the Gulf of Boothia depths of 100 fathoms occur in the northern section and in the vicinity of the western end of Fury and Hecla Strait.

A cursory examination of the 25 bottom samples obtained



north of Fury and Hecla Strait indicates that the bottom is composed predominantly of grey-brown clay and stones.

Surface isopleths of temperature and salinity in the Gulf of Boothia and Prince Regent Inlet indicate the three predominant characteristics of the circulation: The strong southern flow from Lancaster Sound into Committee Bay along the western shore, the contribution of Bellot Strait, and the counter current in the Gulf of Boothia.

The southern current which must enter Prince Regent Inlet through Prince Leopold Channel has a surface temperature of  $-1.6^{\circ}\text{C}$ . and a salinity of 30.5‰, while the average surface conditions at the eastern end of Bellot Strait are, temperature  $-1.50^{\circ}\text{C}$ ., salinity 30.0‰. As would be expected, surface water in Committee Bay has a much lower salinity than that found to the north, but, in contrast, surface temperature is slightly higher. Average surface values for the Bay are, temperature  $-1.41^{\circ}\text{C}$ . and salinity 29.66‰. These variations can only be explained by the influence of the semi-permanent ice cover in Committee Bay which is reported to remain throughout the year.

Typical cross-sections of temperature and salinity show a surface layer of approximately  $-1.40^{\circ}\text{C}$ . underlain by a warmer layer at 20-30 metres, having temperatures from  $-0.8^{\circ}\text{C}$ . to  $-1.1^{\circ}\text{C}$ . Below 30 metres temperatures decrease to a minimum of  $-1.7^{\circ}\text{C}$ . which occurs between 50 and 100 metres. In the deeper sections, there is a marked increase in temperatures below 150 metres. Salinity sections illustrate a regular increase from approximately 30.1‰ at the surface to 30.9‰ at

150 metres.

Three main current patterns appear to control the circulation in the Gulf and the movement of water in Prince Regent Inlet. The most significant of these features is the strong southward current which must enter Prince Regent Inlet between Prince Leopold Island and Cape Clarence and continue along the western shore of the Inlet into the Gulf and Committee Bay. The second controlling factor is the tidal flow through Bellot Strait, and finally, the constant reserve of ice in Committee Bay acts as a summer source of brackish water in the southern end of the Gulf of Boothia.

The reversal of flow in Bellot Strait due to the tide is thought to modify the rate of exchange of water from Prince Regent Inlet into the Gulf of Boothia. This characteristic shows up in a number of longitudinal sections in the vicinity of the eastern end of the Strait where the tidal influence is revealed as a tongue-like feature extending across Prince Regent Inlet and expanding both to north and south.

The controlling influence in the southern end of the system appears to be the semi-permanent ice cover which is reported to exist in Committee Bay.

Investigation of the volume transport in Prince Regent Inlet and the Gulf of Boothia indicates that most of the water entering Foxe Basin through Fury and Hecla Strait is of Lancaster Sound origin.

Surface oxygen content appears to be very uniform at 8.5 ml/l and phosphate at the surface varies irregularly from

1.2 - 1.6 ug. atoms. A distinct oxygen maximum and related phosphate minimum occurs at approximately 15 metre depth. At this level, oxygen values are 9 ml/l or slightly higher and phosphate content is 1.0 ug. atoms. Below 20 metres, oxygen and phosphate concentration becomes homogeneous at values of 7.5 ml/l and 1.7 ug. atoms, respectively.

Through Lancaster Sound, Prince Regent Inlet, and the Gulf of Boothia, percent saturation of surface oxygen is about 100%. Extremely high values of 130-134% saturation were found at several stations in the southern end of the Gulf of Boothia.

A. E. Collin

Oceanographic Observations by the Canadian Hydrographic Service

Ships of the Canadian Hydrographic Service completed their eighth consecutive year of taking oceanographic observations in addition to their regular duties in the post-war period. The observations which are taken at intervals along the ship's tracks have proven invaluable to oceanographic studies in that they provide data which is additional to regular surveys and reach areas seldom visited by oceanographic vessels.

In 1956, a total of sixty stations were occupied by four Hydrographic ships giving a total of over 300 water samples.

W. B. Bailey

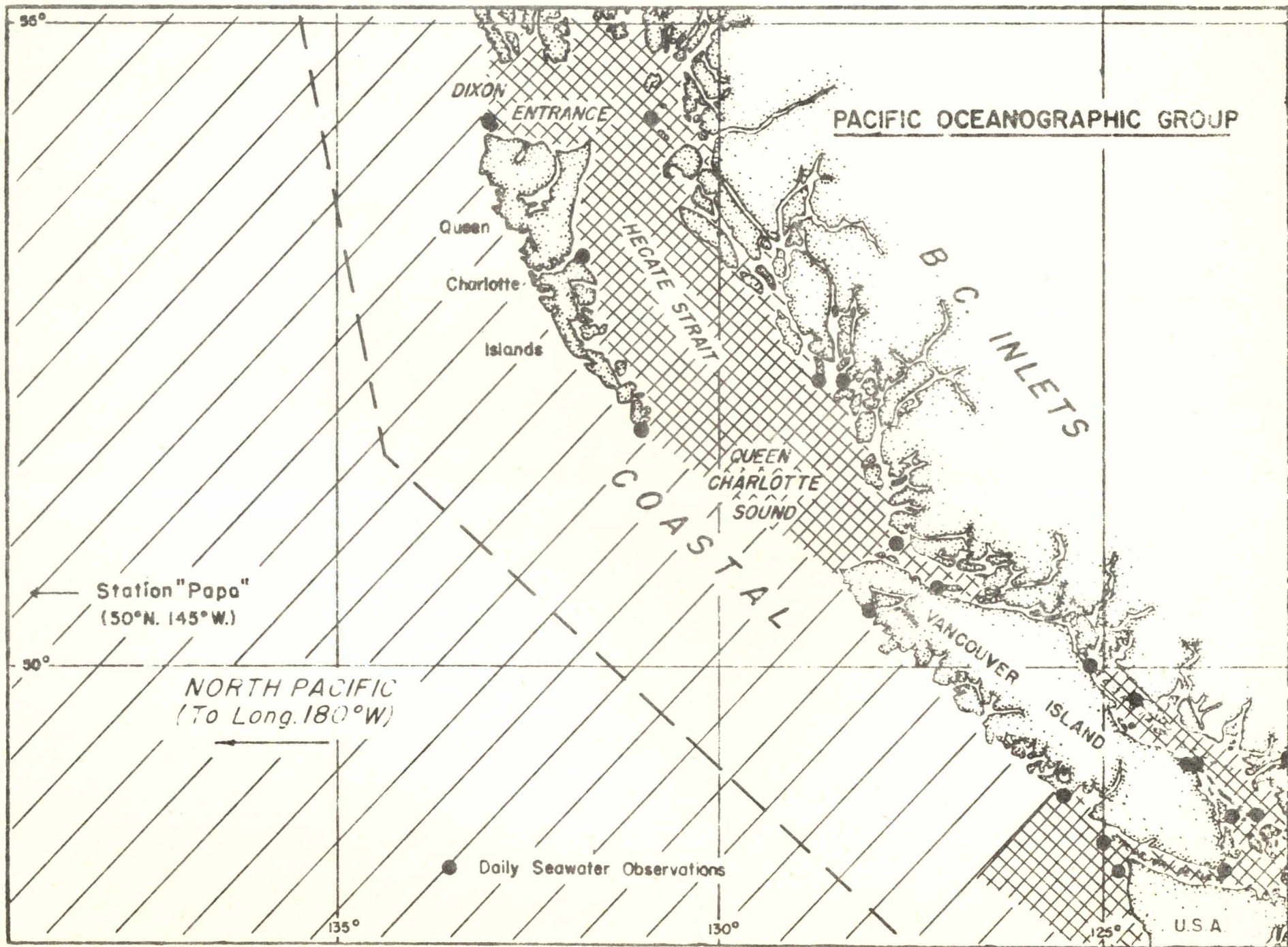
## Technical Services

During the last twelve months the laboratories of A.O.G. have processed analysis of sea water at an increased rate as compared to previous years. Over 7400 water samples have been analysed, of which, more than 5100 have been collected by A.O.G. personnel. The remaining 2100 have been collected by the personnel of the Biological Station, St. Andrews, of the Canadian Hydrographic Service, and of the Naval Research Establishment.

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 recorded on cards. More than 2500 BT slides were processed by A.O.G. personnel during the last twelve months.

The extensive library of oceanographic observations maintained by the Group serves as a reference and may be used by any interested organization. The library was augmented in the last twelve months by more than 3500 BT cards, of which 1000 were sent to the Group from outside. Data from almost 900 oceanographic stations were also added to the library.

L. M. Lauzier



ANNUAL REPORT  
PACIFIC OCEANOGRAPHIC GROUP

Introduction

1. The Pacific Oceanographic Group of the Fisheries Research Board of Canada undertakes oceanographic observations and research of the waters in the northeast Pacific Ocean and in the Pacific approaches to Canada.

2. Under the Canadian Joint Committee on Oceanography the program has been designed to meet the immediate and long-term requirements of the Fisheries Research Board, the Royal Canadian Navy and the Defence Research Board. The Navy has provided two full-time research vessels 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.

3. The dependence of successful oceanographic studies on the existence of close liaison and friendly co-operation between the Group and a number of agencies is acknowledged. With these agencies, contact is maintained at the working level. In particular, the enthusiastic co-operation of other investigations of the Fisheries Research Board, of the Institute of Oceanography at the University of British Columbia and of the Pacific Naval Laboratory has significantly assisted progress in the several programs.

Staff

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

J. P. Tully,

Oceanographer-in-Charge

F. G. Barber,

Associate Oceanographer

A. J. Dodimead,	Associate Oceanographer
N. P. Fofonoff,	Associate Oceanographer (From June 1)
J. D. H. Strickland,	Associate Oceanographer (From December 1)
S. Tabata,	Assistant Oceanographer
C. D. McAllister,	Assistant Oceanographer (From May 1)
G. L. Pickard,	Assistant Oceanographer (Seasonal May 1 to August 31)
H. J. Hollister,	Technician, Gr. 3
R. H. Herlinveaux,	Technician, Gr. 3
L. D. B. Terhune,	Technician, Gr. 3 (From April 1)
L. H. McCracken,	Technician, Gr. 2
J. A. Stickland,	Technician, Gr. 2
K. H. Austin,	Technician, Gr. 1 (From February 1)
D. G. Robertson,	Technician, Gr. 1 (From October 1)
K. S. Booth,	Technician, Gr. 1 (From October 1)
M. P. Sinclair,	Technician, Gr. 1 (From October 1)
W. W. Anderson,	Technician, Gr. 1 (From October 1)
D. H. Kirchgatter,	Technician, Gr. 1 (From October 1)
O. D. Kennedy,	Technician, Gr. 1 (From October 1)
B. C. Davison,	Technician, Gr. 1 (Term to January 31, 1957)
M. A. Smith (Mrs.),	Assistant Technician, Gr. 2

R. D. Teal,	Assistant Technician, Gr. 2 (Term to October 31)
L. M. McKenzie,	Assistant Technician, Gr. 1 (Term to September 19)
B. M. Berisford (Miss),	Stenographer, Gr. 3
E. B. Bennett,	Seasonal Investigator (May 1 to October 3)
C. Sauer,	Seasonal Investigator (May 1 to September 19)

### General Program

5. The general program has been specifically designed to provide a broad knowledge of the waters of all our Pacific Coast regions, to provide general or specific information required by fisheries or defence projects and to study fundamental processes in the ocean which contribute to an understanding of the phenomena involved.

6. The first is well advanced. A majority of the inshore seaways have been surveyed and data records and descriptive reports published. The waters over the continental shelf remain to be observed and a program of observations (Coastal Project) in this region is planned. Earlier preliminary examinations of the off-shore oceanic waters have been augmented by far-ranging synoptic surveys (North Pacific Project) and by the inauguration of a comprehensive program of observations at the mid-ocean Weather Station (Weathership Project, Station "Papa").

7. Information relative to fisheries and naval problems is taken from the general reports, the data, or may require additional data. The North Pacific Project is co-ordinated with the fisheries

program under the International North Pacific Fisheries Commission. The Coastal Project was instituted at the request of the Royal Canadian Navy.

8. A program of fundamental researches in physics and chemistry with particular emphasis on physical processes and productivity has been undertaken.

9. The use of hydraulic models to solve oceanographic mechanisms and assist in data interpretation has continued.

#### Particular Programs

10. The outstanding feature of the year is the advance in research study. This was made possible by the recruitment of additional personnel and a somewhat reduced level of sea operations.

11. Daily Sea Water Observations: Daily observations of sea water temperature and salinity are being made at eighteen positions (mostly lightstations) along the British Columbia Coast. This program started with one station (Departure Bay) in 1914. These data are reported each year (Manuscript Reports).

12. Development of these data has continued. A statistical method of classifying the observations has been devised and a heat budget study embodying the daily sea water data, synoptic data and meteorological observations has been completed of the water in the vicinity of Triple Island.

13. Strait of Georgia: General study of these data has been completed with a comprehensive treatise in two volumes. Complete data records have been published and are available for further research for particular purposes.

14. Juan de Fuca Strait: General study of this region is nearing completion with papers discussing the properties of the water, structure and mechanics.

15. Hecate Project: Data collections have been completed and reported. Research has resulted in descriptions of the mechanics, structure and properties of the water. An alternation of water masses from Summer to Winter has been observed with evidence of consequences to the fisheries.

16. Hecate Model: In order to facilitate appreciation of the oceanography and to assist interpretation of the data obtained in the Hecate region, a hydraulic model was proposed. Construction of the model base was begun in 1955 and work on the model itself was begun in 1956. Procurement delays and bad weather has caused the construction to fall behind schedule by several months.

17. The tidal gates were designed by courtesy of H. A. Simons Limited, and much valuable advice was contributed by local contractors, particularly S. Madill Limited, Quinney and Fuller Construction Company and Rathlef Electric Shop.

18. Coastal Project: This is a new program of oceanographic observations to be made of the waters of the coastal region. Seasonal surveys are proposed from which data of significance to fisheries and naval problems will become available.

19. Weathership Project: 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. Since July, 1952 each ship has been equipped with a winch and bathythermograph, and the ships' companies make

lowerings every two hours enroute to and from the station and twice daily on station. A report discussing these observations has been completed.

20. It has been shown that a definite seasonal cycle of temperature occurs down to a depth of 250 feet. 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. Temperatures during 1955 were markedly colder than at corresponding times during the three previous years.

21. During the past year, the program of oceanographic observations at Station "Papa" was enlarged. In one of the vessels, C.G.S. "St. Catharines", existing space was fitted out as a laboratory and a suitable winch and other equipment installed. A basic program of observations was begun in August; an oceanographer from the Group being aboard the vessel for each patrol.

22. It is anticipated that these observations, which involve the physical and chemical characteristics of the waters, will serve as an index of conditions in the northeastern Pacific and provide an opportunity for study of ocean productivity. Specific studies are also undertaken of such features as internal waves and diurnal plankton movements.

23. NorPac: This was a co-operative survey of the Pacific Ocean north of latitude 20° N in which parts of the area were surveyed simultaneously by oceanographic agencies of United States, Japan and Canada. It was the largest and most complete oceanic survey ever undertaken. A conference of leading oceanographers from each country met in February, 1956 in Honolulu, exchanged data

records and reviewed the results. Research in the various phases of data of particular interest is being undertaken in each country. A thesis describing the mechanics, structure and properties of the water as revealed by the NorPac data of the waters of the northeast Pacific has been undertaken by this Group.

24. North Pacific Project: The principal operational effort has been the surveys of the waters of the northeast Pacific Ocean. This work and the resulting research is part of Canada's contribution to the program of the International North Pacific Fisheries Commission. Two surveys have been completed, one in August, 1956 and one in February, 1957.

25. During August the area north of latitude  $40^{\circ}$  N and east of longitude  $180^{\circ}$  was surveyed in H.M.C.S. "New Glasgow". The observations indicate features very similar to those noted on the NorPac survey of 1955. In the center of the Gulf of Alaska a region of cold water was again observed with which was associated relatively high dissolved inorganic phosphate and low dissolved oxygen values. Similar temperature and salinity gradients were also observed.

26. During the period January 21 to March 5, 1957 a smaller area was surveyed in H.M.C.S. "Oshawa". This survey is the first comprehensive oceanographic survey carried out in this region during the winter months.

27. Surface temperatures were considerably less at this time than during the Summer; however, the north-south gradients were similar. The region or dome of cold water is more apparent during the Winter than in Summer.

28. Drift Bottle Program: Certain facts concerning the water movement in the surface layers of the north Pacific Ocean are well known. The occurrence of the West Wind Drift, the great divergence off the Canadian Coast, and the formation of the California Current and Alaskan Gyral have been described. Unknown are the seasonal and yearly variations in the strength and extent of the principal streams and areas of divergence. A drift bottle program in conjunction with the Weathership and North Pacific Projects was implemented to obtain additional information concerning these features. The program was begun in the late Summer and first returns occurred during the early Winter about 120 days after release.

29. Oceanographic Research in the North Pacific Ocean: Earlier analysis of the summer data of 1955 and 1956 suggested an association between the salmon distribution in the area with the occurrence of a dominant salinity structure. Research during the past year into all available data has indicated the principal factors which lead to this structure and, in turn, lead to the major features of the circulation and temperature distribution.

30. Seasonal temperature cycles in the surface waters are shown to be closely related to seasonal variations in insolation and cloud cover. The marked accumulation of fresh water, north of  $48^{\circ}$  N, is related to the excess of precipitation over evaporation and to the existence of a closed circulation around the north Pacific.

31. The principal features of the circulation are suggested as being winter generated. Winter winds are considerably stronger than summer winds and in Winter are so directed as to produce a strong

cyclonic circulation around the Gulf of Alaska. The summer winds oppose this circulation but, due to its momentum, the circulation persists though much reduced.

32. 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 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 egg survival. A model spawning bed was built in the Model Laboratory where extensive studies of the flow through uniform and random gravels were made. These studies have been reported.

33. It became apparent that modifications of apparatus and methods were required. In particular, a better dye solution and standpipe were indicated. Latest tests indicate that the new dye, food colour in alcohol, and the new standpipe, fitted with stirrer and dilution chamber, are producing reliable results.

34. Marine Physics: A comprehensive analysis is being made of the energy transformations accompanying the displacement and mixing of a water mass in the ocean. This research promises a means of estimating movement of the deep water masses in the north Pacific Ocean.

35. Marine Chemistry: The ionic ratios in the brackish waters near several estuaries have been studied. It was found that the magnesium content was higher and the potassium content lower in these regions than in normal sea water. The increased magnesium

content was attributed to the inflowing fresh water while the decrease of potassium was suggested as being due to absorption by the silt.

36. Studies of methods of analysis for nutrient and respiratory factors in sea water, as well as the significance of the observed distribution of nutrients such as phosphate in coastal and oceanic regions are in progress. A program for the observation of levels of illumination at depth and water transparency is being developed which, it is hoped, will satisfy the requirements of productivity as well as environmental studies.

37. Technical Services: A number of technical services are required to support the operational and research functions. These include analyses of sea water samples, processing and cataloguing of data, preparation of data records, preparation of reports, administration and clerical services, reprint library, draughting and illustrations, bathythermograph calibration and conduct of the daily sea water observations.

#### Incidental Program

38. Exploratory Fishing: Equipment and analytical services have been provided for oceanographic observations made on exploratory fishing cruises in the north Pacific. An oceanographer from this Group accompanied one of these expeditions. In addition, the Group will process and report the oceanographic data obtained.

39. New Winch Design: The Pacific Naval Laboratory carried out extensive research on a new type of spinning reel bathythermograph winch, for which this Group provided funds to cover construction

costs. The design has proven unsuccessful. It has been abandoned and the parts salvaged for use in other equipment.

40. A float for a chain salmon fry deflector was designed and assistance given to its fabrication and installation.

41. Salinometer: A production model prototype of a sea-going salinometer is being built for the Group by the Pacific Naval Laboratory and the University of Washington. The University is fabricating the conductivity cells and constant temperature bath and the Pacific Naval Laboratory the Wenner Bridge assembly. Costs of components and construction are being borne by the Group.

42. A weekly review of sea water temperatures observed at four coastal stations and a comparison with previous years is broadcast every Wednesday morning (7:00 a.m.) from the Vancouver Station, C.B.U., on the Fishermens' Broadcast.

### Facilities

43. Additional offices for research personnel were obtained when one of the two suites in the top floor of the Annex building were turned over to the Group.

44. In October, a Naval vessel, H.M.C.S. "Oshawa" was outfitted and commissioned to replace H.M.C.S. "Cedarwood". The vessel, an Algerine-type minesweeper, is considerably larger than "Cedarwood" and has proved a capable and sea-worthy oceanographic platform.

45. In anticipation of the availability of a digital computer, the ALWAC III-E, at the University of British Columbia, one member of the Group spent a week at the ALWAC plant, Redondo Beach, California, and undertook a programming course. It is evident that

these machines will provide an extremely valuable tool to the oceanographer, both in problems of data processing and research.

### Liaison

46. Pacific Naval Laboratory: There is a close contact at the working level between all members of this Group and the Naval Laboratory staff. The resources, particularly the two ships, 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 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.

47. Construction and installation of modified equipment for bathythermograph calibration was undertaken by the Pacific Naval Laboratory. Design of a bathythermograph winch was provided by P.N.L. as well as the expense of the alterations to H.M.C.S. "New Glasgow" for the summer North Pacific Survey, and to H.M.C.S. "Oshawa" before she took up survey operations. Without this generous co-operation, it would be impossible for this Group to have operated successfully.

48. Institute of Oceanography: There is a free exchange of data and resources between this Group and the Institute of Oceanography at the University of British Columbia. A summer appointment is provided to support Dr. G. L. Pickard in his study of mainland inlets. Employment is also provided for students during the University summer recess.

49. Hydrographic Service: Close liaison is maintained with the Service and a valuable inter-exchange of data takes place. A requested analysis of tidal data in the Hecate region has been undertaken by the Tidal Branch.

50. Department of Transport: Personnel of this Department make the daily sea water observations at the lightstations. 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 Station "Papa" whose personnel carry out the bathythermograph observations.

51. Meteorological Service: Copies of weather data at a number of coastal stations and at the Weathership are provided by the Gonzales Observatory in Victoria and by the Head Office of the Meteorological Service in Toronto. Sea water temperature data observed from coastal vessels is provided by the Port Meteorological Officer at Vancouver.

52. United States Coast Guard: Personnel of the Coast Guard carry out daily sea water observations and twice-daily bathythermograph lowerings from the Swiftsure and Umatilla Lightvessels.

### Publications

53. The following papers have been published during the year (since January, 1956) or are presently in press:

Barber, F. G.

Seasonal Temperature and Salinity Variations in Queen Charlotte Strait. Fish. Res. Bd. Canada, Prog. Rept. Pac., #105, 14-15. February, 1956.

Barber, F.G.

Current Observations North of Triangle Island, B. C. Fish. Res. Bd. Canada, Prog. Rept. Pac. In Press.

The Effect of the Prevailing Winds on the Inshore Water Masses of the Hecate Region, British Columbia. J. Fish. Res. Bd. Canada. In Press.

On the Dissolved Oxygen Content of the Waters of the Hecate Region. Fish. Res. Bd. Canada, Prog. Rept. Pac. In Press.

Dodimead, A. J.

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

North Pacific Project - 1956. News Note, Fish. Res. Bd. Canada, Prog. Rept. Pac., #107, p. 11, November, 1956.

Herlinveaux, R. H.

On Tidal Currents and Properties of the Sea Water Along the British Columbia Coast. Fish. Res. Bd. Canada, Prog. Rept. Pac. In Press.

Kirsch, Milton.

Ionic Ratios of the Major Components in River-Diluted Sea Water in Bute and Knight Inlets, British Columbia. J. Fish. Res. Bd. Canada, 13 (3) 273-289. 1956.

McAllister, C. D.

Pacific Weathership Project. News Note, Fish. Res. Bd. Canada, Prog. Rept. Pac., #107, p. 12, November, 1956.

Pickard, G. L.

Surface and Bottom Currents in the Strait of Georgia. J. Fish. Res. Bd. Canada, 13 (4) 581-590. 1956.

Tabata, Susumu and A. W. Groll.

Effect of Ship's Roll on the Ekman Current Meter. Trans. Amer. Geophys. Union, 37, 4, 425-428. 1956.

and G. L. Pickard

The Physical Oceanography of Bute Inlet. J. Fish. Res. Bd. Canada. In Press.

Tabata, Susumu.

Sea Water Intrusion in Steveston Cannery Basin. Fish. Res. Bd. Canada, Prog. Rept. Pac., #106, 3-6. September, 1956.

Classification of Daily Sea Water Data. Trans. Amer. Geophys. Union. In Press.

Heat Budget of the Water in the Vicinity of Triple Island, British Columbia. J. Fish. Res. Bd. Canada. In Press.

Heat Exchange Between Sea and Atmosphere in Northern British Columbia Coast. Fish. Res. Bd. Canada, Prog. Rept. Pac. In Press.

Tully, J. P.

Oceanography. Amer. Peoples' Encyclopedia, Annual Supplement, Chicago, 825. 1956.

Marine Biology. Amer. Peoples' Encyclopedia, Annual Supplement, Chicago, 736. 1956.

Tully, J. P.

NorPac. Abstract Reprinted from Proc. Hawaiian Acad. Science, 31st Annual Meeting, 1 p. 1955-56.

and A. J. Dodimead.

Pacific Salmon Water? Fish. Res. Bd. Canada, Prog. Rept. Pac., #107, 28-32. November, 1956.

Properties of the Water in the Strait of Georgia and Influencing Factors. J. Fish. Res. Bd. Canada. In Press.

#### Manuscript Reports

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

Hollister, H. J.

The Program of Bathythermograph Observations at the Canadian Ocean Weather Station PAPA (50°00' N, 145°00' W).

17 pp. May 15, 1956.

McCracken, L. H.

A Simple Technique for Sealing Seawater Samples. 3 pp.

November 15, 1956.

Pacific Oceanographic Group of the Fisheries Research Board of Canada.

Physical and Chemical and Plankton Data Record, Project NorPac, July 26 to September 1, 1955. 202 pp. February 1, 1956.

Pacific Oceanographic Group, Annual Report, 1955-56.

75 pp. March 31, 1956.

Pacific Oceanographic Group of the Fisheries Research Board of Canada.

Physical and Chemical Data Record, Dixon Entrance, Hecate Strait, Queen Charlotte Sound, 1934, 1937, 1938, 1951. 56 pp. April 15, 1956.

Data Record, Fraser River Estuary, Steveston Cannery Basin, August 3, 1954 - October 6, 1955. 33 pp. May 31, 1956.

Observations of Sea Water Temperature and Salinity on the Pacific Coast of Canada, Vol. XV, 1955. 93 pp. August 15, 1956.

Review of Canadian Oceanographic Studies in the North Pacific Ocean. 18-29. October 24, 1956.

Physical and Chemical Data Record, Approaches to Juan de Fuca Strait, 1936-1938. 99 pp. November 15, 1956.

Physical and Chemical Data Record, Alberni Inlet and Harbour, 1939 and 1941. 89 pp. February 1, 1957.

Tabata, S.

Heat Budget of the Water in the Vicinity of Triple Island, British Columbia. 17 pp. August 15, 1956.

Classification of Daily Seawater Data. 8 pp. September 1, 1956.

and R. J. LeBrasseur.

Sea Water Intrusion into the Fraser River and Its Relation to the Incidence of Shipworms in Steveston Cannery Basin. 17 pp. May 15, 1956.

Summary Reports

55. The following summary reports are attached:-

- (a) Daily Sea Water Observations, 1956. H. J. Hollister
- (b) Classification of Daily Seawater Data. S. Tabata.
- (c) Heat Budget Study. S. Tabata.
- (d) Significance of Daily Sea Water Data in Recognizing Certain Oceanographic Features. S. Tabata.
- (e) Juan de Fuca Strait. R. H. Herlinveaux.
- (f) Hecate Project. F. G. Barber.
- (g) Hecate Tidal Model. N. P. Fofonoff, L. D. B. Terhune, and M. Pirart.
- (h) Coastal Project. F. G. Barber.
- (i) Weathership Project. C. D. McAllister.
- (j) North Pacific Project. A. J. Dodimead.
- (k) Drift Bottle Program. H. J. Hollister.
- (l) Oceanographic Research in the North Pacific Ocean. J. P. Tully and A. J. Dodimead.
- (m) Hydraulics of Salmon Spawning Gravels. L. D. B. Terhune.
- (n) Marine Physics. N. P. Fofonoff.
- (o) Technical Services. H. J. Hollister.
- (p) Data Records. H. J. Hollister.
- (q) Automatic Processing of Oceanographic Data. N. P. Fofonoff and S. Tabata.

John P. Tully,  
Oceanographer-in-Charge.

Nanaimo, B.C.  
March 31, 1957.

Daily Sea Water Observations, 1956

During 1956, daily observations of sea water temperatures and collections of water samples for salinity determinations were made at eighteen locations on the British Columbia Coast. With four exceptions, the observations were taken at lightstations of the Department of Transport. Daily water temperatures of the Fraser River were observed at New Westminster, B.C. by Department of Fisheries personnel. In addition to these Canadian locations, daily observations were also made from the Swiftsure and Umatilla Lightvessels of the United States Coast Guard.

Weekly reports of water temperatures continued to be sent through Department of Transport Radio facilities from the light-station observation locations of Amphitrite Point, Entrance Island, McInnes Island and Triple Island. These reports were broadcast every Wednesday morning by the Canadian Broadcasting Corporations' "Fishermens' Broadcast" from Station CBU, Vancouver, B.C.

Observations were terminated at three stations:- White Rock in June, Sandspit and Texada in December.

At almost all observing stations on the British Columbia Coast the sea water temperatures in 1956 were colder than the average for the previous ten years (1946-1955). The difference varied from month to month but generally it was largest during the three winter months (1.5 to 2.0 F°); only slight during Spring and Summer (0.5 to 1.0 F°); and then moderate in the autumn months (1.0 to 1.5 F°).

There were some regional exceptions to the overall "colder

than average" picture. April and May temperatures at both Entrance Island and Departure Bay were 1.5° to 2.5° warmer than the ten-year average. June temperatures were 2.5° colder than average and then July and August temperatures again were up to 1.0° to 2.0° warmer than average. At Triple Island and Cape St. James, the July and August sea water temperatures were about 1.0 F° warmer than average, while all other months at these stations showed the colder than average trend.

Salinity differences from average conditions showed considerable variation from region to region, as is expected on the extensive British Columbia Coast. Some interesting comparisons can be noted. Salinities at Kains Island on the northwest coast of Vancouver Island were generally higher (0.3 to 0.5 ‰) than the ten-year average (1946-1955) for all months except January, April and October. At Cape St. James, farther north across the Queen Charlotte Sound, salinities were lower than average (0.1 to 0.4 ‰) during the first five months till June, and then for the next three months till September were higher than average (about 0.3 ‰). (Cape St. James salinities for the latter four months of the year are not yet available.) Such differences of salinity variations at two such "open ocean" stations suggest movements of the discrete water masses that make up the coastal circulation system. At Langara Island, in the extreme northern tip of the Queen Charlotte Islands, salinities were slightly lower than average (about 0.1 ‰) for the seven-month period, January to July, and then the salinity became higher than average for the next four

months, the difference increasing from 0.1 to 0.4 ‰.

The surface sea water temperatures observed at Swiftsure Lightvessel during the first ten months of 1956 were warmer than in 1955, generally about 1 F°, except in June when the 1956 monthly mean was 3.7 F° warmer. Surface salinities at Swiftsure for the first five months of this year were lower than in 1955, sometimes as much as 2.0 ‰. A low of 28.5 ‰ occurred in January and a high of 32.1 ‰ in September.

The data from the Umatilla Lightvessel are not yet sufficient to allow a year-to-year comparison. Water temperatures at Umatilla were generally 1.5 F° colder than those at Swiftsure. Salinity differences between the two locations were widely variable from month to month.

In addition to these daily surface sea water observations, the U.S. Coast Guard personnel on the Swiftsure and Umatilla Lightvessels make a twice-daily bathythermograph cast to a depth of 120 feet, and keep a meteorological record of air temperatures, wind, cloud and sea conditions. These bathythermograph data will be analysed and reported in 1957 as a data record publication.

Volume XVI, 1956, of the series, "Observations of Sea Water Temperature and Salinity on the Pacific Coast of Canada" will be published in July, 1957.

Observations were received during the year from five Canadian tug-boats, operating the entire length of the British Columbia Coast. These include surface sea water temperatures, weather and sea conditions, taken every six hours along the route of the

ship's tow. It is proposed to report these data as weekly temperature means in half-degree squares of latitude and longitude along the coastline.

H. J. Hollister

# TEMPERATURE

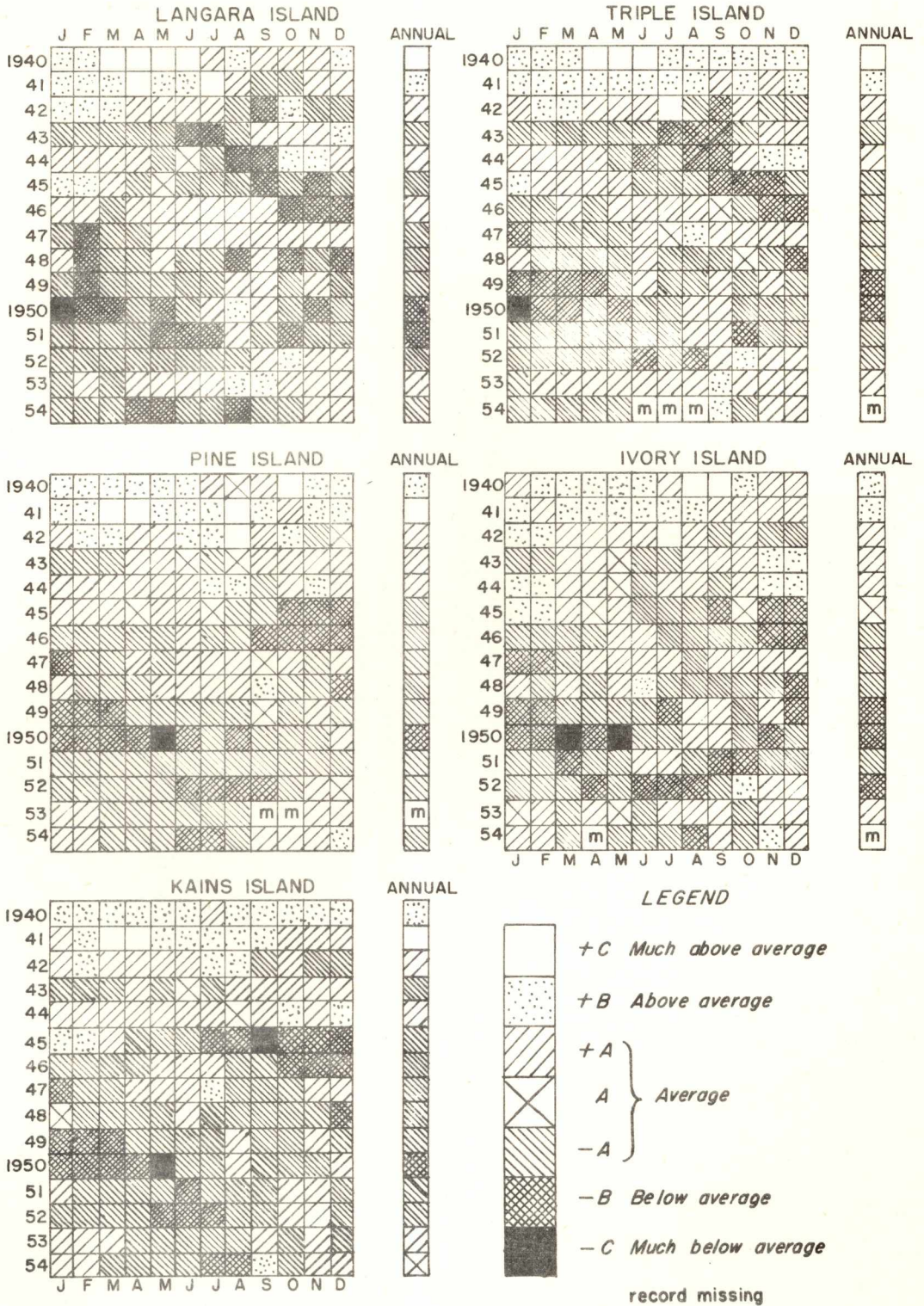


Figure 1

# SALINITY

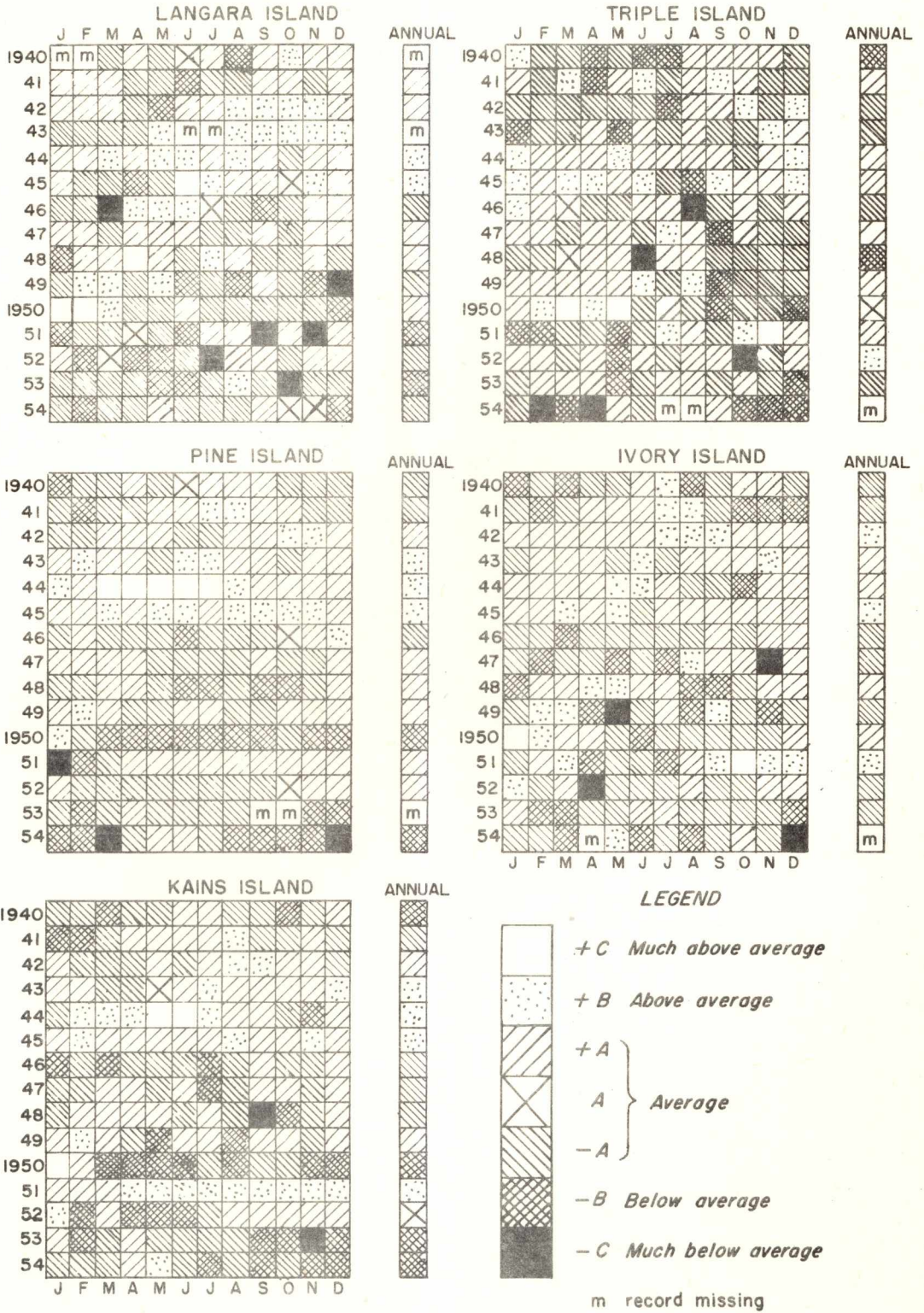


Figure 2

### Classification of Daily Sea Water Data

The daily sea water observations (salinity and temperature) made on the British Columbia Coast represent a number of time series. The limits of the significant variations of these series vary with stations and with seasons. For example, a fluctuation of a few degrees may be considered random at one station while a similar fluctuation may be significant at another. The same reasoning applies to fluctuations in different seasons.

These considerations led to the introduction of a statistical method of classification. The magnitudes of the monthly mean values of salinity and temperature are compared to the grand monthly means (of 15 years) by passing them through a step filter whose jumps are chosen from commonly used multiples of the standard deviation ( $\sigma$ ,  $2\sigma$ ). The results, using this method for the stations, Langara, Triple, Ivory, Pine and Kains are shown in Figures 1 and 2.

In investigations of marine life, the reason for the occurrence or absence or for fluctuations in abundance of species is frequently sought in terms of oceanographic conditions. The present classification would provide a quick method of recognizing first-order correlations and may be used as a guide for more detailed studies.

### Heat Budget Study

The study of the heat budget of the water in the vicinity of Triple Island has been completed. It was based on meteorological and oceanographic data from 1947 to 1955. The values used in the heat budget analysis are derived from formulae; none of the components of the heat budget equation are measured. Therefore, the present results are probably accurate to about 20%. Refinement of the study would require instrumentation.

Both the energy transfer processes and the advective processes were found to be significant in affecting the heat budget of the water. All the components of the heat budget equation were found to be important and none should be neglected when analysing the effect of heat transfer on sea temperature in the northern waters.

The total heat released to the atmosphere by the condensation of water vapour is about five times as large as that made available by conduction of sensible heat from the sea.

Comparison of the total heat transfer at the air-sea boundary at Triple Island, and the rate of change of heat content of the water in the vicinity of Triple Island during May, 1954 and June, 1955 was made. The excess increase in the heat content between May and July, 1954 is probably due to inshore transport of warmer water from the south. The decrease in heat content during July and August, 1954 is attributed to inshore transport of cold oceanic water. Between August, 1954 and February, 1955 the decrease in heat content was much smaller than would be expected from the loss occurring at the sea surface. This probably is due to the

warmer oceanic water entering through Hecate Strait and Dixon Entrance. From February to April, 1955 intrusion of cold water from the north is suspected. The influence of advection on the heat budget of the water was small during April to June, 1955.

There was an apparent loss of heat of about 25% at the air-sea boundary during the period 1947 to 1954. Losses occurred in every year except 1947. Appreciable year-to-year variations occurred in all the components of the equation. There must have been an appreciable transport of warmer water into the region, otherwise the water temperature in this locality would have decreased by approximately 2 Centigrade degrees in the eight years.

With the aid of heat budget study, work is in progress to explain the formation of local water masses in the Hecate Strait - Dixon Entrance region.

S. Tabata

Significance of Daily Sea Water Data in Recognizing Certain Oceanographic Features

Comparison was made between the salinity and temperature data obtained from Langara Lightstation and those from the seven oceanographic surveys in Dixon Entrance - Hecate Strait area during the period May, 1954 to June, 1955. It indicated that the salinity and temperature in the vicinity of Langara can, in general, be represented by Langara data with an accuracy of about 0.2 ‰ and 0.5 F° in Winter, and 1 ‰ and 4 F° in Summer.

The daily sea water data suggest that significant variations of the properties can occur from week to week. A synoptic survey taking more than one week in inland waters may require the data to be interpreted with this in mind. In fact, it may be necessary to revise the present observational techniques.

From the daily sea water data, it appears possible to detect the beginning of the intrusion of cold oceanic water into Dixon Entrance during the Summer.

The study also showed that tidal mixing had significant effect on the variation of properties in the vicinity of the lightstation.

This study also suggests that oceanographic surveys adjacent to a time series station are required before an accurate recognition of oceanographic events from daily sea water may be made.

## Juan de Fuca Strait

Synoptic surveys and comprehensive current measurements were made in the strait during 1951 and 1952. Studies designed to indicate the influence of topography, tidal factors and seasonal variations of winds and runoff on the structure and distribution of properties are being made.

The tidal and topographic features combine to produce relatively large variations in water properties and structure over a tidal period. Such variations have been observed close to a sill which extends across the strait in the vicinity of Victoria and are related in part to a flood and ebb bias in the deep and surface waters respectively. This bias, described in previous work, is a consequence of the seaward movement of fresh water from land drainage.

On the flood, the deep waters are the dominant flow which moves up and over the sill into the deep region on the inshore side of the sill. On the ebb, the surface layers are the dominant flow which tend to trap the lower depth high salinity waters on the inshore side of the sill.

R. H. Herlinveaux

## Hecate Project

Studies in the data obtained in 1954 and 1955 in Queen Charlotte Sound, Hecate Strait and Dixon Entrance have continued. A seasonal variation of temperature and salinity of these waters has been described and related to an accumulation of less dense surface water close to the coast caused by the strong winter winds. It has been suggested that the observed sea level variations and the observed seasonal depth migrations of demersal fish may be related to the phenomena.

Associated with this seasonal water mass variation is a marked seasonal variation in dissolved oxygen content. Values as low as 3 mg/l are frequent during the Summer at depths as shallow as 150 meters. The corresponding winter values are of the order of 5 mg/l.

T-S relationships of the waters of Queen Charlotte Sound indicate that at depths immediately below the halocline a warmer water occurs during the late Summer. A similar, but less marked feature was observed in the seaward approaches to Dixon Entrance and is also indicated in earlier data obtained in the approaches to Juan de Fuca Strait. Seasonal variations in the movement of the deeper water, consistent along the entire coast, are suggested. A full description of these variations will necessarily await a more adequate knowledge of coastal and oceanic water movements. It is apparent that immediately adjacent to the coast and parallel to it, a strong set or net movement occurs to the northwest during the Winter. In Summer, current observations indicate that this net movement is much reduced.

### Hecate Tidal Model

Oceanographic surveys in the Hecate region have provided data to describe the properties of the water and their seasonal variations. An important part of this project is to provide data sufficient to enable description of the tidal and non-tidal currents and the circulation systems. Studies of the available current data indicated that formidable amounts of observational time and data would be required.

Alternative approaches to the problem were sought and it was concluded that some form of model would be required.

The most promising approach was offered through the use of a physical analogue; particularly, an hydraulic model. The hydraulic model can be constructed to take into account many details of shoreline 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 of the model with a minimum expenditure of effort as compared with obtaining similar information from the prototype or the 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.

Active construction commenced on such a model of the Hecate region in the middle of April, 1956.

Construction: Prior to April the Lambert Conformal Projection

of the region to be modelled, slightly more than half the coast of British Columbia, from Alaska to Vancouver Island, had been prepared, the reinforced concrete base, 105 feet long and 65 feet wide, had been poured, and part of the rough model form of concrete building blocks had been placed. The general plan of construction and part of the detailed design work had been completed.

Construction has been nearly completed, with installation of gate seals and fabrication of the observation cage the only major items remaining undone.

When the rough form had been completed and thoroughly checked, the reinforced concrete walls of the model were erected. Pillars to support the reference rail system and anchor bolts where necessary were incorporated in the wall design.

After the walls had hardened, the tidal gates which were to simulate tides entering Hecate Strait through Queen Charlotte Sound and Dixon Entrance by tilting on their lower edges and thus displacing water, were built locally by contract and installed under supervision. The largest of these is over 34 feet long and 6 feet high, and weighs more than 2 tons.

The reference rail system was then installed and levelled up to within  $1/32$  inch. This system comprised two parallel rails 25 feet apart supported by the pillars on the walls, and a transverse travelling beam supported by two wheels at one end and one wheel at the other which could be moved along the two longitudinal rails. Two T-squares with adjustable blades sliding on the transverse beam provided vertical arms for the reference system. The

rails were graduated in nautical miles from arbitrary model center-lines while the vertical members were graduated in fathoms. Sag of the transverse beam was compensated for by reading the vertical graduations against a curved line on the T-square head.

The concrete blocks were then covered with a thin layer of concrete grout in which were stood 120 transverse rows of 10-inch monel wires. A cross-section was drawn for each row and, using the reference system, the wires were cut to the heights of the finished concrete (within half a fathom). Two, and in some places three, coats of grout, bringing the concrete to the tops of the wires completed the contouring. Waterproofing was then applied, white on the underwater areas and green on the land areas.

Electronics: Four major electronic devices were required for the operation and control of the model. These comprise:-

- (1) A computer or tide predictor, the brain of the model.
- (2) A servo motor control unit, two of which are required.
- (3) A tide guage (servo type), of which six units are to be built.
- (4) A main control panel, to simplify and co-ordinate the switching of the electronics system.

The computer has been designed and is now under construction. Most of the electronic circuitry of this component has been tested. The servo control unit has been designed and the first unit is nearing completion. The tide guage is in an advanced stage of design and the circuitry tested. The main control panel is in

the planning stage and completion must await the installation and some testing of electronic gear on the model.

N. P. Fofonoff

L. D. B. Terhune

M. Pirart

## Coastal Project

A program of oceanographic observations is being undertaken of the waters of the coastal region (frontispiece). The area constitutes the principal remaining region for which a comprehensive body of data does not exist.

Earlier observations made in specific parts of the region have been studied and serve to guide the program. Most of these are summer data and most are restricted to the shallower water immediately adjacent to the coast. One such group of data is that obtained during 1936-1938 in the approaches to Juan de Fuca Strait. Here seasonal data exist.

Particular emphasis is to be placed on the extent of variations in the properties and movement of the deep oceanic water, on the water structure and distribution of properties over the continental rise and on the formation of and properties of the water in the region of the halocline.

F. G. Barber

## Weathership Project

Ocean Weather Station "Papa", situated at latitude 50° N, longitude 145° W, is alternately manned by one of two ships. Each ship is relieved on station by the other every six weeks. In August, 1956, Weathership C.G.S. "St. Catharines" was installed with the equipment necessary for carrying out detailed oceanographic observations. The ship has carried an oceanographer on each of the three patrols since the installation of the equipment.

The basic program consists of weekly deep serial casts (analyses for temperature, salinity, oxygen, phosphate, nitrite, pH and alkalinity), weekly plant pigment analyses, a daily plankton haul and twice-daily bathythermograph lowerings. In addition, daily sea sampler lowerings (analyses for salinity and phosphate), series of hourly bathythermograph casts and series of surface plankton hauls have been attempted.

The series of hourly bathythermograph observations indicate that marked fluctuations in the depth of the thermocline occur. In some, the fluctuations exhibit a semi-diurnal period with an amplitude up to 15 meters.

Horizontal surface plankton tows started in November-December revealed a marked diurnal variation in abundance of surface plankton. Samples between sunrise and early afternoon were very sparse. In late afternoon moderate to large concentrations of small black amphipods were caught. After sunset concentrations of copepods and euphausiids rose to a maximum around midnight and then decreased.

Two 24-hour plankton series in early and late February gave

similar results. Between sunrise and sunset only small amounts of medusae and chaetognaths occurred. After sunset the concentration of crustaceans, mostly euphausiids, increased to a maximum about midnight and decreased to nil by dawn. A total of about 20 small fish (lanternfish and two or three other species) were caught in surface tows after dark. Velella were observed for about the last two weeks of February.

Vertical plankton hauls from 150 meters depth gave low to moderate concentrations of plankton, chiefly copepods, during August-September. Similar hauls taken during November-December and January-March produced only low concentrations of small medusae and chaetognaths. A series of deeper vertical plankton hauls taken in early March showed that copepods begin to occur between 200 and 300 meters and are in moderate abundance between 300 and 500 meters. A few euphausiids were captured in this latter depth range.

C. D. McAllister

## North Pacific Project

The NorPac Project completed in September, 1955 may be regarded as the first step in the development of the North Pacific Program. This project gave the first complete picture of the north Pacific Ocean and helped define the area of importance to the International North Pacific Fisheries Commission research program.

The first oceanographic survey, co-ordinated with the research program of the International North Pacific Fisheries Commission was undertaken in August, 1956. The survey covered the Gulf of Alaska and the adjacent ocean south to latitude 40° N and westward to longitude 175° W. (Figure 3). Observations of temperature, salinity, total and inorganic phosphates, nitrites, silicates, alkalinity and hydrogen ion concentration were made at standard depths to 2000 meters depth. Plankton collections were made to a depth of 150 meters. The ship, H.M.C.S. "New Glasgow", steamed a total of 8000 miles, during which time 85 hydrographic stations were occupied.

During this period limited oceanographic observations were made from the exploratory fishing boats at each station they occupied.

Preliminary analyses of these data and comparison with observations taken in the earlier studies have been carried out and are reported in another summary.

To further our understanding of this area, a winter cruise was proposed to determine:

- (1) The winter characteristics of the upper zone of low

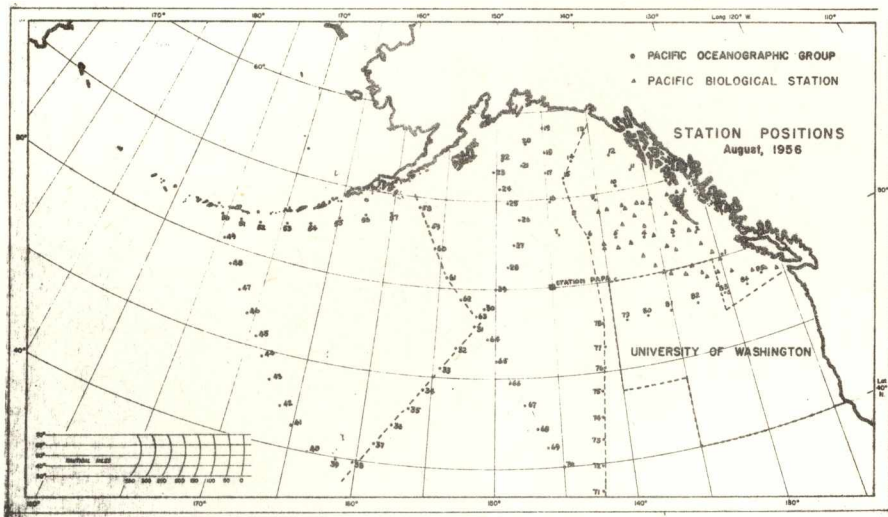


Figure 3

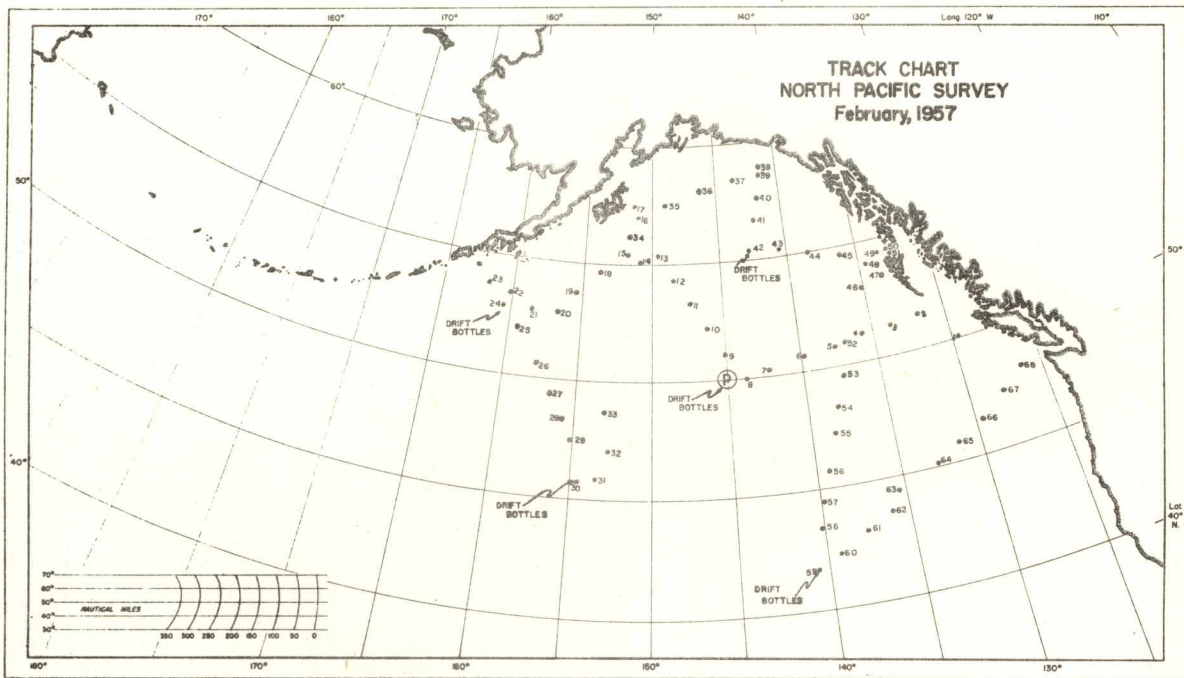


Figure 4

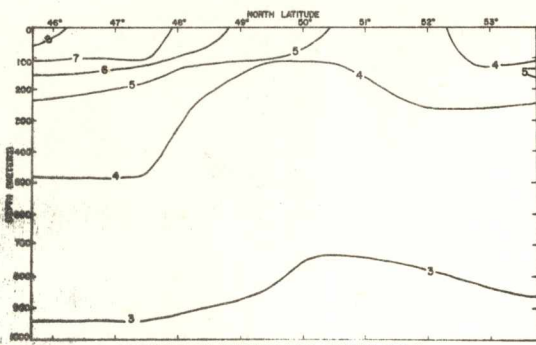
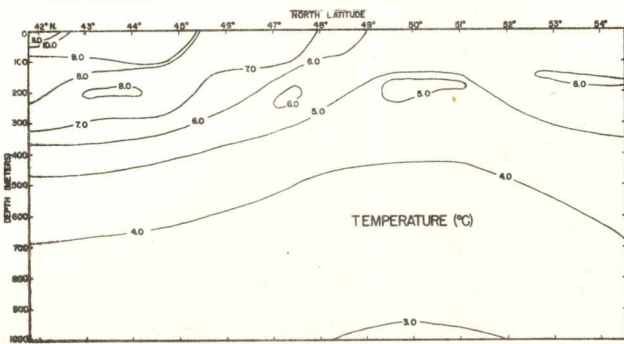
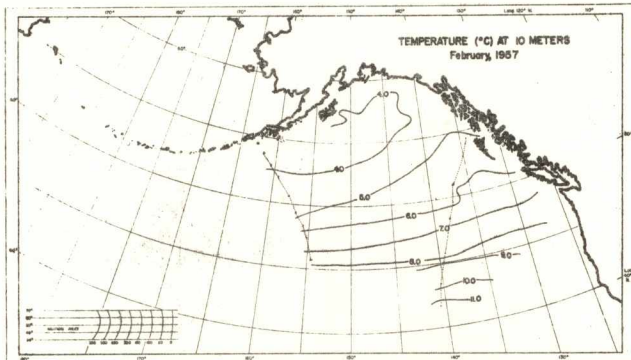


Figure 5

salinity water throughout the area.

(2) The southern limit of the low salinity region, which is anticipated at about latitude  $40^{\circ}$  N.

(3) The winter temperature distribution and structure and in particular the cold centre which is anticipated just south of Kodiak and the Shumigan Islands.

(4) The winter distribution of plankton, and nutrient constituents of the water.

(5) The winter circulation around the Gulf of Alaska.

The winter cruise took place during the period January 21 to March 4. The research vessel, H.M.C.S. "Oshawa", under the command of Lt.-Cdr. J. Barrick, steamed 6500 miles. Sixty-eight hydrographic stations were occupied in the area extending from the North American Coast westward to longitude  $162^{\circ}$  W and from the Alaskan Coast south to latitude  $41^{\circ}$  N (Figure 4).

At each hydrographic station samples were taken from the surface to a maximum depth of 2000 meters. The samples were analysed for salinity, temperature, dissolved oxygen, inorganic phosphate, nitrite, silicate, alkalinity and hydrogen ion concentration. Plankton samples were taken from a depth of 150 meters. Drift bottle releases were made at four stations (Figure 4).

This was the first attempt at taking oceanographic observations over such a large area under winter conditions. Fortunately only five working days were lost out of six weeks because of adverse weather conditions so that the original program was almost completed as planned.

The temperature data from this cruise are shown in Figure 5.

The horizontal temperature distribution indicates the existence of a cold cell (less than  $4^{\circ}$  C) in the northwestern portion of the Gulf of Alaska with temperatures being slightly warmer toward the Alaskan coast. South of this cold cell the isotherms run east and west. The temperature gradient from south to north is very similar to that observed in the summer months. The temperature structure shows that the marked thermocline present in the Summer has disappeared because of the winter cooling and mixing. Secondly, the dome of cold water ( $4^{\circ}$  C) is more pronounced and extends farther south than in the summer temperature structure (third diagram of Figure 5).

A. J. Dodimead

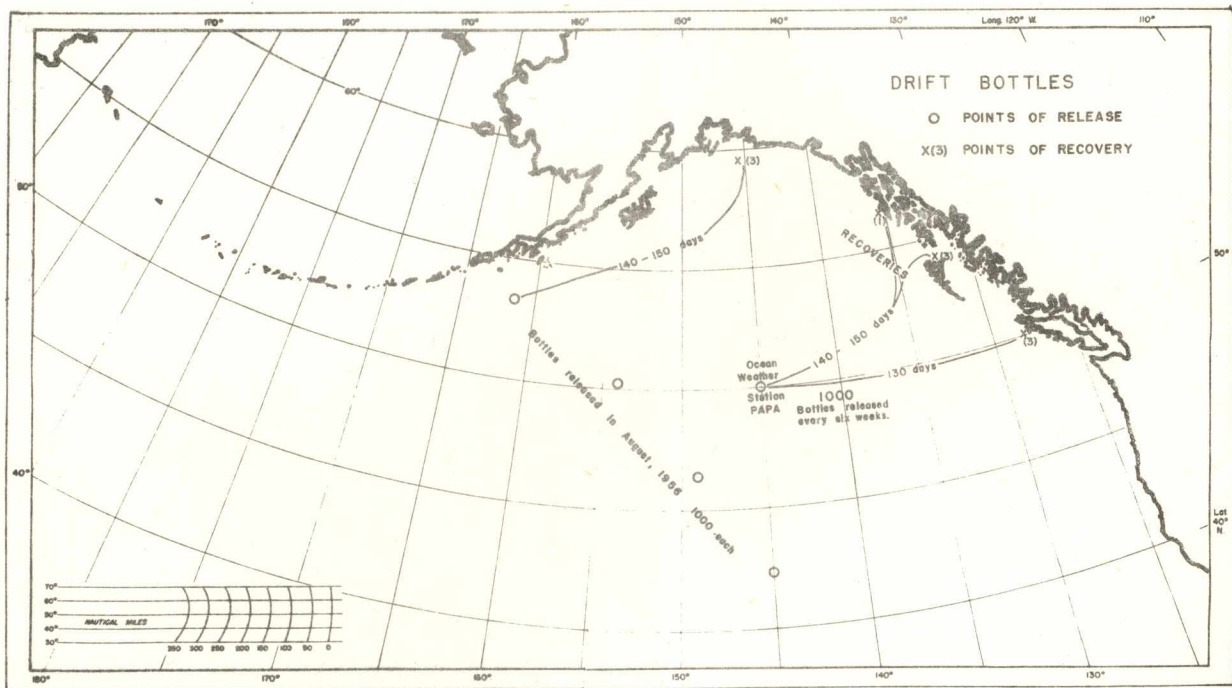


Figure 6

### Drift Bottle Program

A program of releasing drift bottles in the northeast Pacific Ocean was commenced in August, 1956. The drift bottle is a brown glass 12-oz. beer bottle, corked and sealed with pitch, and containing a yellow-coloured postal reply card. Instructions requesting the finder to report location and date of recovery are printed on the card in English, Spanish and Japanese. A reward of \$1.00 is offered for the return of the card with this information.

Lots of 1000 bottles each were dropped at four positions during the August, 1956 North Pacific Survey, and another 4000 were released during the February, 1957 survey. A total of 5000 bottles since August 25, 1956 have been released in lots of 1000 every six weeks from Ocean Weather Station "Papa". The latest release was on March 7, 1957.

There have been a total of 33 returns. Eight bottles were recovered in the northern regions of the Gulf of Alaska from a release south of Unimak Island on August 23, 1956. Five were recovered on the west Vancouver Island and Washington coasts from a release at Station "Papa" in August 25, 1956. A release at the same location in November 29, 1956 has so far produced a recovery of 18 bottles, all in the northern Queen Charlotte Islands. The latest reported returns have been three bottles recovered in the Baranoff-Chicagoff Islands group in southeastern Alaska. These were from 1000 bottles released at Station "Papa" on November 2, 1956.

H. J. Hollister

## Oceanographic Research in the North Pacific Ocean

Data obtained from the two summer cruises in the north Pacific, together with previous data available in the literature, make it possible to present a preliminary assessment of some of the principal features of oceanography of the northeast Pacific Ocean.

### Temperature

The observed distribution of temperature over the surface and in south to north is shown in Figure 7. These data show that there is a gradient of temperature from latitude 40° N in mid-ocean northward and eastward toward the North American Coast. The isotherms enter the area from the west and curve southward as though there was a central body of warm water in mid-ocean south of latitude 40° N. The minimum temperature occurs in the western part of the Gulf of Alaska. From this center, the temperature increases shoreward.

The longitudinal section shows that the temperatures decrease with depth. There is an upper, warm layer of the order of 50 meters depth. Below this is a thermocline, extending to about 100 meters, and then the gradual gradient of decreasing temperature in the deep water. The temperature decreases to the north in the upper layers and in the depths so that the temperature gradient in the thermocline remains nearly constant through the area. In this deep water the isotherms enter the area from the south and rise to the northward, coming nearest to the surface in the region of coldest surface waters in the Gulf of Alaska. From there they slope downward towards the coast.

It is evident that there is a lateral temperature gradient

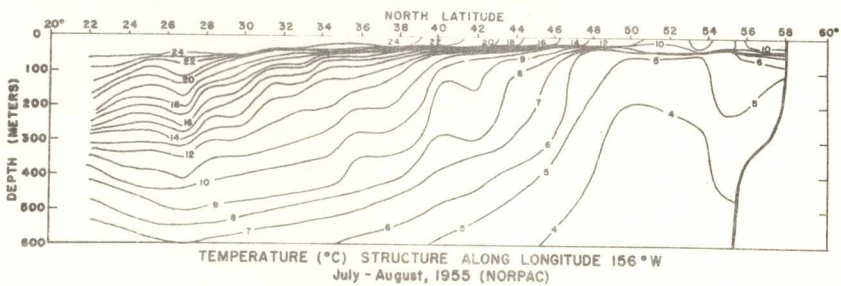
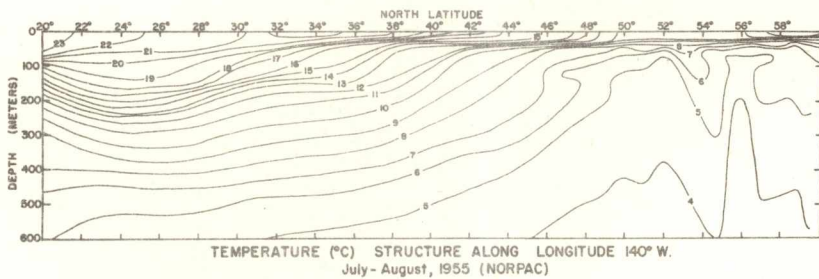
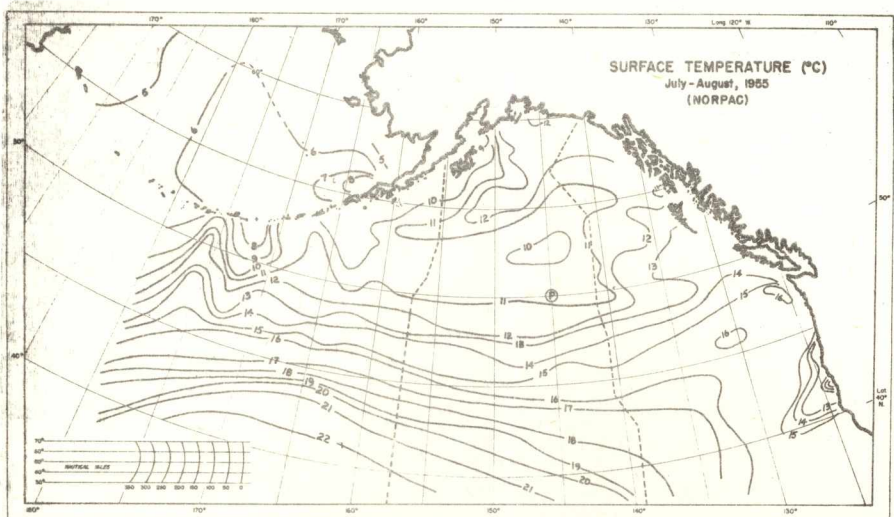


Figure 7

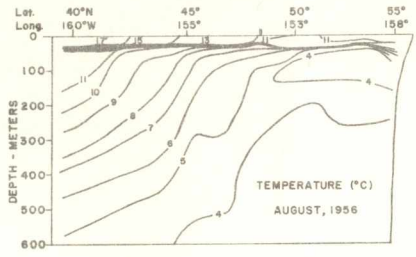
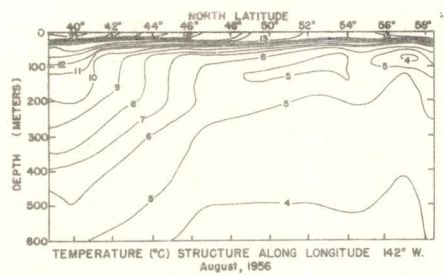
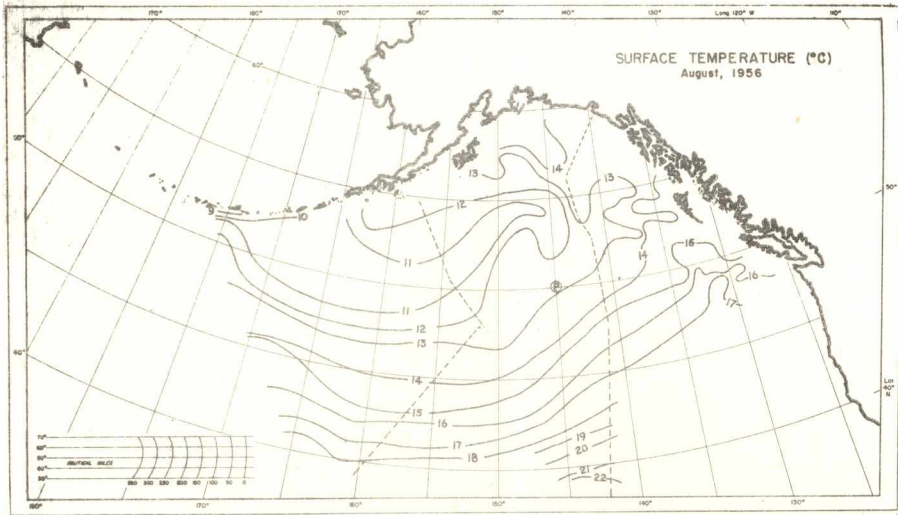


Figure 8

separating the sub-Tropic waters in mid-ocean from the sub-Arctic waters in the Gulf of Alaska and along the Aleutian Islands. The upper and deep waters are separated by a marked thermocline throughout the whole area.

Figure 8 shows the corresponding data observed in the Summer of 1956, with the same general features. In these it is to be noted that the cold waters extended farther southward but not as far eastward towards the North American Coast.

### Salinity

The distribution of salinity over the surface, and in longitudinal section in the August survey of 1955 is shown in Figure 9. There is a general south to north gradient over the surface. The highest salinities occur in the mid-ocean in the sub-Tropic latitudes and decrease north and east toward the North American Continent. This corresponds to the mid-ocean temperature gradient, and like it, may be regarded as a boundary between the sub-Tropic and sub-Arctic waters.

A second feature of the diagram is the plateau or secondary maximum of salinity (32.8) in the Gulf of Alaska. Around this the salinity decreases shoreward. At first glance, this salinity maximum appears to correspond to the temperature minimum but its location is not quite the same.

The longitudinal sections are most striking. Southward of latitude 36° N the surface salinities exceed 34 ‰ and become less with depth to a minimum between 400 and 500 meters. This is typical of the Tropic and sub-Tropic regions. North of latitude 36° N the surface salinities are less than 33.8 ‰ at the

surface and increase with depth.

In this northern sub-Arctic region there is an upper zone of relatively homogeneous low salinity water, less than  $33.0\text{‰}$ , extending to about 100 meters depth. Below this is a halocline extending to 175 to 200 meters depth in which the salinity increases to  $33.8\text{‰}$ . This halocline is a boundary separating the upper low-salinity zone from the deep regions where the salinity is greater than  $33.8\text{‰}$  and increases gradually with depth. These sequences of structures along the section are illustrated in the figure.

The salinity gradients in these sections do not correspond to the temperature gradients. The south-north gradient marks the separation of the sub-Tropic and sub-Arctic surface waters. The vertical gradients separate the upper and lower zones. However, between latitudes  $34^\circ$  and  $38^\circ$  these are not distinguished. These are the latitudes of the so-called Polar Front as defined by the surface temperature isotherms. Furthermore, there is no longitudinal salinity gradient in the deep zone, and very little indication of a "humping up" of deep water in the vicinity of the surface salinity maximum in the Gulf of Alaska.

Figure 10 shows similar data observed a year later, during August, 1956. The general situation was the same as in the previous year. The boundary between sub-Arctic and sub-Tropic waters was somewhat farther south, and the secondary maximum in the Gulf of Alaska had a greater extent and coincided with the temperature minimum, and with a dome of saline water.

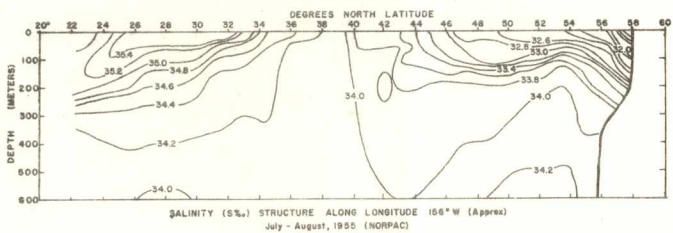
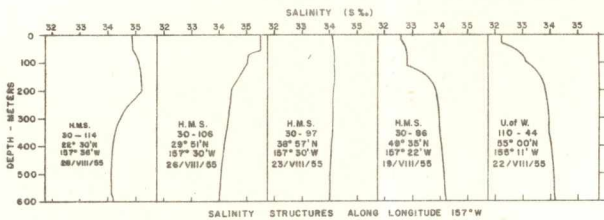
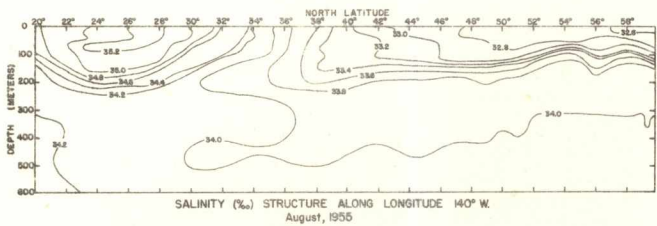
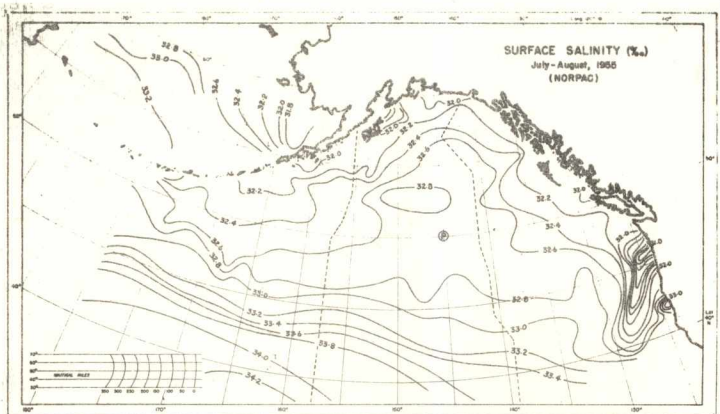


Figure 9

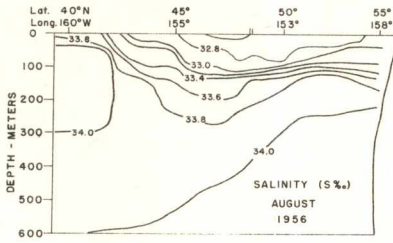
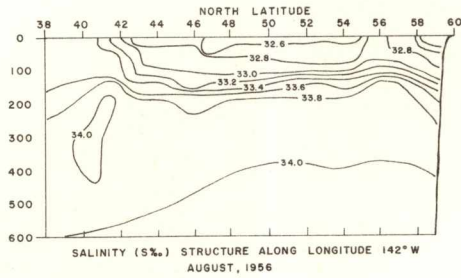
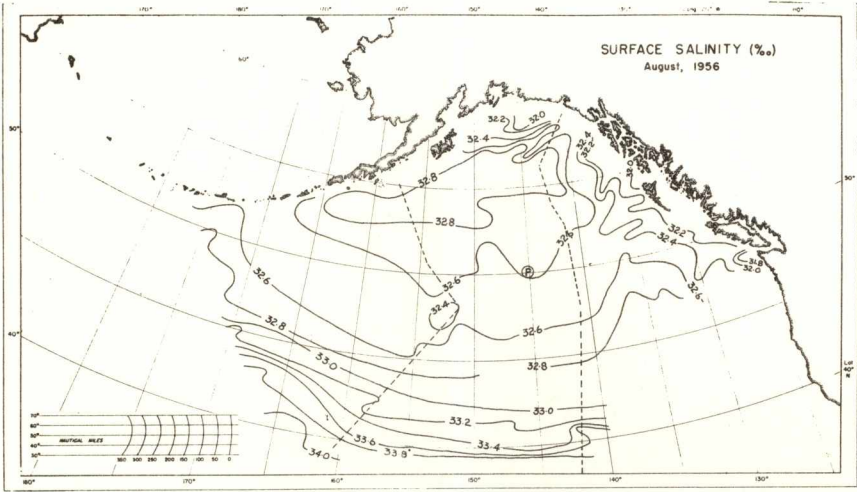


Figure 10

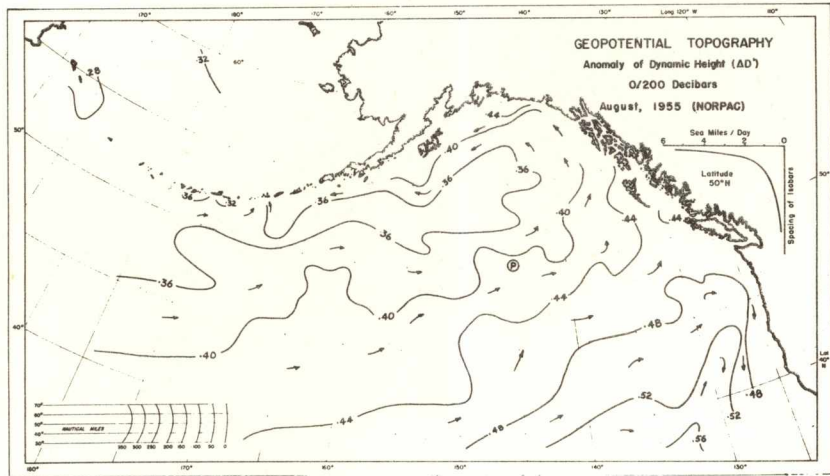
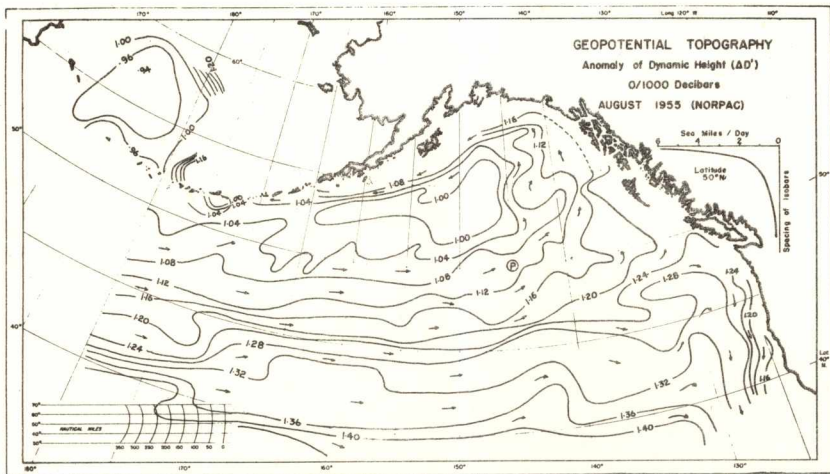


Figure 11

### Mechanism

The geopotential topography in the northeast Pacific is shown in Figure 11. The contours show the variations of sea surface referred to a presumed equipotential surface at 1000 meters depth.

The principal features of physical structure are reflected here. In the Polar Front there is a broad movement progressing eastward at less than 2 miles per day. The southern side of this current progresses to the American Coast where it turns southward to join the Tropical circulation system, and complete the mid-ocean circulation. The northern side of the current veers northward around the Gulf of Alaska. The contours indicate that very little of this water is recirculated; therefore, it is deduced that the current moves eastward close along the Aleutian Islands and is dissipated through the passages into the Bering Sea. There is some evidence in the figure of a strong northward set in the vicinity of longitude 180° and a cyclonic gyral in the western Bering Sea. Earlier studies in 1947 showed a northward and westward movement in the eastern Bering which accords well with these observations.

The strong north set in the vicinity of longitude 180° coincides with the water mass boundary remarked earlier. It may well be that this marks the boundary of the afferent and efferent water masses. If so, it is worthy of closer examination.

The diagram suggests that the sub-Arctic waters form a closed circulation. The Oyashio waters move south along the Asiatic coast to meet the Kuroshio waters advancing from the south. The two waters turn eastward mingling, and cross the ocean in a broad

movement in which there is a south-north gradient of properties. The northern side of this current, consisting chiefly of Oyashio water, circulates around the Gulf of Alaska and is largely dissipated into the Bering Sea where it rejoins the Oyashio Current.

In order to determine to what degree this movement was inherent in the upper or lower zone, the geopotential topography was referred to a base at 200 meters depth, the approximate depth of the upper zone. This diagram indicates an approximately similar configuration, but the velocities are so small as to be within the limits of error. There is, in fact, practically no motion inherent in the upper zone. At the time of the NorPac Survey it was floating on, and being carried by the deep zone waters. In this case, the driving force cannot be at the surface. This contradicts the accepted concept of a wind-driven system during the summer months.

The average winter and summer wind systems, from the Climatic Atlas, are shown in Figure 12. During the Summer the light winds in mid-ocean contribute to the trans-Pacific Drift ( $45^\circ$  cum sole to the right of the wind) but in the Gulf of Alaska the major winds oppose the direction of the gyral. In the Winter the winds are considerably stronger and coincide with the direction of the gyral.

Along the Canadian periphery these two type wind systems appear as northwest in Summer, and southeast in Winter. The third diagram in the figure shows the average force of the two major wind directions in each month of the year. The southwest winds dominate in Winter, and diminish toward mid-Summer. The

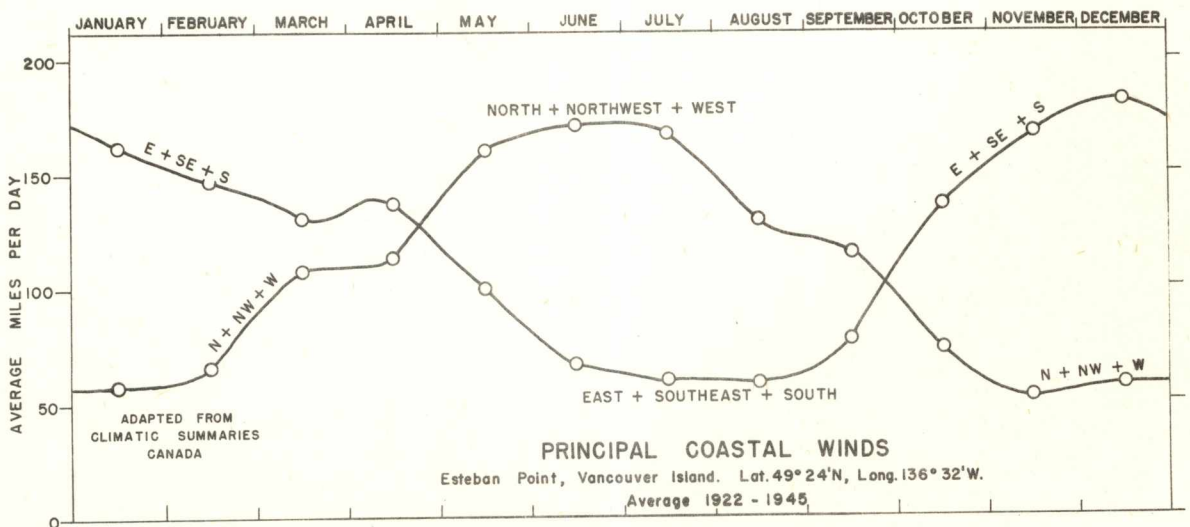
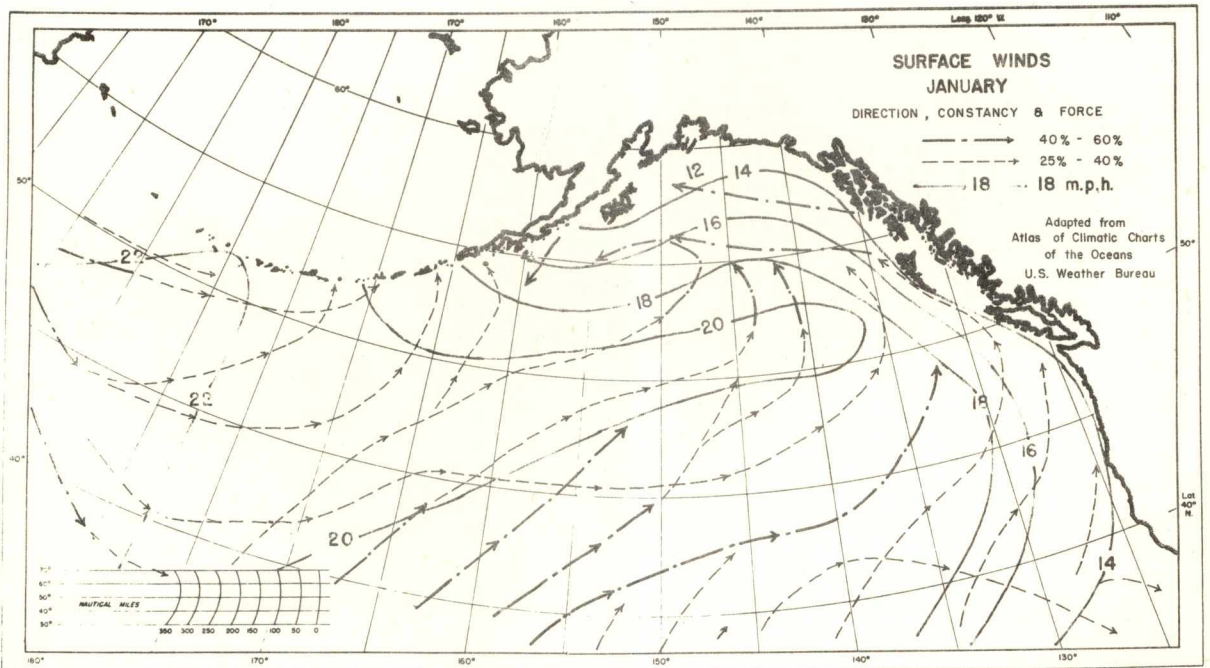
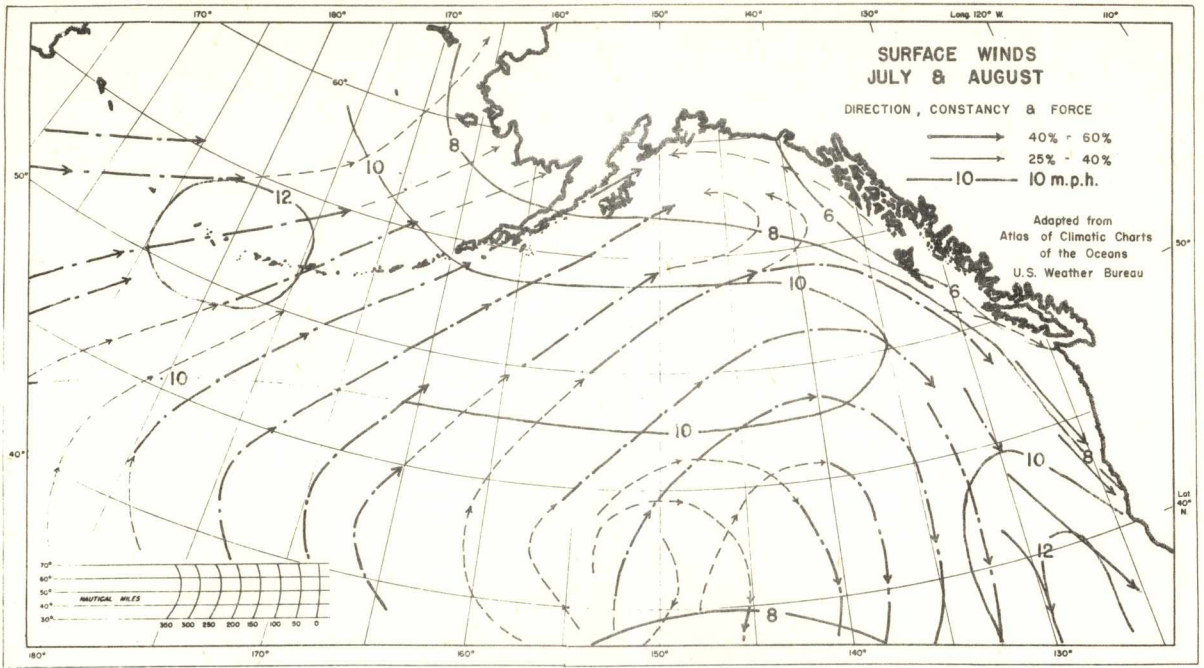


Figure 12

cycle of northwest winds is opposite, and their summer maximum is nearly as great as that of the winter winds. The consequences of these wind cycles in coastal waters has been studied and has been shown that the coastal current system is accelerated during the prevalence of southeast winds, and that surface ocean waters are accumulated along the coast. In Summer, during light northwesterly winds this system relaxes. The currents diminish to the orders observed in the NorPac Survey, and the surface waters do not accumulate along the coast. Applying this evidence and reasoning to the Gulf of Alaska, it may be predicated that the gyral is wind accelerated during the prevalence of winter-type wind circulation (October to April) and relaxes or is opposed during the Summer.

The consequences of such winter acceleration on the structure of the water mass would be to cause a transport of surface ocean waters toward the periphery of the system and give rise to upwelling, or uprising, in the middle. Then when the forces are withdrawn in Summer, the system would relax. However, the gyral would persist for some time because of its momentum. This suggests that the Alaska Gyral is a winter-generated system which persists through the Summer, by virtue of its momentum. Further, the structure and annual configuration of properties are determined through the Winter and persist, although relaxing, through the Summer.

J. P. Tully and A. J. Dodimead

## Hydraulics of Salmon Spawning Gravels

From January to March, and again in December, 1956, work was done on the standpipe for measuring rate of water seepage through gravel. The substitution of "Nabob Green Food Colour" for methylene blue, the addition of alcohol to the colour, a new design of standpipe with a stirrer and a dilution chamber which can be sealed at its upper end, have at last produced a method that appears to be reliable. On the basis of 150 measurements in a fairly uniform gravel with a permeability of 6300 cm/hr. performed in the calibration trough with five standpipes, the standpipe appears to have a probable error of 9%. The calibration curve for that permeability is a straight line from the origin of the graph with a slope of 87.9 centimeters per hour to 100 dye numbers per hour. Calculations and a smaller number of measurements performed in a glass trough with a transparent replica of the standpipe in a pea gravel with a permeability of about 90,000 cm/hr indicate that the slope of the calibration line is a function of permeability, so that calibration curves will have to be obtained over the whole range of permeabilities. Since there seems to be no theoretical reason to expect a single calibration curve for dilute rate versus gradient, the present calibration has been given for dilution rate versus velocity. Gradient data are, however, being kept so that when more data have been obtained, the final calibration curves may be prepared in either manner.

It is expected that it will be necessary to perform another 1000 to 1500 dilution measurements in the calibration trough to have sufficient data for complete calibration.

L. D. B. Terhune.

## Marine Physics

A comprehensive analysis is being made of the energy transformations accompanying the displacement and mixing of a water mass in the ocean.

Preliminary investigation has yielded a possible correlation between the rate of mixing and the resultant change of total potential energy.

The analysis consists basically of a generalization of Hesselberg's and Sverdrup's concept of vertical stability. Parameters have been defined which give, besides the work required to produce a vertical displacement of a water mass, the changes of all the thermodynamic potentials (e.g., internal energy, enthalpy, free energy, etc.) and related quantities such as entropy and potential energy. Furthermore, the effect of mixing on all these quantities has been determined.

If a more definite correlation between the rate of mixing and potential energy change can be established either by laboratory experiments or by direct analysis of oceanographic data, considerable insight will be gained into mixing processes in the ocean. A more accurate knowledge of mixing processes would be useful in studies of the ocean structure, nutrient cycles, dispersion of waste products in the ocean, etc.

A paper is being prepared for publication which will incorporate the results obtained to date.

## Technical Services

Salinity determinations of the seawater samples collected during the August, 1956 North Pacific Survey and the August and November oceanographic programs at Station "Papa" were carried out in the specially-designed titrations' laboratory. From these surveys there were 1450 samples analysed to an accuracy of  $\pm 0.02$  ‰ and 280 samples analysed to an accuracy of  $\pm 0.06$  ‰. Eight hundred and forty samples collected by the Marine Salmon Investigation of the Biological Station during their experimental fishing program in the northeast Pacific Ocean were also analysed. Five thousand, five hundred sea water samples for salinity determination were also received from the stations of the daily sea water observations project.

The bathythermograph calibration unit which was installed by the Pacific Naval Laboratory in 1955 has been used to calibrate a total of 34 instruments from the Royal Canadian Navy, the Pacific Naval Laboratory, the Biological Station, and our own Group. The unit is presently being enlarged by the engineering section of the Pacific Naval Laboratory to permit the calibration of five bathythermographs at one time, and also to contain the large sea sampler instruments for determination of the closing depth of the sampling chambers.

The chemistry laboratory has been maintained on a joint basis with the Biological Station and the facilities have been used extensively to make total phosphate analyses on approximately 2000 sea water samples collected during the August North Pacific Survey and the Marine Salmon exploratory fishing cruises. Large supplies

of reagents for shipboard chemical analyses during oceanographic surveys were all prepared here.

H. J. Hollister

## Data Records

Four publications of physical and chemical data records have been made during 1956. These are items 14 to 17 in the accompanying list of data record manuscripts.

Publication of the physical and chemical data record for the 1956 North Pacific oceanographic survey will be completed in May, 1957. This Group will also prepare and publish the data record of the results of the exploratory fishing work by the Marine Salmon Investigation of the Biological Station, as well as the results of the analyses of the plankton collections on both these North Pacific projects.

The backlog of unpublished earlier oceanographic data collections is rapidly being processed, and it is expected that the use of the ALWAC III-E computer at the University of British Columbia, along with the Flexowriter typing machine, will speed the work. It is planned to process the data recently collected on the February, 1957 North Pacific Survey through this arrangement.

It is proposed to publish annual data record volumes of all the bathythermograph data collected at Ocean Weather Station "Papa" since July, 1951. A partial publication of the summer 1955 data was made in 1956, in a manuscript report describing these observations. The 1956 volume is now in preparation and will be published in June, 1957. The physical and chemical and plankton data collected in the oceanographic phase of this project will also be included in the bathythermograph data volume.

List of Pacific Oceanographic Group Data Record Publications in  
the Manuscript Report Series of the Fisheries Research Board of  
Canada, Joint Committee on Oceanography

- No. 1 Observations of Seawater Temperature and Salinity on the Pacific Coast of Canada, Volumes I to XV, 1914 through to 1955. 1947-1956.
- 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.

- No. 14 Physical and Chemical Data Record, Dixon Entrance, Hecate Strait, Queen Charlotte Sound, 1934, 1937, 1938, 1951. April 15, 1956.
- No. 15 Data Record, Fraser River Estuary, Steveston Cannery Basin, August 3, 1954 - October 6, 1955. May 31, 1956.
- No. 16 Physical and Chemical Data Record, Approaches to Juan de Fuca Strait, 1936-1938. November 15, 1956.
- No. 17 Physical and Chemical Data Record, Alberni Inlet and Harbour, 1939 and 1941. February 1, 1957.

H. J. Hollister

### Automatic Processing of Oceanographic Data

The purchase of a medium-speed, general purpose, electronic digital computer (ALWAC III-E) by the University of British Columbia has resulted in the Group taking an active interest in high-speed automatic data processing.

The electronic digital computer is a great boon to workers in geophysics who must handle masses of data in describing and analysing large-scale, natural phenomena. In oceanography, in particular, much routine processing and computation is necessary before data are ready for analysis. Often these preliminary computations prove to be the bottleneck in carrying out extensive oceanographic surveys with limited manpower resources.

The shortage of trained personnel in oceanography will be considerably alleviated by introducing machine methods of routine data processing. Furthermore, the data will be more accurate and inclusive. Quantities such as pressure and density in situ can be included in data records. These are normally omitted in manual computations because the labour involved makes their determination uneconomical.

Full use of the electronic digital computer will greatly increase the capacity and scope of research as problems too complex for manual analysis fall easily within the capabilities of the electronic computer.

It is planned that conversion to automatic data processing will take place gradually. The most pressing problem - that of interpolating to standard depths and computing sigma-t, dynamic height, sound velocity, etc. - is being currently considered.

By the end of March, 1957 the computer program for these computations will be ready to accept original data for processing. Eventually, the program will be expanded to accept raw data directly with the minimum of intermediate manual computations.

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