

FOURTH ANNUAL REPORT

1965

Report BIO 65 - 17

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BEDFORD INSTITUTE OF OCEANOGRAPHY

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1965

Part A Atlantic Region, Marine Sciences Branch,
Department of Mines and Technical Surveys.

Part B Atlantic Oceanographic Group,
Fisheries Research Board of Canada.

Report BIO 65-17

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Foreword

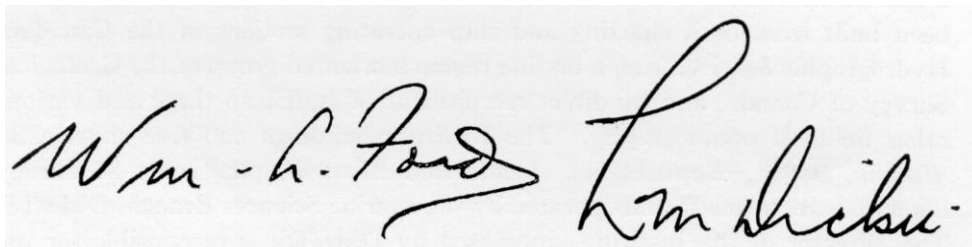
The Bedford Institute of Oceanography (BIO), now in its fourth year, may be viewed as a promising experiment in the organization of resources for marine research. The activities of BIO form part of a broad national program coordinated by the Canadian Committee on Oceanography, on which eight agencies of the Federal Government and four universities are represented. The Institute houses on one campus and, in varying degrees, integrates several organizations which previously had operated more or less in isolation from one another.

The largest unit is the Atlantic Region of the Marine Sciences Branch, Department of Mines and Technical Surveys of Canada (DM&TS). It has been built from both charting and ship operating sections of the Canadian Hydrographic Service, from a marine research oriented group of the Geological Survey of Canada, and by direct recruitment of staff into these and various other fields of oceanography. The Institute buildings and five ships, CSS *Hudson*, *Baffin*, *Kapusking*, *Acadia* and *Maxwell*, plus some 31 survey launches, are "owned" and operated by the Marine Sciences Branch, DM&TS. The Director of the Institute, appointed by DM&TS, is responsible for the general operations of the plant and ships and for the program and staff of the Branch in the Atlantic Region. The program embraces physical and chemical oceanography, air/sea and air/ice/sea interactions, marine geophysics, marine geology, tides and currents, hydrographic charting, and, in support of all of these, instrument research and development.

The second largest unit in the Institute is the Fisheries Research Board of Canada's Dartmouth laboratory, known as the Atlantic Oceanographic Group. This laboratory is an independent entity within the Institute with its own Director, research program, administration, and support services, responsible to the Chairman of the Fisheries Research Board of Canada in Ottawa. Up to 1965 its main area of research was in the field of environmental oceanography in coastal and shelf waters of interest to fisheries. It employed a staff in the fields of physical and chemical oceanography, geology and geochemistry, as well as a small group in biological oceanography. The biological field of research is in the process of considerable expansion into new investigations concerned with the measurement of production, abundance, and distribution of fish and their foods in close conjunction with the environmental studies. CNAV *Sackville* is allocated by the Royal Canadian Navy to the Fisheries Research Board (FRB), Dartmouth, and is included in the Institute's ship pool. In addition the biological research vessels MV A.T. Cameron and MV E.E. *Prince* are programmed jointly by FRB, Dartmouth Laboratory and the other biological stations on the east coast in St. Andrews, New Brunswick, and St. John's, Newfoundland.

The Institute houses the Secretariat of the International Commission for the Northwest Atlantic Fisheries (ICNAF). While Mr L. R. Day, Executive Secretary, and his staff of five, participate in and contribute to the general scientific life of BIO, they are not directly concerned with its program. Also accommodated in BIO are several small groups totalling 12 persons from other branches of DM&TS engaged in activities unrelated to oceanography. Accordingly, the work of ICNAF and of these other groups is not included in this report.

In keeping with the underlying objective of building a strong marine research community through effective collaboration, based upon the mutual interests of the many disciplines here represented, this Annual Report of the Bedford Institute of Oceanography is presented as a joint undertaking.

The image shows two handwritten signatures in black ink on a light-colored background. The signature on the left is 'Wm. C. Ford' and the signature on the right is 'L. M. Dickson'. Both are written in a cursive, flowing style.

Director, BIO, for
Marine Sciences Branch,
Department of Mines and
Technical Surveys.

Director,
Fisheries Research Board,
Dartmouth, in BIO.

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Part A

**The Annual Report For 1965 of the Atlantic Region,
Marine Sciences Branch, Department of Mines and Technical Surveys**

Part A

The Annual Report for 1965 of the Atlantic Region, Marine Sciences Branch, Department of Mines and Technical Surveys

Director's Remarks

In the 3½ years since the doors of the Bedford Institute of Oceanography were opened in July 1962, the complement of the Marine Sciences Branch in the shore establishment of the Institute has grown several fold from a small nucleus to a total of some 210. Naturally enough there have been many growing pains some of which remain much in evidence as a consequence of continued rapid growth into 1966. During the first 2 years, as key scientific and survey personnel arrived, the main features of a broad program of oceanographic research and survey took shape. Since then the central objectives have remained largely unchanged; as new staff joined, attention has been focused on adding strength to the program rather than on launching new undertakings.

The general nature of the program is the oceanographic application of the physical sciences and engineering in a spectrum of activities ranging from long term phenomenological research, through applied research and instrument design and development, to surveys such as those required in the production of marine charts. Not only does this very broad approach within the one organization justify the provision of large modern facilities, notably ships, but it encourages among the staff the interdisciplinary exchanges of ideas and experience which are essential to the effective study of the oceans. Many of the projects arrange themselves naturally into another kind of spectrum extending from the interface between atmosphere and sea, through the water mass itself, to the sea bottom and the earth beneath. The presentation of project reviews more or less follows this logical sequence (Table of Contents) with the object of providing an overall view of the program and of the relationships among its component parts.

As explained in the Foreword, the plant of the Institute is under the jurisdiction of the Marine Sciences Branch, DM&TS, but also houses the Atlantic Oceanographic Group of the Fisheries Research Board as well as some other

groups. The pattern of growth of the entire organization is given in some detail in Table 1. In December 1962, only 5 months after the new laboratory was occupied, the staff was 112, or if the crews of MSB ships are included, 349. By December 1965, the corresponding figures were 255 and 562. The bulk of the increase has been in MSB personnel but plans for expansion of the FRB component are now being reflected in a marked upswing in its strength. Indications point to a considerable further increase in both MSB and FRB staff which is expected to bring the overall laboratory complement to about 330 by the end of 1966. The main aim of recruitment for the next year is a rounding out of the technical and administrative support to provide a more adequate backup to the professional: only about 25% of the increase is intended to be of new scientific staff. The substantial number of 237 shown for 1962 in Table I under the heading of ships was the total of officers and men manning the four ships in the Atlantic Region of the Canadian Hydrographic Service. These ships and their crews were, of course, a key factor in the creation of the Institute since they provided the means for an immediate start on oceanographic research at sea, as well as carrying on their traditional role of hydrographic survey. The commissioning of CSS *Hudson* in December 1963 brought the personnel strength of the ships' group up to about the present level and greatly increased the sea-going research capability of the Institute. The present ships' complement of 307 is not sufficient to operate the vessels on an annual basis and at the same time provide for compensatory leave, vacation time and statutory holidays. In order to realize the full potential of the fleet consideration is being given to increasing the complement by some 25%-30%. All these indications of continued growth lend strong emphasis to plans for extension of accommodations in the Institute, particularly in light of the firm expectation that the design capacity of the present facility will be exceeded during 1966.

Considerable emphasis is given to a program of seasonal employment of selected students from

TABLE 1. Growth of staff in BIO.

	MSB	FRB	ICNAF	Others ^a	Lab Total	MSB Ships	Grand Total	Remarks
Dec. '62	94	15	-	3	112	237	349	Lab occupied in July '62
" '63	134	15	6	5	160	300	460	<i>Hudson</i> commissioned
" '64	158	15	6	8	187	300	487	
" '65	212	(39)	(6)	12	255	307	562	
" '66	(274)			(12)	(331)	(307)	(638)	Projected

^a Comprised of staff of purchasing agent and other departmental personnel not engaged in oceanography

universities and institutes of technology. The primary objectives are to introduce students to the work of the Institute and to provide a preliminary appraisal of them as potential permanent staff. Another consideration is their significant value as assistants to the regular staff in carrying forward both field and laboratory projects during the busy summer season. This year 31 university and 17 institute of technology students were employed under this program, and a summary of their impressions of it will be found in Appendix .A-4.

The writer, who took up the duties of Director at the beginning of April this year, takes pleasure in this opportunity to acknowledge the very great accomplishments of his predecessors. Dr W. N. English, who had the onerous task of being the founding Director and held the post until the end of August 1964, will be remembered for his initiative, imagination and drive under which the broad program of the laboratory took the shape in which in large measure it remains today. It was he as much as anyone who gave the Institute its *esprit de corps*. Upon the departure of Dr English, Dr L. A. E. Doe was appointed Acting Director and despite a heavy schedule of research activities ably carried out the direction of BIO. To add to the pressures a prior commitment took him to Pakistan for 2 months to participate in a regional training program sponsored by UNESCO. During his absence Dr R. L. G. Gilbert assumed the responsibilities of the Director's Office. The writer owes a great debt of gratitude to both Dr Doe and Dr Gilbert for the imaginative, competent and devoted manner in which they exercised the responsibilities of the post. In consequence, the process of turnover was accomplished with ease and the path forward made that much the smoother.

Wm. L. Ford,
Director

Oceanographic Research

The Oceanographic Research section functions in practice as a loosely coordinated aggregate of project groups, each of which is pursuing an essentially independent program of research. These programs are coordinated as necessary to make effective use of technical resources and personnel, but each group enjoys a large measure of freedom in the development and execution of its own projects. Most of the groups are still critically short of staff, since a net increase of 10 individuals of all categories in 1965 was necessarily spread thinly over the whole section. It is expected, however, that the recruitment of a substantial number of new personnel in 1966 will bring all the projects closer to an efficient level of operation.

During 1965 the emphasis of some of the groups, especially of those involved with experimental as opposed to observational or theoretical techniques, has been on the development of procedures and the acquisition of essential equipment. In Frozen Sea Research and Air-Sea Interaction studies, for example, this has involved a large measure of development work on new instruments and techniques. All the groups, nevertheless, have been engaged in handling and interpreting scientific results. The formation of a Computer group and the installation in the fall of a CDC 3100 computer has increased very significantly the Institute's capability for data processing and analysis. The activities of each project group will be outlined in the following individual reports.

Dr C. R. Mann, who had been head of the section since its inception, relinquished this position in October in order to devote more time to his own research, and Dr L. A. E. Doe assumed the duty. Some regrouping of personnel within the section is expected to take place early in the

New Year, since it is planned to form a new section to be called Applied Oceanography. This section will be composed mainly of personnel who are at present in two or three of the research project groups - but will also include individuals from the Hydrographic section and the Fisheries Research Board unit. One of its purposes will be to undertake applied research projects to meet requirements for information on the marine environment for governmental, industrial, and commercial purposes. This group will be an interesting experiment in the cooperative integration of personnel belonging to administratively distinct units; if it functions successfully, it will be a significant step in the development of BIO as a community of agencies collaborating in the field of marine science.

L. A. E. Doe

Air-Sea Interaction

L. A. E. Doe

V. N. Beck
R. H. Loucks
B. G. Pottier¹

S. D. Smith
B. Trudel

The Air-Sea Interaction group has been concentrating its efforts since its formation on the development of instruments and techniques for the measurement of turbulent transports in the atmosphere over the sea surface. Work has centred around the "Doe" thrust anemometer, a device which measures the three components of the wind vector by its thrusts on a small sphere, and the BIO moored stable platform which is designed to hold the instruments steady over water with depths as great as 50 fathoms. Some work has also been done on the development of circuits and the testing of sensors for heat and humidity measurements which, in combination with the thrust anemometer, will enable the determination of the turbulent fluxes of heat and water vapour as well as of momentum. The immediate goal is the measurement of wind stress on the sea surface, and eventually also the energy exchanges between the ocean and the atmosphere.

This year's activities can be considered as divided into four phases. **Phase one** which occupied roughly the first half of the year, consisted of preparation for a field program which

was carried out during a 4-week period in July and August. Effort was concentrated on completing and testing equipment and planning the field exercise. During this period, however, the group also managed to write and present a group of six short papers for the First Canadian Conference on Micrometeorology which was held in Toronto during April. These are included in the list of publications, Appendix A-1.

Phase two was the field operation itself. The stable platform was erected in a depth of approximately 70 ft. about 2 miles due north of North Point lighthouse, Prince Edward Island, and data were telemetered by radio link to a temporary laboratory set up in a prefabricated hut ashore. Since the instruments were still essentially in the breadboard stage, this meant frequent trips between the platform and the shore by both launch and rubber dinghy in order to keep the equipment working and to study its future design requirements. A number of data runs to measure the turbulent transport of momentum, heat, and water vapour were completed under conditions ranging from gentle to moderate wind and sea. These data have not yet been analyzed to the point where the success of the experiments can be fully evaluated.

Phase three essentially overlaps all the other phases and has consisted of assembling and testing a system for digitizing the data. In this, the group has been largely dependent upon the services of the Engineering Design group, and has provided assistance mainly in testing and monitoring the equipment. Progress has been slow, but the emphasis has been on thoroughness and caution in order to establish the accuracy of the system and to avoid unnecessary mistakes. While this has delayed the data processing, it should result in dependable equipment and relatively undistorted data.

Phase four is just starting as this year draws to a close. In it the lessons learned from difficulties encountered in the field last summer will be applied to the redesign and rebuilding of the equipment for future field applications. Work has already started on the electronic systems, and early in the new year a start should be made on the construction of a new stable platform to be installed in an exposed location outside Halifax Harbour. Present indications are that by next

¹ Left BIO in 1965.

summer the equipment should be developed sufficiently to obtain wind stress data under at least moderately strong wind conditions in water between 35 and 50 fathoms. Development of the heat flux and humidity flux instrumentation has had to be set aside for the time being because of the pressure of other work.

Before next summer's field installation is established, it is anticipated that the existing backlog of data records will have been digitized and analyzed to yield a series of stress determinations under a moderate range of wind and sea conditions.

Stuart Smith, a member of the group on educational leave at UBC where he is doing a thesis on wind turbulence and stress determinations, has been using one model of the thrust anemometer which is partly his own design, and he reports good agreement between the turbulence spectra obtained with it and those obtained by hot wire anemometer. He has been using analogue techniques for his computations, and it will be interesting to compare results obtained with the new digital equipment at BIO.

L. A. E. Doe

Frozen Sea Research

E. L. Lewis

J. D. Bradbury¹
P. H. Bridge
J. A. Elliott

Mrs. J. Hackney¹
R. W. Mackay
S. W. Moorhouse¹

During the past year the effective size of the group has been doubled: J. A. Elliott returned from educational leave at IOUBC where he had completed his Master's degree; S. W. Moorhouse was appointed as logistics and maintenance officer on June 1; Mrs J. Hackney became the group's secretary on April 1. J. D. Bradbury joined as a technician late in the year.

New premises at 825 Devonshire Road, Esquimalt, B. C. were acquired on October 1, which provide office, equipment, maintenance and storage space for the group. It continues to occupy laboratory spare at the Pacific Naval

Laboratory, DRB, which also houses the cold rooms and provides machine shop facilities.

During January-March, experiments on heat flow and temperature profiles in sea ice were continued from the previous year at the field location in Cambridge Bay, Victoria Island, N. W. T. An investigation of the water column under a growing ice sheet was carried out and as a result a contract was let to a Cambridge Bay resident to carry on time series observations throughout the year. It is intended to return to Cambridge Bay for March-April, 1966, to conduct further investigations of the water structure and its relation to ice growth.

Analysis of the heat flow data computed from field measurements has been proceeding. Work is centred on devising the simplest possible model giving an adequate description of the thermal properties of sea ice for practical purposes. Temperature profiles in an ice sheet were calculated for a number of models and are being tested by the index of correlation of their fit to the experimental data. The effect of ice growth on water column structure is beginning to be understood and it is hoped that next winter's work will enable a more complete picture to be seen.

Laboratory experiments directed towards determining the mechanism of the salt-induced convective overturn under a growing ice sheet have been carried out and are continuing. A Schleiren system has been used to photograph the falling salt "fingers". For comparison purposes temperature-induced convective overturn is also being investigated. Experimental techniques of considerable complexity are involved.

The three small cold chambers installed at PNL have yet to be accepted because of their failure to maintain the specified temperature stability during recent acceptance tests. However, it is anticipated that the fault will soon be corrected. Construction is continuing of the Arctic research vehicles, both self-propelled tracked and sled-mounted units; the fiberglass superstructures made under contract at HMC Dockyard, Esquimalt, B. C., are now complete, and assembly and construction work is in progress at our maintenance facility. Special tanks for use in the work on convective overturn are being

¹ Joined BIO in 1965.

constructed, and further modifications and construction of specialized equipment for use in an arctic environment are underway. The outfitting of our new premises has been a considerable labour; at the time of writing most of the required equipment has been installed.

E. L. Lewis

Theoretical Studies

G. T. Needler

C. Quon
R. F. Reiniger

C. K. Ross
K. O. Westphal

R. F. Reiniger
C. K. Ross

The strength of this group has been considerably augmented by the return of Mr Ross and Mr Reiniger to full time work at BIO in May after receiving their Master's degrees in applied mathematics from the University of Toronto.

Models of ocean circulation

Work in several aspects of models of ocean circulation has been carried out. In particular, a study has been undertaken on a certain class of solutions of the equations governing thermohaline circulation. These solutions in some instances can satisfy a boundary condition on the bottom of the ocean and give reasonable values for the magnitude of the temperature, its variation with depth and for the vertical velocity component at a surface below the Ekman layer. A BIO report on this topic is being prepared. Additional research has been carried out on the approximations involved in the work on long waves on the beta-plane and also, with Dr Mann, on some aspects of the problem of time variability in the ocean as related to standard sections.

G. T. Needler

Numerical analysis of oceanographic data

During the past year work has been completed on a new interpolation scheme which can be used to obtain the value at standard depths of an oceanographic parameter which has been

measured at discrete depths. Basically, the method is similar to the one now used by CODC: however, by incorporating a weighting factor into the routine, "overshoots" which were occurring in the old system and are thought to be unreal, are removed. The method for obtaining the error involved in this interpolation also remains quite similar; the main difference is to include the weighting factor mentioned above, in the error calculation. A report on this work is being prepared. In the latter part of the year, work was started on the preparation of a library of oceanographic computer programs to be used on the CDC 3100 and PDP-8 computers.

Heat transfer in sea ice

At the beginning of the year a report was published on the freezing of a water column under the influence of radiation cooling (BIO Report 65-1). After further work had been undertaken on the convergence of the power series expansions which are involved, a paper on this work was submitted to the International Journal of Heat and Mass Transfer.

Since there was a genuine need to investigate the influence of Stefan-Boltzmann's radiation law on the motion of a phase change front, an approximate method has been used to study the effect. Numerical work has been completed and a report on this work is being written.

Using the data which have been collected by Dr E. L. Lewis, Frozen Sea Research, an investigation has been made, employing numerical analysis, on the extent to which one can predict the temperature structure in sea-ice. Based upon a finite ice sheet as a model, an equation has been obtained from which it ought to be possible to deduce the constant of thermal diffusivity. Currently a study is being made of the accuracy requirements for temperature measurements in sea-ice if various physical parameters are to be derived from these measurements.

K. O. Westphal

North Atlantic Physical Oceanography

C. R. Mann

B. D. Carson¹
T. R. Foote
G. J. Gibson²
A. B. Grant

J. R. N. Lazier
E. A. Lewis
W. G. Warshick¹

Oceanographically, the Northwest Atlantic is extremely complex and not at all well understood: as such, it presents a most challenging problem for basic research. Moreover, there are few facts available for practical purposes and models of the circulation are generally inadequate as a basis for prediction of oceanographic conditions. The currents, and consequently the distribution of temperature and other properties in the area, are part of the general circulation of the North Atlantic. An understanding of the local oceanography requires a knowledge of the oceanography of the North Atlantic as a whole. Since its inception the Institute has supported fundamental study of the North Atlantic not only to find solutions to local problems but to contribute to knowledge of the world oceans.

In 1964-65 the group engaged in this project has concentrated on two major studies, one on the nature of the Gulf Stream system to the southeast of the Grand Banks and the other on the formation and subsequent spreading of deep water in the Labrador Sea in winter.

Gulf stream

Most of the routine analysis of the 1963-64 cruises southeast of the Grand Banks is complete. An Atlas of all the data is being published by the Queen's Printer (BIO Report 65-16). Dynamic topographies reveal a trough of low pressure extending far to the southeast of the Tail of the Banks, much further than indicated by the United States Ice Patrol data. This is in agreement with Worthington's idea of two gyres in the North Atlantic (Fig. 1). The distribution of properties (temperature, salinity, oxygen) across the trough does not show the centre of the trough filled with water of low salinity from the Labrador current, nor do these properties show a change across the trough as would be expected if two separate gyres were operating. The studies to date have established the course of the Gulf Stream after it passes the Tail of the Banks; the Stream constitutes the

southern side of the trough. They have not, however, established unambiguously the existence of a separate gyre to the north or the mechanism by which the strong warm current flowing northeast past the eastern side of the Grand Banks is fed. To do this, more detailed work close in to the Tail of the Banks will probably be necessary.

C. R. Mann

Labrador Sea

The investigation of the physical oceanography of the Labrador Sea, started in 1964, is being continued. The primary interests in the investigation are the formation and movement of the Labrador Sea water and the North Atlantic deep water. During the year more data pertinent to the area have been obtained and plotted. In the Labrador Sea proper the data being used include: the *Erika Dan* survey in the winter of 1962, the ICNAF Norwestlant surveys of 1963, and the data regularly collected by ICNAF members along the west coast of Greenland. The water masses adjacent to those of the Labrador basin are being investigated using the data collected during the IGY by the ships, *Anton Dohrn*, *Gauss*, *Discovery*, and *Lomonosov*. These data are being plotted and studied as background material for a cruise planned for *Hudson* early in 1966.

Between August 22 and October 22 a research cruise was undertaken aboard the Canadian Coast Guard icebreaker *Labrador* (Fig. 2). Eight members of the BIO staff and two from the US Naval Oceanographic Office took part in this cruise. The oceanographic sampling program consisted of 125 stations in the northern Labrador Sea and Davis Strait. The purpose of this work is to map more comprehensively than is possible with the rather inadequate existing data the water masses and currents of the area, especially the West Greenland current, and the outflow from Baffin Bay. Magnetometer observations were taken throughout the cruise except in a few locations where heavy ice was encountered. For the fifth year oceanographic stations scattered between Smith Sound and the Strait of Belle Isle were occupied as part of the US Naval Oceanographic Office program of forecasting ice conditions in northern waters.

J. R. N. Lazier

¹ Joined BIO in 1965.

² Left BIO in 1966.

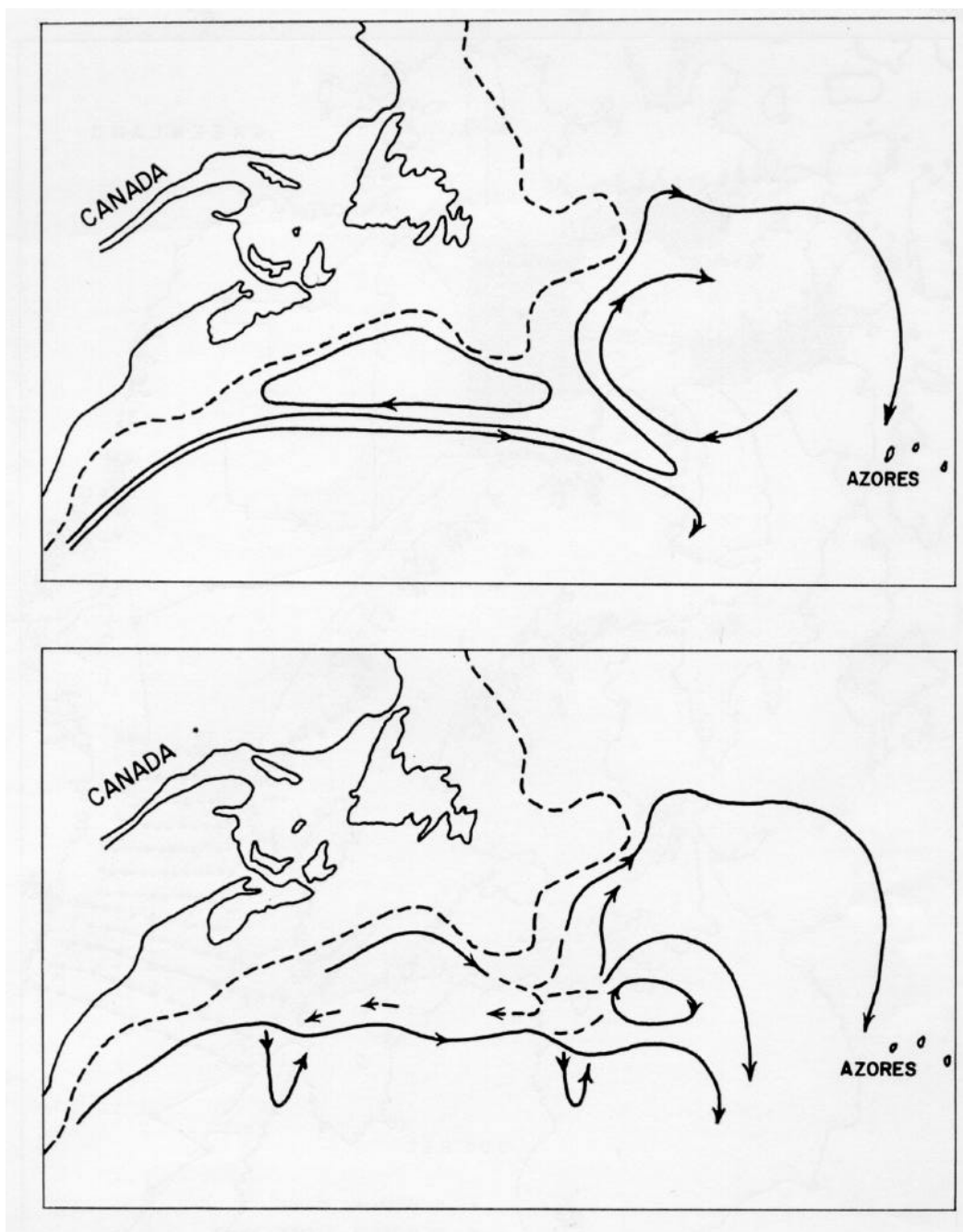


Fig. 1. Schematic diagram of currents in the vicinity of the Grand Banks and Gulf Stream. The upper figure illustrates Worthington's proposal. The lower figure is a proposal resulting from BIO studies. Dotted lines indicate currents whose existence is uncertain -- they may be transitory.

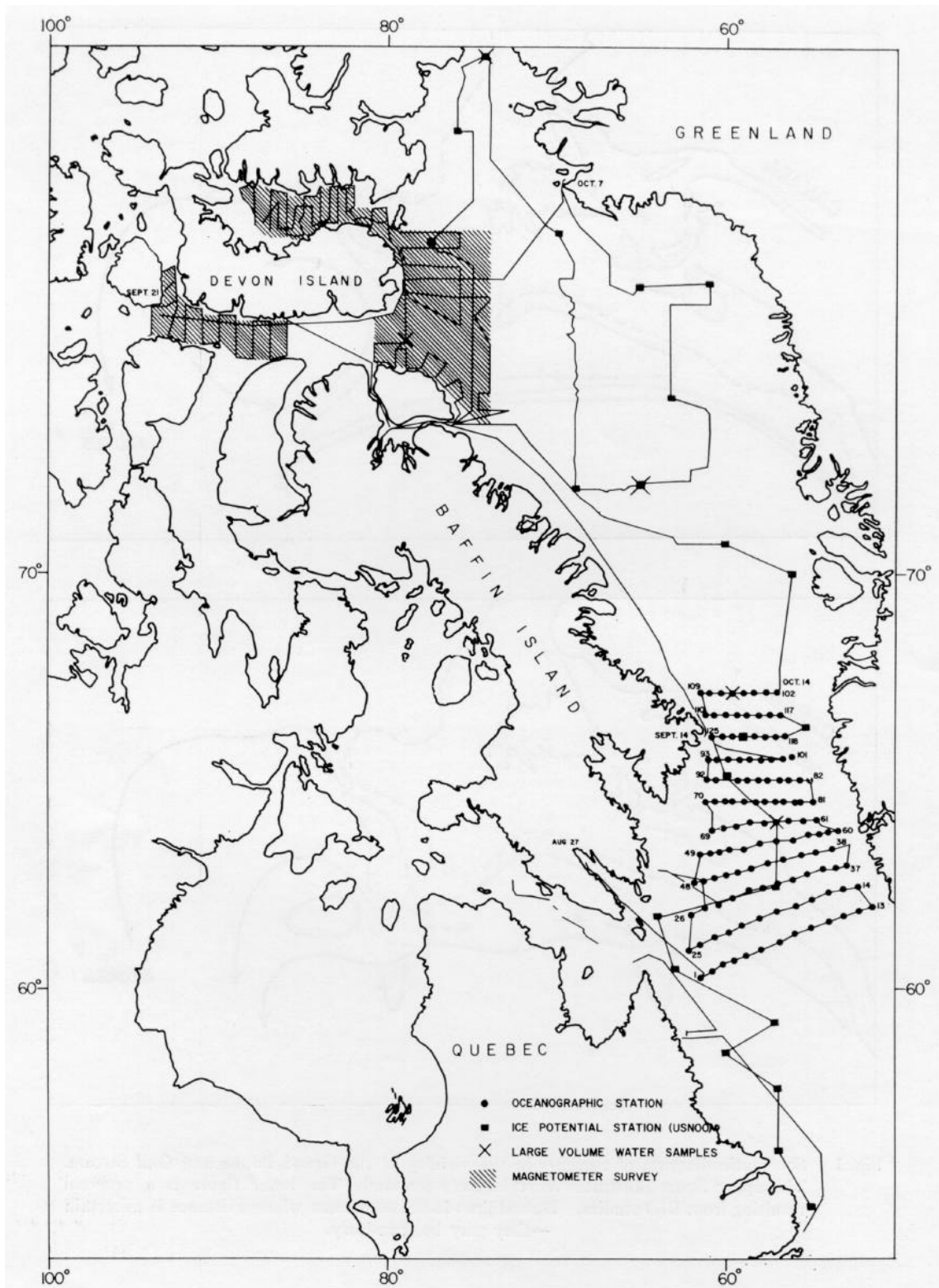


Fig. 2. Track chart of the CCGS Labrador showing location of magnetic and oceanographic observations taken from June 30 to July 7, 1965 and August 27 to October 22, 1965.

Other projects

Collection and processing of BT data from Sambro Light Vessel off the mouth of Halifax Harbour was continued twice daily and the compiled data forwarded to St. Andrews for studies of longterm changes in temperature. Compilation of the 1964 Ice Forecasting cruise to the Gulf of St. Lawrence was completed. The 1965 cruise was undertaken and preliminary data sent to Ice Central, Halifax, for forecasting purposes. A study of BT data requirements of East Coast establishments showed that BT processing could be done effectively at CODC and it was turned over from BIO to CODC in July. An evaluation of Francis Associates' expendable BT was undertaken in December.

A study of the variability of oceanographic conditions on the Halifax section, running from Halifax south over the Scotian Shelf, was commenced in August and is continuing.

T. R. Foote
G. Gibson

Coastal Oceanography -- St. Lawrence Estuary

W. D. Forrester

M. E. MacLean
B. D. Price¹

R. G. Tippet¹

The major effort of this group in 1965 has been the planning, preparation, and execution of an oceanographic and current survey in the St. Lawrence estuary near Father Point, P. Q. The purpose of the survey was to learn more about the circulation in the Gulf of St. Lawrence and also to assess the usefulness of the geostrophic approximation in coastal channels. A major innovation in oceanographic sampling technique was employed in that strings of water bottles were anchored across a section and tripped simultaneously by clockwork devices that dropped messengers at a pre-set time. Simultaneous sampling removed the doubt about how much conditions might change during the time occupied in observing a series of stations, and comparison between geostrophic currents and directly measured currents was put on a firmer basis.

The field work was carried out from the chartered vessel MV *Theta* during the second half of September and the first half of October, as a joint operation with the Current Studies group, without whose cooperation the mooring of current meters and water bottles would have been a much more formidable task. Eighteen current meters were moored in the cross-section between Cock Point and Pointe à Michel from September 17 to October 4 (Fig. 3). During this time seven strings of water bottles were moored on each of 11 days in the same cross-section of the estuary and set to trip simultaneously, at the same time as an eighth oceanographic station was observed from the ship. The success of the simultaneous water sampling was about 85%; one string of 12 bottles was lost, but the sub-surface float and the messenger release were recovered. From the 18 current meters about 60% of usable record was obtained. Following this phase of the survey, 15 current meters were moored in close array in three strings between oceanographic stations 4 and 5 from October 6 to October 12; for 48 hr during this period oceanographic stations were observed from the ship at locations 4 and 5, where each location was occupied about every 2 hr. The purpose of this more detailed look at a portion of the cross-section was to evaluate the order of time change in conditions and to determine what type of average current best agrees with the calculated geostrophic current, so that the data from the complete cross-section could be more reliably assessed. Before the ship survey began, temporary tide gauges were installed at Rivière du Loup, Pointe au Pic, and Les Escoumins to supplement permanent gauges on the St. Lawrence. From the changes in water level integrated over the surface of the estuary it is hoped to calculate the transport (less the river flow) through the cross-section and thus to obtain another condition to control the assumptions that must be made in the reduction of the other data.

The reduction and analysis of the current and oceanographic data obtained this season and the interpretation of the results will occupy the efforts of the group for most of 1966, and no field program is planned for next season.

W. D. Forrester

¹ Joined BIO in 1965.

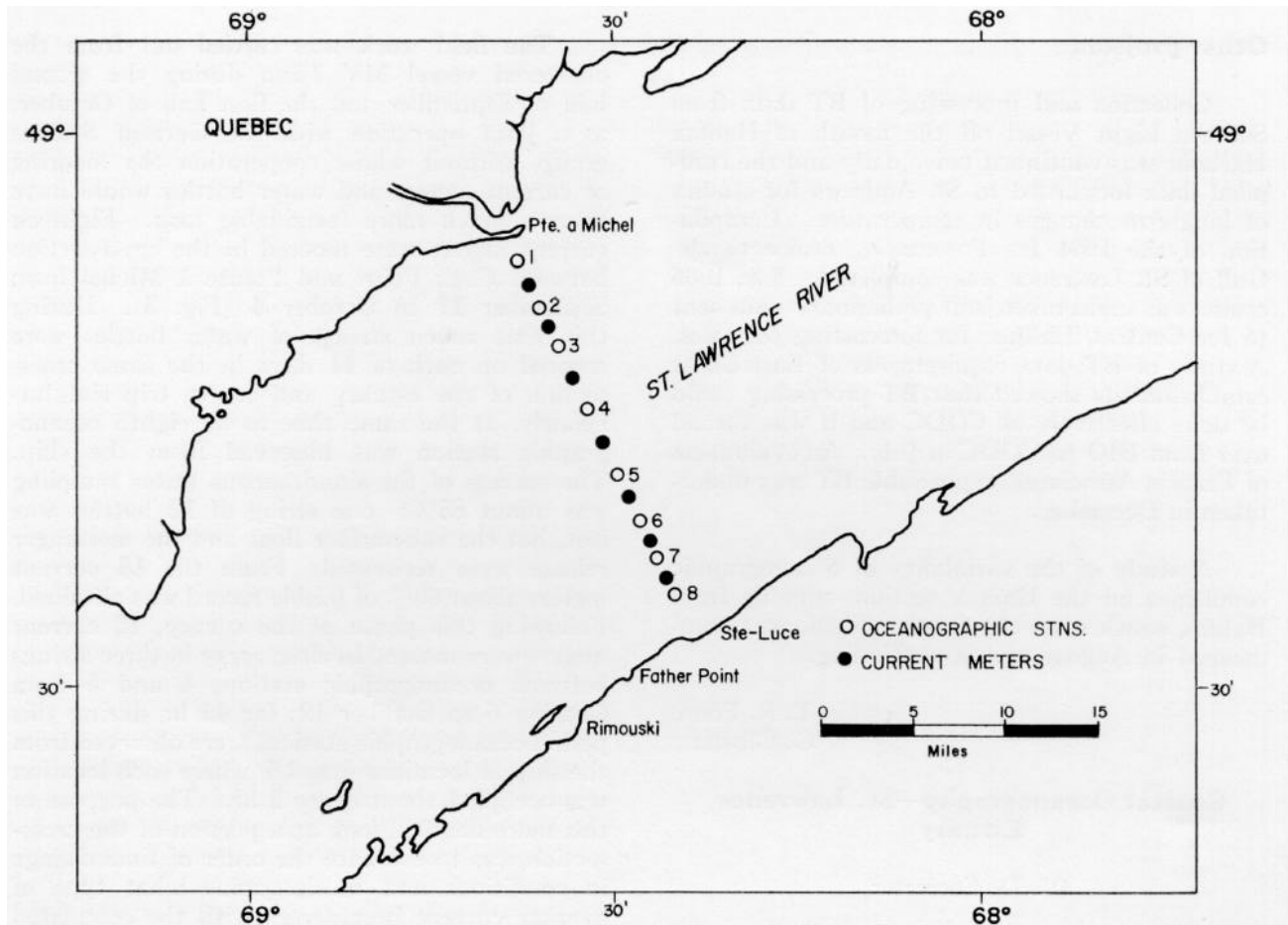


Fig. 3. Location of current meters and oceanographic stations occupied in the St. Lawrence estuary during the period of September 27 to October 4, 1965. Water samples and temperature were obtained simultaneously throughout the section, repeatedly, by means of a system of moored buoys and automatic tripping.

Current Measurement Studies

W. I. Farquharson

D. Dobson
F. D. Ewing

D. J. Lawrence¹
W. J. MacNeil¹

A primary objective of the group is the development, evaluation and application of techniques of direct measurement of water movements for comparison with the calculated values obtained by the indirect methods of classical physical oceanography. Assistance is also provided to other projects in the use of current meters and analysis of current data.

The early part of the year was devoted to detailed examinations of the Braincon current

meters acquired after evaluation tests the previous year, and in collaboration with W. D. Forrester in technical discussions and trials of equipment to be used in a joint current and oceanographical survey in the St. Lawrence.

In March a 3-day meeting was held at BIO to discuss techniques, instrumentation and data processing used in current surveys. It was attended by representatives from MSB Headquarters, the Central and West Coast regions, and the US Coast and Geodetic Survey. It was followed by a 1-day meeting in Ottawa concerned primarily with tidal publications, the processing of tidal records, and liaison between the various units.

The following projects were carried out between May and November 1965:

¹ Joined BIO in 1965.

Bay of Fundy

For the first 3 months the group collaborated with the Hydrographic Service in their tidal and current survey of the Bay of Fundy (p. 43). Messrs Dobson, MacNeil and a summer student installed and maintained a network of tide gauges at the head of the Bay, while Mr Ewing took part in the survey of the currents.

St. Lawrence

At the beginning of September the group together with the coastal oceanographic group under Mr. Forrester, embarked in MV *Theta*. On arrival in the St. Lawrence 18 current meters were moored on the cross-section from Cock Point to Pointe à Michel, as part of the joint survey reported on p. 19. Subsequently, 15 of these meters were concentrated over a portion of the cross-section, while five meters of a variety of types were suspended immediately below one another on another mooring for the purpose of intercalibration. The current meter moorings and the attached instruments were retrieved without loss. This was the first extensive trial of the Braincon meters and their overall success was assessed at 60%, which judging by previous experience is reasonable for a new type of instrument.

Ocean mooring trials

These were carried out in depths of about 950 fathoms in "The Gully", southeast of Sable Island. Prior to proceeding to the St. Lawrence 10 days were spent in evaluation tests of the new mooring materials acquired as a consequence of experiments conducted in 1964. These initial tests were unrewarding as the mooring, and the instruments attached to record its behaviour, were lost owing to the mechanical failure of one type of rope at a fraction of its specified breaking strain. The ship returned to this area on completion of the St. Lawrence survey and continued the search for the lost mooring. Subsequently, a new mooring was laid with three Braincon meters suspended from a sub-surface float. This mooring was also instrumented to record its behaviour, though not as fully as was desirable owing to the previous losses. The instrument mooring was attached to two anchors, one at each end of a groundline. A release gear freed this mooring at a preset time, permitting the submerged float to rise to the surface but with its mooring still attached to the second anchor. The instruments and mooring were recovered,

the two upper current meters were found to have operated successfully, the deepest one failed due to fouling by the groundline.

In general, the equipment and material devised or acquired for this year's experiments both in the St. Lawrence and in "The Gully" proved satisfactory except one particular type of rope which repeatedly failed.

W. I. Farquharson

Chemistry and Marine Radioactivity

I. M. H. Pagden

A. R. Coote

W. Young

R. S. Hiltz.

The present programs in chemistry and radiochemistry were initiated with the intention of supporting physical oceanography. Chemistry has been directed towards developing new techniques for the identification of water mass types. Radiochemistry has been directed towards using the distribution of fallout fission products as a means of observing transport phenomena in the ocean.

Chemistry

The distributions of silicate and dissolved oxygen were observed in the region of northern Labrador Sea and Davis Strait. High silicate and low oxygen values along the coasts of Baffin Island indicate the outflow of Baffin Bay water over the sill at Davis Strait. Use was made of the Pomeroy-Kirschman alkaline-iodide reagent and a glycerin-starch indicator in these oxygen determinations. Both of these reagents significantly improved the end-point detection of the Winkler method.

An initial attempt to develop a quick method for the determination of total silicate was not successful. However, evidence found by investigators elsewhere that polymeric silica may occur in the oceans suggests that such a method should be useful and is worthy of further effort.

A. R. Coote

Marine radioactivity

During the year 31 samples for fission product analysis have been taken at stations in Baffin Bay, Labrador Sea and the North Atlantic. The Atlantic stations were used for sampling water of Mediterranean origin and for commencing

ing experiments on the contamination of samples due to shipboard processing.

Thirteen complete caesium separations and strontium separations have been made; another 15 samples are incompletely separated. The sampling should be maintained, even though the processing lags, since the accumulation in the oceans of fission products from atmospheric fallout may be a unique event. Fractions of these water samples have been sent to the Central Institute for Industrial Research, Norway, for the analysis of stable rare earth elements. The results will assist the interpretation of radioactivity levels of fallout fission products.

The sample preparation area has been isolated to reduce airborne dust content. It awaits the installation of a filtered air supply before separations of very low activity samples are performed. A naval mortar, cast in 1878 and weighing 11 tons with 15 inches of iron surrounding the charge space is being used as a ready-made radiation shield for sample analysis. It has been so placed outside a window that samples may be put into the barrel from within the building. Experiments are in progress to measure the background within the barrel and the contributions to it from various sources.

Preliminary experiments have been done at Chalk River Nuclear Laboratories on the observation of a number of radio isotopes produced by pile irradiation of ocean salt samples.

Services

Part of the technical effort of the section is devoted to the routine measurement of salinities; approximately 4,000 samples were processed in 1965, and chemical reagents were prepared for physical oceanographic studies by other groups.

I. M. H. Pagden

Environmental Prediction

C. D. Maunsell

W. B. Bailey
J. Butters
R. R. Weiler

} Oceanographic Services
for Defence

M. P. M. Reddy - NRC Postdoctoral Fellow

One of the important reasons for expending Canadian oceanographic work by establishing BIO was to provide a source of information about conditions to interested parties. Information on

specific points is often provided by individual staff members from data gathered in their research, but there is a need for a service to provide environmental data over a large area. At present this is provided by Oceanographic Services for Defence, which is jointly staffed by MSB and the Department of National Defence. This group basically serves the Canadian Maritime Forces, but also supplies data to interested research laboratories, meteorological offices and fishing companies ranging from California to Scotland.

Fisheries interests would like to see an increased emphasis on monitoring of conditions in various areas along the coast. This cannot be provided by the present program using only surface temperature data reported by ships of opportunity and a small amount of data on water structure given by bathythermograph observations. Within the next year, activities in environmental forecasting and other applied oceanographic fields will receive increased emphasis as described in the introduction to the Oceanographic Research section.

The group is fortunate to have the company of Dr M. P. M. Reddy, a National Research Council postdoctoral fellow from India. A summary by Dr Reddy appears on p. 24 on his special study of the effect of waves on a shoreline.

Oceanographic Services for Defence (OSD)

Charts summarizing the estimated distribution of sea surface temperature and layer depth over an area extending from the tip of Greenland to Bermuda and from the North American continent to 35° W. are prepared and broadcast daily by radio facsimile and also distributed by mail. These charts are largely based on the sea surface temperature data included in the weather reports from ships in the area. The temperature data indicate the location of boundaries between water masses. The limited number of bathythermograph observations available give further information about the character of these masses. A sample chart of sea surface temperature is included as Fig. 4.

As well as issuing regular charts the staff attached to OSD are called upon to provide other oceanographic assistance to the Maritime Forces. This includes the preparation of long range forecasts of conditions for planned exercise areas usually in the Northwest Atlantic and on occasions in the eastern North Atlantic and the

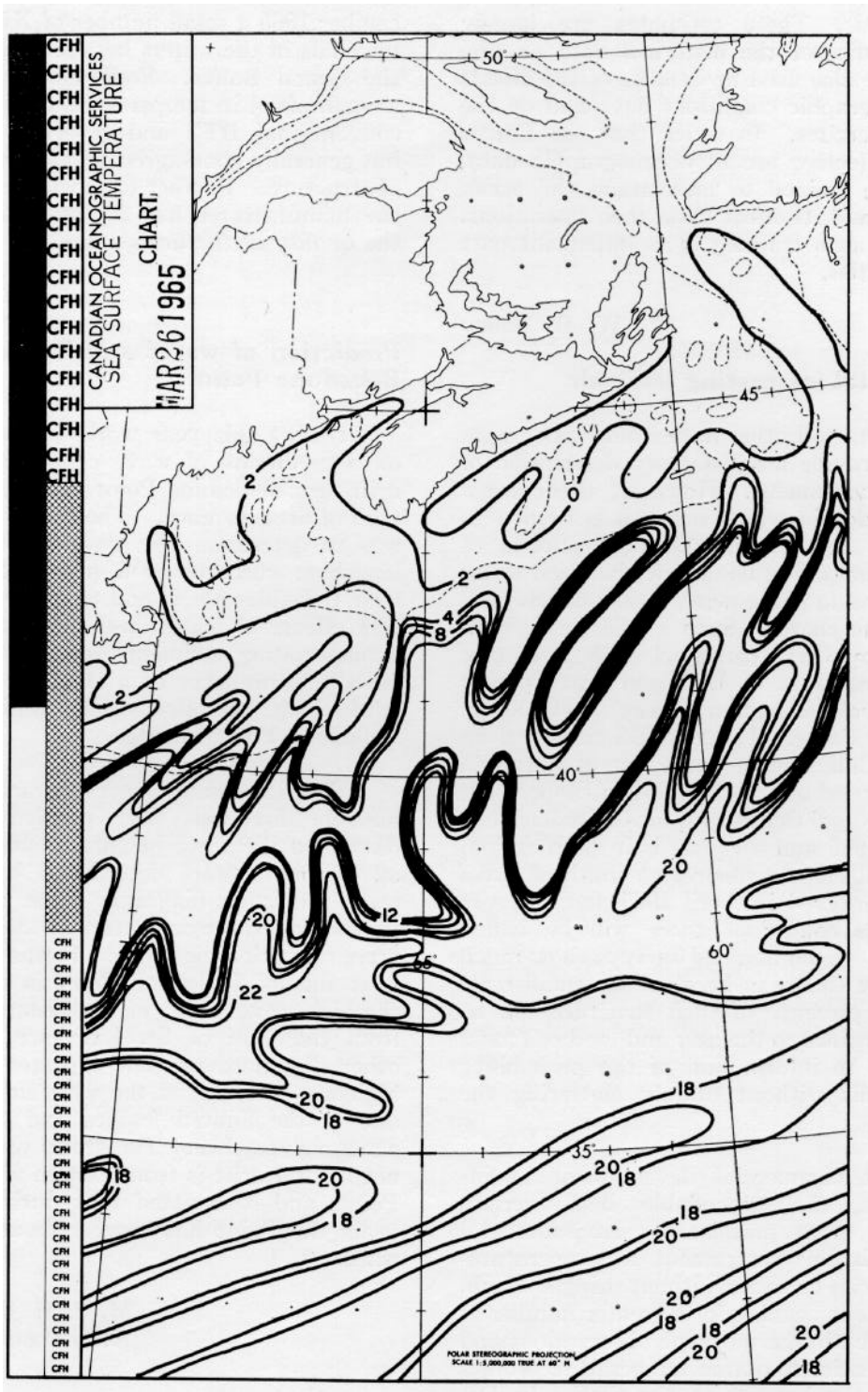


Fig. 4. Daily sea surface temperature chart.

South Atlantic. These estimates are largely based on studies of the historical data on file. Such data are also used for studies of the effects which oceanographic conditions have had on the success of exercises. In order that the Forces may make effective use of oceanographic data, they must be trained to understand the ocean environment and its effect upon their operations. Assistance in such training is an important part of OSD activities.

W. B. Bailey

Environmental forecasting research

The charts and other data from OSD are an attempt to provide a satisfactory description of the ocean environment. However, there are a number of fields in which research is needed to improve this description. Detailed studies of ocean areas containing boundaries between water masses can lead to refinements of the models used in plotting the charts. Such studies have been carried out by OSD personnel with assistance from other members of BIO and participation by the Royal Canadian Navy and Royal Canadian Air Force. The CANUS survey of an area of the Gulf Stream northwest of Bermuda which was carried out in late 1964 in cooperation with the US Naval Oceanographic Office has been analyzed in 1965 and a report is in preparation. An area in the slope water region south of Nova Scotia was surveyed in April 1965 and a report describing the conditions there will be issued early in 1966. Such detailed surveys show much finer structure than can be given on small scale charts. The presence of such structure can be of great importance to the user and methods must be developed to inform him of the probability of such details without unduly cluttering the charts.

A recent commercial development in instrumentation, the expendable bathythermograph, offers great promise for environmental studies. With this instrument a temperature-depth profile can be taken without using a winch. This can make it possible for a greater number of ships to take bathythermograph observations and also make it easier to obtain temperature profiles extending to the bottom on the shelf. In De-

ember 1965 a small number of XBT's were used for trials in the waters between Nova Scotia and the Grand Banks. Preliminary analysis shows a small offset in temperature on comparison with conventional BT's and reversing thermometers but generally good agreement in the reproduction of structure. Further tests will be required since the manufacturer has reported difficulties with the quality of the units supplied.

C. D. Maunsell

Prediction of waves and littoral current at Belledune Point

During this year work has been completed on a prediction of wave conditions and littoral drift near Belledune Point, Chaleur Bay, on the Gulf of St. Lawrence. The purpose of this study was to determine the wave characteristics and longshore currents at a proposed harbour site near Belledune Point and to understand the relative effects of waves and longshore currents in transporting sediment around the Point. The harbour is to serve as a shipping point for ores smelted at the Brunswick Mining Company, Belledune Point Smelter.

The deep water wave characteristics for all possible directions were predicted using wind data, and the wave heights in shallow water for all directions were determined by constructing wave refraction diagrams. The probable directions of longshore currents were also derived using wave refraction diagrams. It was found that the west side of Belledune Point is protected from the high wave action of the eastern swell coming from the Gulf of St. Lawrence. Waves from other directions are not expected to cause any high wave action on the west side of the Point due to the limited fetches and the absence of wave convergence. The study predicts that the net littoral drift is from east to west around the Point; and it is noted that during the past 30 years the Point has moved about 250 ft westward.

M. P. M. Reddy,
NRC Postdoctoral Fellow

Marine Geophysics

B. D. Loncarevic

D. L. Barrett
 R. V. Cooper¹
 G. N. Ewing
 L. J. Fitzgerald
 R. Hurdal²

D. R. Locke¹
 K. S. Manchester¹
 S. P. Srivastava¹
 H. R. Steeves¹

Summary

The group doubled in size during 1965. As a result it was possible to spend 573 man-days at sea compared to 273 in 1964, and at the same time to make considerable progress in the analysis and interpretation of field observations. On seven cruises, 22,585 nautical miles of shipborne gravimeter data and 40,325 nautical miles of shipborne magnetometer data were obtained. A significant improvement was achieved in the efficiency of operations at sea, measured by the quantity of data collected per day at sea. The data are summarized in the last two lines of the table shown below:

This achievement can be attributed to two factors:

1. greater experience of the group;
2. vastly improved reliability of equipment due to the efforts of Engineering Services.

The operational capability for making measurements at sea will produce a large amount of data. It is hoped that the installation of a digital computer at BIO, introduction of shipborne digital

computers next year and the arrival of new staff will make it possible to establish reduction routines before the backlog of data becomes a serious problem.

Mid-Atlantic Ridge

Detailed surveys of contiguous areas made by RRS *Discovery II* in 1960 and CSS *Hudson* in 1965 have made it possible to compile maps of bathymetry, total field magnetic anomaly and gravity anomaly which cover an area approximately 50 x 20 miles along the crest of the Ridge, centered on lat 45°30' N., long 28° W. Within the surveyed area, the median valley and the associated belt of large positive magnetic anomalies are continuous and display a striking lineation in direction 020°. Minor features, revealed by closed contours, are developed *en échelon* and have an elongation of about 4:1. Trench floor sediments were not observed but several minor ponded sediment basins were seen on the flanks. Near the northern end of the area, the valley is partially blocked, apparently by confluent flows from two unusually large volcanoes standing on either side of the valley. Underwater camera photographs showed pillow lavas, and olivine basalts and dolerites were dredged near this point by RRS *Discovery II*.

Magnetic anomalies within the surveyed area can be simulated by a two-dimensional model in which steeply dipping contacts separate blocks of rock having different magnetizations, see Fig. 5. These blocks could be entirely within the volcanic layer extending to a depth of 5 km below sea level, but the central block, immediately underlying the median valley, must be much

	<u>1963</u>	<u>1964</u>	<u>1965</u>
Days at sea	210	273	573
Ship gravimeter (miles)	2,500	7,500	22,585
Ship magnetometer (miles)	5,990	9,500	40,325
Gravimeter miles/man-day at sea.. . . .	12	28	40
Magnetometer miles/man-day at sea.. . . .	28	35	70

¹ Joined BIO in 1965.

² Left BIO in 1965.

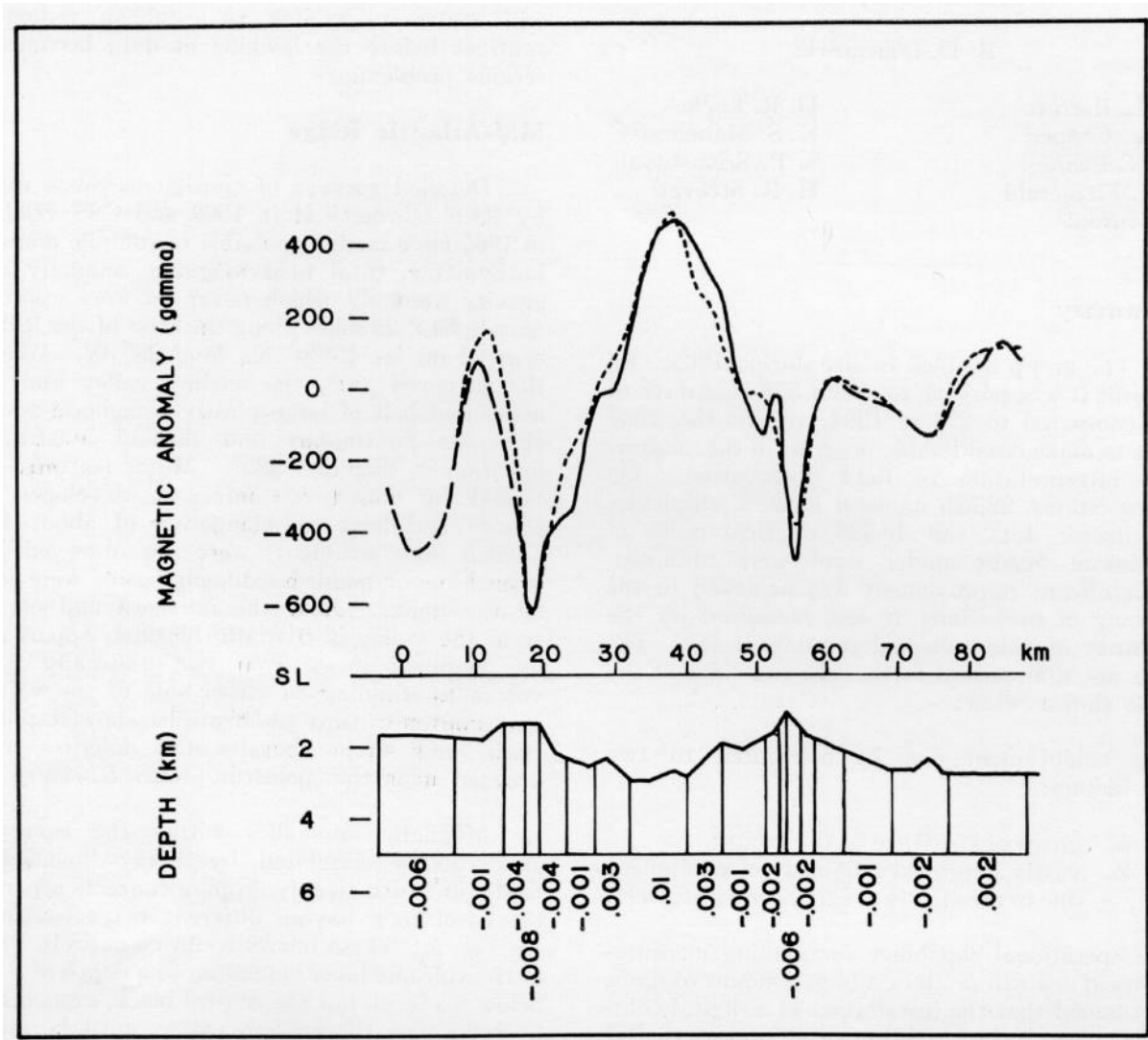


Fig. 5. Inferred magnetic model, mid-Atlantic Ridge, at about $45^{\circ}30' N$. Solid line is the observed and dashed line is the calculated magnetic anomaly derived from a total of 18 normally and reversely magnetized blocks (see lower diagram), with effective susceptibilities ranging from +0.01 to -0.008.

more strongly magnetized than those adjacent to it. The free air gravity anomaly shows a strong resemblance to the topography which largely disappears when the Bouguer anomaly is calculated, indicating that the intrusive body immediately underlying the median valley is not significantly different in density from those bodies beneath the elongated sea mounts which overlook the valley. Small variations in the Bouguer anomaly indicate that there is an increase in

density in a northwest direction across the survey area. The mechanism by which the valley was formed remains obscure, although it is thought to be a volcanic, rather than a tectonic, feature.

Orpheus anomaly and continental drift

The area around the large negative gravity anomaly east of Cape Breton Island, the Orpheus anomaly, which was mapped last year, was a

scene of considerable commercial exploration activity. In cooperation with G. D. Hobson, Geophysics Division, Geological Survey of Canada, three seismic profiles were obtained over the anomaly. Preliminary interpretation of seismic data by G. N. Ewing indicates that the gravity anomaly is probably due to a deep trough-like structure filled with consolidated sedimentary rocks. The various layers over the centre of the anomaly have the following thicknesses and velocities: water -- 152 m, unconsolidated sediment -- 280 m (2.29 km/sec), first layer -- 405 m (3.48 km/sec), second layer -- 1,140 m (4.36 km/sec). The underlying layer had a velocity of 5.54 km/sec. North of the anomaly, the structure is: water -- 82 m, unconsolidated sediment -- 20 m (2.00 km/sec), first layer -- 700 m (4.64 km/sec), second layer -- 640 m (5.40 km/sec). The next layer is the crystalline basement with an apparent velocity of 6.15 km/sec. South of the anomaly, the structure is: water -- 93 m, unconsolidated layer -- 410 m (2.02 km/sec), first layer -- 1,350 m (4.27 km/sec). The underlying layer has an apparent velocity of 5.45 km/sec.

A reconnaissance gravity and magnetic survey was carried out over the western approaches to the English Channel in order to compare the observed anomalies with those observed over the Nova Scotia continental shelf. Three distinct gravity anomaly belts were mapped which resemble the Orpheus anomaly. However, the western approaches anomalies, unlike the Orpheus anomaly, are most likely due to granitic intrusions. The presence of clearly marked patterns of gravity and magnetic anomalies on continental shelves may be important in studying the arrangements of continents, assumed by proponents of the continental drift theories.

Hudson Bay and approaches

Gravity and magnetic observations were made on board CSS *Hudson* throughout the Hudson Bay cruise (see also Marine Geology, Hydrography, and Fig. 6), and on MV *Theron* on the return voyage from Churchill to BIO. The gravity data will be analyzed in conjunction with the bottom gravimeter data obtained by the Dominion Observatory, as a joint project. Magnetic data will be used to supplement the airborne magnetometer data obtained by the Geophysics Division, GSC.

The most interesting observation obtained during the run up the Labrador coast and through

Hudson Strait was a large negative gravity anomaly over Ungava Bay. The corresponding magnetic trace showed very long period anomalies. These two observations indicate that a considerable thickness of sediment may be found in Ungava Bay.

A gravity track across the entrance to Labrador Sea from Cape Farewell, Greenland to Newfoundland, does not show a gravity anomaly normally associated with a mid-ocean ridge, thus casting further doubt on the postulated existence of such a ridge in the Labrador Sea.

Arctic geophysics

Reduction and analysis of the 1964 Lancaster Sound magnetometer survey was completed by D. L. Barrett. A large normal fault, with the southern side downthrown about 8 km, is indicated along the south coast of Devon Island. This feature trends northeasterly in Baffin Bay and has been traced eastward as far as long 75° W. Normal faulting to the south and folding and thrust faulting to the north indicate that Devon Island has been subjected to major tectonic forces resulting in a relative northward movement of about 8 km. During a preliminary examination of the 12,560 nautical miles of 1965 magnetic data (Fig. 2), it has been noted that the interpreted fault, immediately south of Devon Island, extends westward to long 86° W, where it either terminates or turns northward.

Nova Scotia continental margin

The results of several seismic refraction profiles are available on the continental shelf and slope of the eastern seaboard of Canada. Gravity measurements have also been made along two tracks, perpendicular to the shelf edge, which begin near the coast of Nova Scotia and end on the abyssal plain. A density distribution was assumed for several models which resulted in a computed gravity field satisfying the observed gravity measurements. One model is in agreement with all seismic data and suggests that horizontal and vertical density variations occur in the upper mantle down to 100 km. A full report on this investigation has been published as BIO Contribution No. 45.

Electromagnetic coastal effect

Dr S. P. Srivastava is building an electromagnetic model of the eastern coast of Canada to study the effect of the coast on the diurnal

magnetic variations. The model is similar to the one built by Roden in 1964 (Geophysical Journal No. 4) for the Japanese coast except that it also incorporates the conductivity distribution in the mantle. The basic assumptions underlying this model are: (1) the ocean is considered to be a

rectangular sheet of non-magnetic material, infinite in length; (2) the conductivity of the continents is extremely low compared to sea water and hence can be represented by air in the model; (3) the conductivity values in the crust and mantle remain constant.

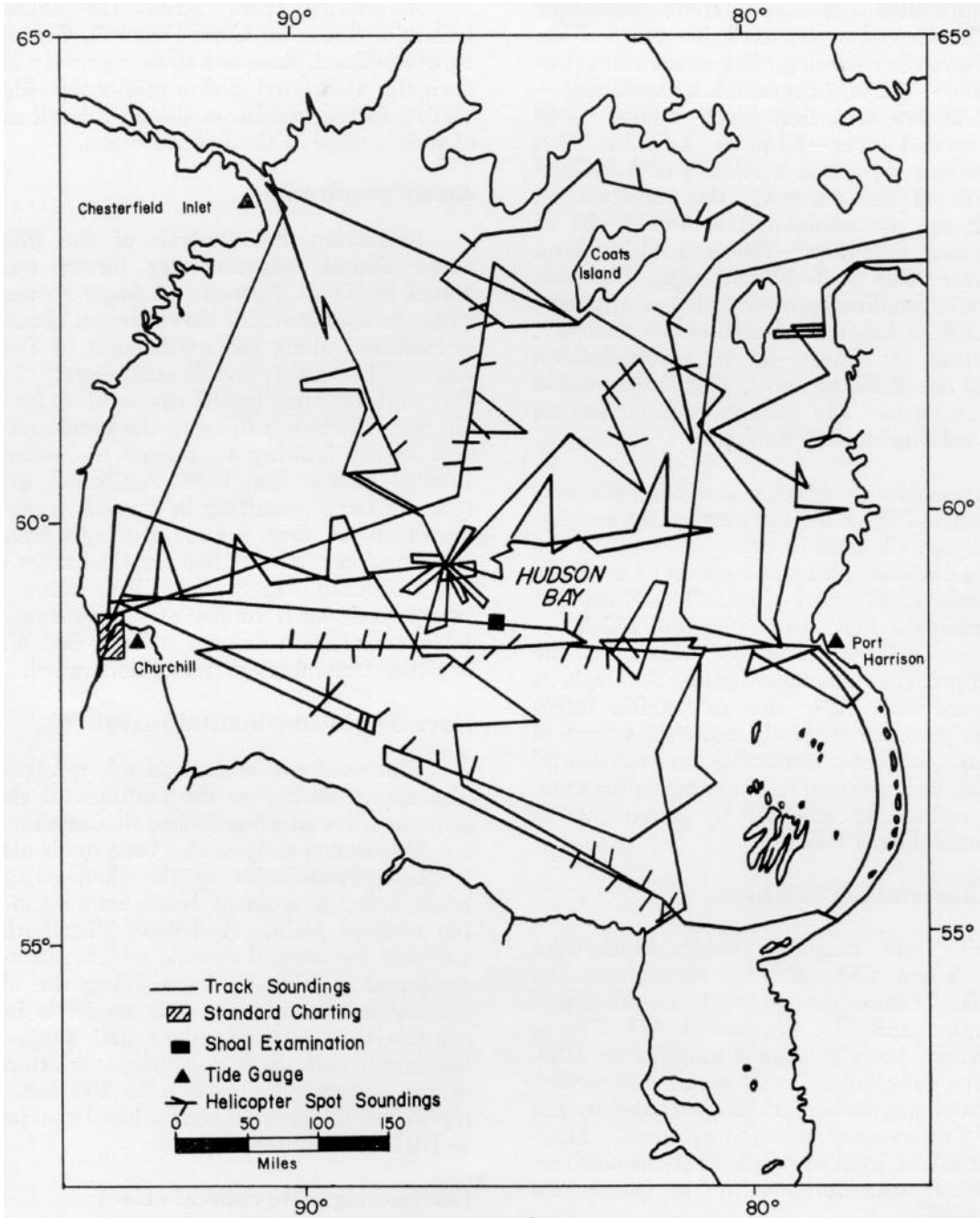


Fig. 6. Track chart of CSS *Hudson* for the geological, geophysical and hydrographic survey of Hudson Bay, July 16 to September 28, 1965.

As an extension of this investigation, it is hoped to use buoy magnetometers to check the results of model investigations (see also p. 48). In March one magnetometer operated for about 3 days in a pressure container. The scatter of readings precluded detailed analysis but a small phase shift is indicated between the observed diurnal variation at BIO and the sea recording site, 30 miles offshore.

Other investigations

Gravimeter and magnetometer reliability evaluations were carried out on CSS *Hudson* following the pattern established during trials on CSS *Baffin* in 1963. An analogue computer was built by D. R. Bower of Dominion Observatory to monitor cross coupling errors in gravity measurements. Preliminary examination of data indicates that cross coupling errors did not exceed 0.7 mgal, though winds were mostly between 20 and 30 knots during the trials. This confirms previous conclusions that *Hudson* is an unusually stable oceangoing platform very well suited for gravity measurements.

Technical assistance was given to Project *Navado* personnel in HNLMS *Snellius* during their visit to Halifax gravity test range in August. Their gravimeter reliability data are being analyzed as a joint project.

Since March 1965 a VLF navigation system employing transmissions from very low frequency radio communication stations has been in operation on CSS *Hudson* while a ground monitor station was operated at BIO and at Churchill, Manitoba, during the Hudson Bay project. In spite of known potential, the application of this navigational system has been very slow due to a requirement to produce grid charts manually and apply corrections for each operational area. It is intended next year to use a shipborne computer to plot an off-line ship's track using VLF data.

During the survey of the mid-Atlantic Ridge, navigation was by means of reference buoys moored on 2-mm-piano wire with 3%-8% scope. Each buoy carried a battery-operated radar transponder, and the relative position of the ship was plotted every 2 min on a chart table coupled to the navigational radar set. The transponders had a reliable range of 12 nautical miles with

maximum ranges of up to 17 miles. The accuracy of a simple fix was estimated as 0.2 nm; the error is mostly due to the movements of the buoys.

Mr K. S. Manchester participated in the trials of the oblique echo-sounder which are discussed in detail on p. 49. The records showed linear trends cutting across survey lines in the test area in Chedabucto Bay. The direction of lineation agreed well with the fold axis of the bedrock on Ile Madame, indicating that the bottom configuration was controlled by underlying bedrock.

B. D. Loncarevic

Computing Services

C. D. Maunsell¹

A. V. LeBlanc²

P. S. Trites

R. C. Richards

For the first 10 months of 1965 all computing in support of the BIO research programs was carried out on outside computers, but at the end of October a Control Data 3100 computer was installed. With its installation computing has entered a new phase, requiring the conversion of previous programs and the development of a number of new ones in order to carry out jobs which had had to be postponed while awaiting the new computer.

Prior to the installation of the 3100, regular computing time had been made available on the Ferranti-Packard FP 6000 computer at the Naval Research Establishment through the courtesy of the Chief Superintendent. By this arrangement a considerable number of programs were developed and run. A number of other programs were developed using the IBM 1620 at Dalhousie University and sent to the Department of Mines and Technical Surveys Computing Centre for production runs. Some other programs were run on computers at the Nova Scotia Technical College and at the University of Toronto.

The Marine Geophysics group made effective use of an on-line shipboard computer on *Hudson* during March and April. As a result two ship-

¹ Part time since June 1965.

² Joined BIO in 1965.

board computers are to be delivered next year for use on *Hudson* and *Baffin*. They will be of major assistance in carrying out preliminary data reduction at sea, and hence make it possible to investigate anomalies while the ship is still in the area.

It is by now clear that the peripheral equipment at present with the 3100 computer can seriously limit the work of the central processor, but it is not yet possible to specify in detail how much this will affect operations.

C. D. Maunsell

Marine Geology

B. R. Pelletier

G. A. Bartlett
D. E. Buckley
R. Cormier
G. A. Duncan
A. C. Grant¹
T. A. Holler
L. H. King

Miss K. M. Kranck¹
J. I. Marlowe
R. M. McMullen
Miss S. S. M. Pitcher
Miss F. J. E. Wagner
G. Vilks

General Remarks

During the year 1965, field projects in Marine Geology were carried out over the Arctic Ocean, Hudson Bay, the inshore waters of the Atlantic Provinces, the Scotian Shelf, and adjacent continental slope. As in previous years these activities involved studies of sediments on the sea floor and the associated fauna, submarine topography, geological formations and structures, and stratigraphy of the unconsolidated sedimentary layers. This year a greater use was made of sonic aids such as the depth sounders and various types of sub-bottom profilers. Underwater photography was used more extensively to support a physical study of the sea bottom. Water chemistry and current measurements were also emphasized as all investigators strove toward a program of integrated disciplines in order to obtain a more complete representation of the total environment.

This year the staff increased although two members were regrettably lost who had enhanced earlier programs with their fine contributions.

¹ Joined BIO in 1965

R. J. Leslie joined the Texaco Exploration Company, and D. R. Horn remained at the University of Texas to complete his studies. Three new members have been added: A. C. Grant, a former seasonal employee, who received his M.Sc. from the University of New Brunswick at the time he joined the staff; Miss K. M. Kranck, also a former seasonal employee, who received her Filosofie Licentiat from Uppsalla University, Sweden; and R. M. McMullen who recently received his Ph.D. from Reading University, England. Two new technician positions were won by Miss S. S. M. Pitcher, also a former seasonal employee, and T. A. Holler formerly of the Atlantic Oceanographic Group. On the educational front, G. Vilks returned from Dalhousie University in September, and D. E. Buckley should return from the University of Southern California in the spring of 1966.

Members of the section were extensively involved in joint projects with other sections of BIO as well as with universities and with other governmental agencies. A notable example was the 1965 Hudson Bay Project in which six universities, eight departments of government involving at least 20 agencies, and six industrial concerns cooperated directly on the program. Members of the staff have also been consulted on numerous occasions by representatives of both industrial and academic institutions.

B. R. Pelletier

Physical Geology and Geochemistry

Investigations in physical geology involve studies in marine geomorphology, sedimentology, certain factors of physical oceanography, and general features of bedrock such as mineralogy, petrology, stratigraphy and structure. These projects are listed below, and where a more significant project in another discipline was undertaken, it is listed elsewhere. For convenience the projects are listed geographically beginning in the western Arctic and ending over the Scotian Shelf.

Arctic Ocean

As a continuous project, bottom studies of the Arctic Ocean adjacent to the Canadian Archipelago have been conducted since 1960.

Generally, the Arctic Continental Shelf is submerged to a depth of 400 m. When the land stood higher relative to sea level, the inner part of the shelf underwent fluvial erosion, followed by glaciation. Subsequently, the land rose as indicated by the succession of raised beaches on the Arctic Islands. The sediments are coarse in shoal areas, and in deeper areas where oceanic currents are present. Near shore the sediments may be divided into deltaic and non-deltaic types. Mechanical properties of deltaic sediments vary progressively and exponentially with distance of sediment transport. This phenomenon is not readily apparent in non-deltaic sediments. Over the Continental Shelf no regular gradation occurs due to the influence of ice-rafted sediments which tend to mask the sediments derived from land. Carbon content varies between 0.6-1.0%, and carbonate content is generally less than 6%. These low contents may reflect a sparse fauna living in mainly ice-covered waters, which are relatively poor in phytoplankton. This work is presented in BIO Report 64-16 and BIO Contributions No. 26 and 29.

B. R. Pelletier

Arctic Archipelago -- Prince Gustaf Adolf Sea

A full report on the Sedimentology of this area has been submitted for publication as a Bulletin of the Geological Survey of Canada (BIO Contribution No. 50) and has also appeared as BIO Report 65-15. Data from 80 core samples show that sedimentation in Prince Gustaf Adolf Sea has been closely linked with oceanographic conditions. Faunal, mineralogical and physiographic evidence indicates that this Sea was formerly a restricted marine or glacio-marine environment. A post-glacial rise in sea level has allowed ventilated water from the Arctic Ocean to cross topographic sills and move through the area, bringing about a change from a reducing to an oxidizing environment of sedimentation.

J. I. Marlowe

Arctic Archipelago-Barrow Strait

In the late summer of 1962, the Canadian Hydrographic Service conducted an oceanographic study of Barrow Strait from the CSS *Baffin*. During the survey 139 bottom samples were collected, and are being described on the basis of texture and mineralogy. These data

will be related to existing oceanographic data, and the physical and geological features in Barrow Strait and surroundings.

P. J. Wise

General Baffin Bay area

Twenty-nine core samples collected from Baffin Bay during the 1964 northern cruise of CCGS *Labrador* have been studied and the data from them compiled (Contribution No. 48). This report relates the mineralogy of coarse sand-to-gravel-size particles from samples in the Bay to iceberg tracks, and offers evidence that the Baffin Land Current, in which southerly iceberg drift is concentrated, has in the past occupied a wider and more easterly track than it does at present. A second manuscript, dealing with the occurrence and significance of turbidite sediments in Baffin Bay, is in preparation.

J. I. Marlowe

Northern Baffin Bay

Bottom sediments collected in northern Baffin Bay during September and October of 1964 aboard CCGS *Labrador*, were analyzed at the University of New Brunswick. The results of these analyses are presented in an M.Sc. thesis, and have been issued as BIO Report 65-9. Particle size distribution, organic matter content, calcium carbonate content, and gravel lithology were examined in 69 snapper samples of bottom sediment. These parameters were investigated relative to a hypothetical model of Baffin Bay as a dynamic sedimentary basin, with sediment transport mainly by ice-rafting, and ice-movement controlled by surface currents. The regional distribution of gravel, sand, silt, and clay is in accord with the sedimentary model, and sorting characteristics of these materials indicate significant water movement to a depth of approximately 400 m. Sediment color and organic matter content show regional relationship to water depth, but exhibit anomalous variation in the zone traversed by the West Greenland Current. Carbonate content of the sediment and gravel lithology reflect sediment transport by the Baffin Current from Palaeozoic terrains to the north and west.

A. C. Grant

Southern Baffin Bay and Labrador Sea

A series of 71 bottom samples were collected aboard CCGS *Labrador* and are being analyzed in the sedimentological laboratory. The data from these analyses will be prepared for the BIO Date Series reports in order to make this material available to interested workers.

T. A. Holler
S. S. M. Pitcher

Hudson Bay-1

Marine geological work was undertaken in Hudson Bay in 1961 and 1965. The writer took part in both cruises, and his former colleague R. J. Leslie took part in the cruise of 1961. The studies included investigation of raised beaches, bathymetry, water chemistry, investigations of planktonic and benthonic organisms, current measurements, bottom photography, bottom fauna, and bottom sampling by means of snapper samplers, dredges, and cores. Geophysical research to support the project was also carried out with the aid of both bottom and surface gravimeters, air and seaborne magnetometers, deep crustal and shallow seismic surveys, and sub-bottom profiling in unconsolidated sediments as well as bedrock structures. The MV *Theta* (1961), MV *Theron* (1965), CSS *Hudson* (1965), launches, a Hiller helicopter, and a North Star four-engined aircraft were used to support the overall project. An indication of the scope of the 1965 operation is given by the track chart of CSS *Hudson* alone, Fig. 6, and the location of the more than 900 stations occupied, Fig. 7.

Bathymetric contours ranging from 0 to 200 m are approximately concentric with the periphery of Hudson Bay. Long submarine ridges and valleys tend to disrupt the uniform saucer-shaped appearance of the floor of the Bay which is further dissected by a submerged Tertiary drainage system. Sediments are generally coarser in the shoals and peripheral areas, where ice-rafted materials tend to mask the normal marine distribution (see Contribution No. 26). A highly oxidized upper layer conforms to areas occupied by highly oxygenated waters which also occur over the shoals and peripheral areas of the Bay. A faunal zonation also occurs and is reported by Leslie (BIO Report 65-6). Bedrock studies supported by geochemical investigations, photographs, and bathy-

metric records indicate the major portion of Hudson Bay to be underlain by Palaeozoic carbonates. The eastern portion from the Ottawa-Belcher Islands to the mainland, and the western portion between Churchill and Chesterfield Inlet are underlain by Precambrian quartzite volcanics, siltstones and carbonates (BIO Report 65-12).

B. R. Pelletier

Hudson Bay-2

Approximately 1,125 miles of sub-bottom reflection profiling was completed as one phase of the Hudson Bay Oceanographic Project (July 16 -September 25, 1965). This program was designed to examine the thickness and lithology of unconsolidated bottom sediment, the configuration of the sub-bottom bedrock surface, and bedrock lithology and structure.

Along the tracks surveyed, this profiling method was successful in determining Precambrian-Palaeozoic contacts, and in defining the attitude of Palaeozoic strata. The maximum accumulation of bottom sediment recorded was about 100 ft.

The interpretation of these recordings is continuing in conjunction with examination of the echo-sounding records of CSS *Hudson* and the MV *Theron*. The sediment samples collected from these vessels, and the sounding records of MV *Polarhav* and MV *Brandal* supplied by courtesy of the Richfield Oil Company, Calgary, Alberta.

A. C. Grant

Riviere Bonaventure-Chaleur Bay, Quebec

Forty recent bottom samples from the fluvial, estuarine-channel, estuarine, and marine environments in the lower portion of Riviere Bonaventure, Chaleur Bay area, Quebec, were collected for physical, chemical, mineralogic, petrologic, and X-ray analyses (BIO Report 65-10).

Temperature and salinity stratification are dominantly controlled by water depth. Chemical analyses and Ca/Mg, Na/K, and CaCO₃/non-carbonate ratios serve to define clearly the fluvial, estuarine, and marine waters. Generally, Eh of the sediment is less than that of the water at

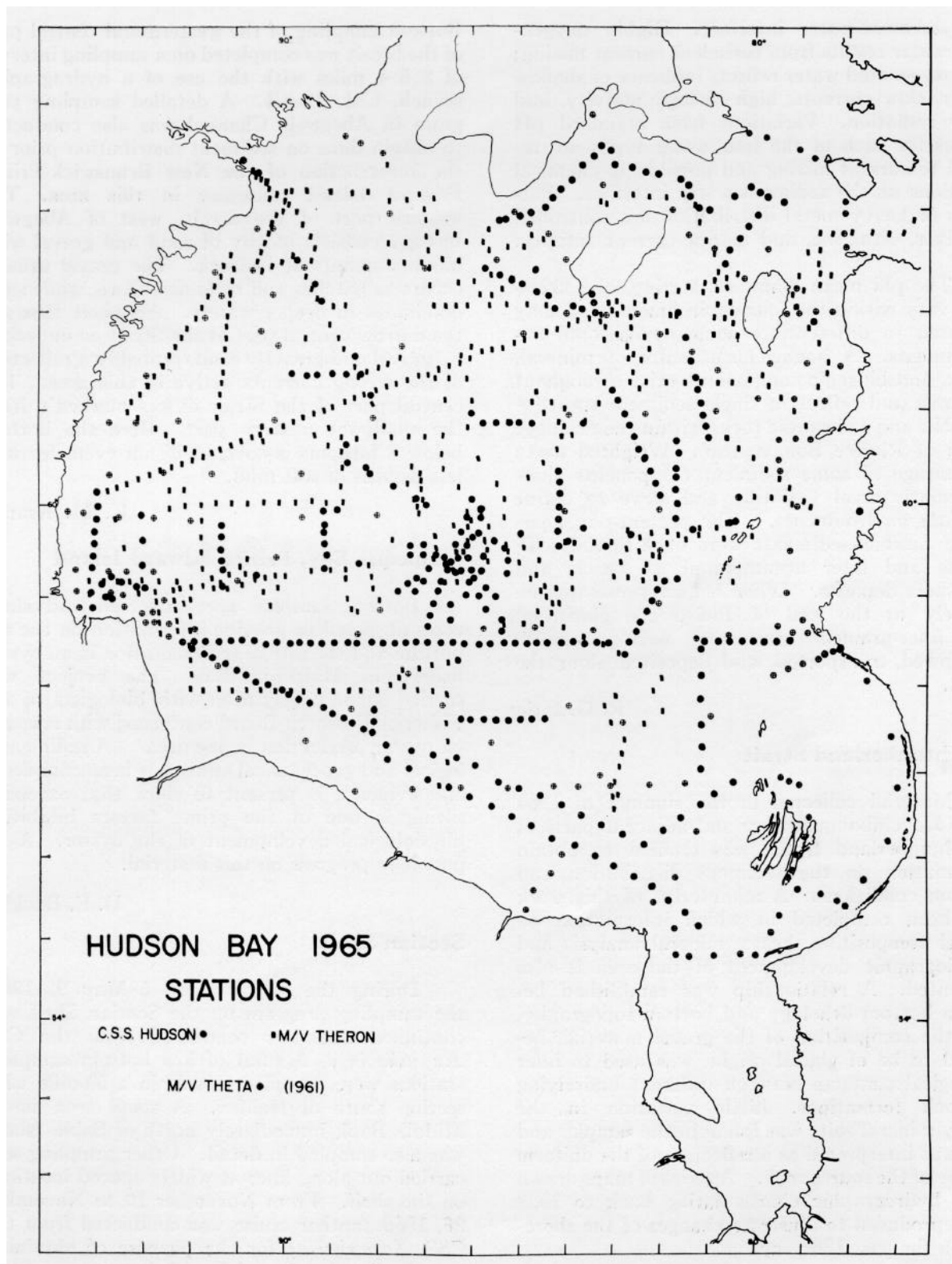


Fig. 7. Geological and geophysical sampling stations occupied in 1961 and 1965 surveys.

the sediment-water interface. Highly oxygenated water results from turbulent current mixing; less oxygenated water reflects influence of shallow water, slow currents, high biologic activity, and solar radiation. Variations from standard pH values for each of the four water types are related to current mixing and possibly to chemical reactions at the sediment-water interface. Patterns of heavy metal distribution are controlled by river, estuarine, and marine-current activity.

The phi mean diameter, sorting, and skewness vary within the four environments and may be used to differentiate some depositional environments. A homogeneous suite of mineral, lithic, and biogenic components exist throughout the area and reflects a single sediment source -- the soils and Palaeozoic rocks within the drainage basin of Rivière Bonaventure. Weighted mean percentage of some sediment components show systematic areal variation and serve to define the four environments. The present-day near-shore marine sediments were once fluvial sediments and later accumulated as beach and nearshore deposits. When sea level rose approximately at the end of Pleistocene glaciation the finer-grained sediments were drowned, winnowed, transported, and deposited along the coast.

R. G. Pirie

Northumberland Strait

Material collected in the summer of 1964 from Kouchibouguac Bay and adjacent parts of Northumberland Strait was studied to obtain information on the sediment distribution and bottom conditions. A manuscript of this work has been completed in which information on gravel composition, heavy mineral analysis and physiographic development of the area is also presented. A relationship was established between bottom lithology and bottom topography, and the composition of the gravel material, believed to be of glacial origin, was used to infer geological contacts between different underlying bedrock formations. Little variation in the heavy mineral suite was found in the samples and this was interpreted as a reflection of the uniform nature of the source rock. A series of maps drawn after hydrographic charts dating back to 1839 are reproduced to illustrate changes of the shoreline in the past 126 years.

Sedimentological work in Northumberland Strait was continued in the summer of 1965.

Bottom sampling of the western and central part of the Strait was completed on a sampling interval of 2.5-4 miles with the use of a hydrographic launch, CSL *Tudlik*. A detailed sampling program in Abegweit Channel was also conducted to obtain data on sediment distribution prior to the construction of the New Brunswick-Prince Edward Island causeway in this area. The western part of the Strait, west of Abegweit Passage consists mostly of sand and gravel with minor amounts of bedrock. The gravel usually occurs as patches and reefs nearshore, while sand dominates in deeper waters. Abegweit Passage, the narrow central part of the Strait, is underlain by gravel and gravelly sand, probably a reflection of the strong currents active in this area. The central part of the Strait differs markedly from the shallower western part. Here the bottom below 8 fathoms is covered by an even, featureless deposit of soft mud.

K. M. Kranck

Malpeque Bay, Prince Edward Island

Bottom samples were collected and short cores obtained to provide information on the sea bottom and the rate of sedimentation in an oyster fishery in Malpeque Bay. The project was carried out in cooperation with biologists of the Fisheries Research Board concerned with research on oyster production in the area. A sedimentological and geochemical study has been completed and evidence is present to show that excessive silting is one of the prime factors inhibiting physiological development of the oyster. A report is in progress on this material.

D. E. Buckley

Scotian Shelf

During the period April 5 -- May 9, 1965, the sampling program on the Scotian Shelf was continued and was conducted from the CSS *Kapuskasing*. A total of 579 bottom sampling stations were occupied mostly in a 50-mile wide section south of Halifax. A small area across Middle Bank immediately north of Sable Island was also sampled in detail. Other sampling was carried out along lines at widely spaced locations on the shelf. From November 10 to November 26, 1965 another cruise was conducted from the CSS *Kapuskasing* for the purpose of obtaining "sparker" records with sub-bottom profilers across some of the more interesting topographical features on the shelf.

A total of five sedimentary facies have been recognized and mapped on the basis of textural analyses on bottom samples, and in terms of an echogram classification utilizing echograms obtained during the hydrographic survey on the shelf, as well as those obtained on the ecological cruises. The classification is based on the shape of the surface of the bottom, and on the relative degree of compaction of the sediment. Together, these techniques constitute an effective approach to the problem of obtaining a detailed picture of the surficial bottom geology. Presumably, the area was covered with glacial drift during the Pleistocene and subsequently, during a low stand of sea level indicated by a submarine terrace at 110-120 m, the glacial debris was re-worked around the topographic highs and much of the finer sediment was transported and deposited in the adjacent basins.

Seventeen representative samples from the five sedimentary facies have been chemically analyzed for their major elements. These data support the conclusion regarding provenance of the marine facies as reached by the sedimentological study. The relation of the major elements to the mineralogy of the samples has been studied by Dr Charles Phipps, a visiting professor from the University of Sydney, Australia. This study reveals an immature suite of minerals.

The organic components in the sediments are also being studied in order to relate the chemical nature of the organic matter to the depositional environment. Although the facilities and techniques for measuring the properties of the organic matter are all satisfactory, the problem of isolating the organic matter has still not been satisfactorily solved and is thus inhibiting progress. The present techniques provide yields of only approximately 50% and it is considered unwise to proceed further with the structural analysis until a higher percentage of the organic matter can be at least accounted for if not isolated. Work is in progress on this matter.

During the oblique echo-sounder trials which are discussed in some detail under Engineering Services (p. 49), a 1-day traverse was run across Emerald Bank to evaluate the feasibility of using this instrument on the Scotian Shelf for geological work. The trial indicated that the instrument is capable of differentiating sand and gravel bottoms.

During the November cruise "sparker" records were obtained along approximately 300

miles of track. These records show that the major topographical features are erosional rather than depositional; the present topography is to a large degree controlled by an ancient erosional surface probably developed during maximum glaciation. This surface forms a major Pleistocene unconformity with respect to the subsequent sedimentary deposits. A second unconformity also exists at the base of the late or post-glacial sediments.

L. H. King

Continental Slope off Nova Scotia

Work on this continuing project was extended from "The Gully" to Cabot Strait Trough. The present line of investigation is concentrated on the bedrock underlying the unconsolidated sediment of this structural province, and includes sampling of the sea floor by dredge and corer, geomorphic studies, and continuous records with a sub-bottom profiler. The combined data indicate that gently-dipping, resistant layered rocks occur along the continental slope. Information obtained on two short cruises on CSS *Kapuskasing*, during March and November of this year, is being evaluated.

J. I. Marlowe

Bay of Fundy survey, western portion

Systematic bottom sampling was undertaken by BIO hydrographers and samples were submitted to the sedimentological laboratory. Analysis was carried out on this material by R. Cormier, and chemical analyses for CaCO₃ and organic carbonate content were undertaken by G. Duncan. A compilation of these results embodying illustrations of the bathymetry, textural parameters, and chemical data are included in a report under preparation.

R. Cormier
G. Duncan

Micropalaeontology

Arctic Ocean

This is a continuing project since 1960 and involves a study of the marine fauna from the Arctic Continental Shelf on the western coast of the Canadian Arctic Islands. Much of the early work is summarized in BIO Report 64-1 and

Geological Survey of Canada Paper 61-27. Of the 133 species recognized, 86 are foraminifera, 25 are molluscs, 11 are ostracods, and 11 others. Although there appears to be no significant variation in species as related to the substrate, there appears to be a zonation according to bathymetry. The zonation is a broad feature and the faunal change is noted only in areas where the bathymetry has varied by an amount of several hundred metres. It is hoped to gain some information on relative uplift of the Arctic Islands when an analysis of this fauna is complete.

F. J. E. Wagner

Arctic Archipelago

A continuous project on foraminiferal studies in the inshore waters of Queen Elizabeth Islands commenced in 1962. During the first season samples of bottom sediments were taken along the western shores of Ellef Ringnes Island (Marlow & Vilks, Geological Survey of Canada Paper 63-22). Subsequent samplings were carried out in East Bay, MacKenzie King Island in 1963 and Satellite Bay, Prince Patrick Island in 1964 (BIO Report 64-4, and Contribution No. 16). In conjunction with the inshore studies, Foraminiferal content of the sediments from Prince Gustaf Adolf Sea was also investigated (p. 31). Further sampling of bottom sediments will be carried out to the west of the areas investigated.

The long range objective of these investigations is to assist in the reconstruction of post-Pleistocene history of the marine areas in these islands. Studies to date indicate that the fauna present at localities shallower than 200 m differ from those found at deeper stations in Prince Gustaf Adolf Sea. The differences in these faunas are used in studies of cores taken from the inter-island seas to interpret past fluctuations of sea level.

G. Vilks

Hudson Bay-1

Seventy-three bottom grab samples and six cores have been analyzed for their foraminiferal and sedimentary characteristics in order to describe the foraminifera of Hudson Bay, the faunal distribution, and the environmental factors influencing the distribution. Shallow coastal regions and offshore shoals have an abundant and diverse fauna characterized by hyaline forms.

Sediments of these shallow regions have a median diameter in the range from fine sand to silt. Basinal areas are characterized by sediment with a relatively high organic carbon content and a median diameter of clay size. These regions maintain a sparse fauna composed mainly of arenaceous forms. Calcium carbonate percentages in the sediment are greatest in regions with abundant foraminiferal populations, probably due to the presence of calcareous foraminifera. There is a positive correlation between the oxygen content of the bottom water and the abundance and diversity of foraminiferal assemblage. Salinity and temperature of the bottom water are fairly constant throughout the bay and thus show little relationship with faunal trends.

During and immediately after the final stages of glaciation, large amounts of detrital debris were carried into Hudson Bay by rivers and ice. Removal of accessible glacial debris, and decreased runoff into the bay resulted in lower rates of sedimentation and deposition of finer-grained, more consistent sediments. Salinity of the bay waters increased because of decreased dilution by fresh water runoff, and environmental conditions approached those of the present.

The first foraminifera to enter the bay were members of the hardy Cosmopolitan Bay Fauna represented mainly by *Elphidium incertum* and *Cassidulina islandica*. Amelioration of the environment is reflected in the cores by the first appearance of an abundant and diverse benthic foraminiferal population composed mainly of members of the Deep Bay Fauna. Planktonic forms are sensitive environmental indicators, and their presence is a second indication of the conversion to more normal marine conditions. As post-glacial isostatic adjustment caused Hudson Bay to become shallower, the Deep Bay Fauna was gradually replaced by the Intermediate Bay Fauna, and in shoal areas the latter was replaced by the Shallow Bay Fauna.

R. J. Leslie

Hudson Bay-2

Both fossil and recent specimens are included in this study. Recent specimens were obtained primarily from grab samples, but some were collected by dredging. Preliminary identifications give a list of 103 species including 54 foraminifera, 28 pelecypods, 10 gastropods, 2 barnacles, 1 brachiopod, and 8 others. Sedimentological

studies and sea chemistry are being undertaken at BIO and the data from these investigations will be added to the biological data and other oceanographic data in order to present a total environmental framework for these organisms. A zonation is readily apparent on the basis of bathymetry and it may be possible to relate aerial distribution to various oceanographic and physiographic factors. Shells collected from raised marine deposits in the Churchill area, Manitoba, and from Coats, Gilmour, Mansel and Southampton Islands, N. W. T., will be used for carbon-14 dating to give some indication of the rate of uplift at these points around Hudson Bay.

F. J. E. Wagner

St. Lawrence River and Gulf, and adjacent shelf

This is a combined land and sea project designed to investigate the post-Wisconsin microfaunas and sediments of Eastern Canada. Samples of unconsolidated sediments were collected in the provinces of Quebec, New Brunswick, and Newfoundland, and from the St. Lawrence River and Gulf area as well as the adjacent Continental Shelf. An attempt is being made to correlate the marine beds of all areas, to compare the faunas, and to determine the relationship between these faunas and their associated sediments. The study is proceeding along ecological, stratigraphic, mineralogical, biochemical and taxonomic lines. The laboratory work is being carried out at Carleton University.

Recent foraminiferal faunas of the Gulf of St. Lawrence are composed of arenaceous and calcareous forms. Depth zones based on characteristic faunas can be recognized. Preliminary results for Pleistocene foraminiferal faunas suggest that calcareous species are similar to Recent and living ones, but arenaceous forms are almost entirely absent.

Calibration curves and precision and accuracy estimates were determined in preliminary X-ray diffraction work on the magnesium content of foraminiferal tests. Approximately 60 diffraction patterns for 35 specimens from bottom sediments of the Gulf of St. Lawrence and the Atlantic Shelf are now on file. An X-ray diffraction study has been conducted of the magnesium content of several species of foraminifera chiefly from Cabot Strait and Grand Banks area.

K. Hooper

Foraminiferal studies of Bras d'Or lakes

Samples of bottom sediments were taken from 322 locations. The sampling program was designed to achieve three objectives: (1) to investigate the distribution of Foraminifera in bottom sediments within a small area (spatial analysis); (2) to investigate changes in foraminiferal numbers in bottom sediments over a period of three months (temporal analysis); (3) to investigate the applicability of association analysis to studies of foraminiferal populations.

For the temporal and spatial analyses, foraminiferal counts from the sub-samples will be compared between samples, between stations, between areas and between visits. The comparisons will be made by performing analysis of variance, utilizing the IBM 1620 computer at Dalhousie University. The program for these calculations has been written by Dr E. H. Anthony, Institute of Oceanography, Dalhousie University. For the association analyses a record will be made of foraminiferal species present in each sample. The information will be sent to the CSIRO Computing Research Section, Canberra City, Australia. Initial statistics suggest that the population is overdispersed (highly clumped), i.e. variance exceeds mean. This is shown in the field sampling program in which wide areas on the bottom contain few fauna but certain areas contain a high population. As expected, analysis of variance shows smallest discrepancies between sub-samples within a given Ekman dredge sample and larger discrepancies between different samples at a given station.

G. Vilks

Shallow waters adjoining the Atlantic provinces and New England states

A preliminary field and laboratory study of benthonic Foraminifera in coastal and nearshore environments of the Atlantic provinces and New England states to determine the distribution, abundance and ecology of Foraminifera in these areas was completed in 1965.

Studies in the Miramichi River and other estuaries influenced by the Gulf of St. Lawrence indicate that most estuarine environments are characterized by two foraminiferal faunas; a *Miliammina* fauna which inhabits waters with salinities less than 20‰ and an *Elphidium* fauna which inhabits waters with salinities between 20‰ and 29‰. The *Miliammina* fauna, com-

posed almost entirely of arenaceous species, represents the inner estuarine environment, while a progressive increase in the *Elphidium* or calcareous fauna represents the influence of more saline waters in the open Gulf.

Investigations in Tracadie Bay and associated bays of Prince Edward Island indicate the presence of a restricted fauna, with fewer genera, species and smaller populations than faunas in bays having open circulation with the Atlantic Ocean. There is no previous record of the recent occurrence of *Ammonia beccarii* in western Atlantic waters this far north. Its absence along the Atlantic coast and Bay of Fundy suggests that it may be relict to the Gulf of St. Lawrence system (BIO Report 65-3).

Four foraminiferal biofacies are present (inter-tidal, backbay, nearshore and open ocean) in most Nova Scotian bays. Generally the faunas are more prolific and diverse than those associated with the Gulf of St. Lawrence. Backbay, nearshore, and open-bay faunas are transitional. Foraminifera are microenvironmentally distributed within each biofacies. Therefore, geographic position and spacing of sample stations are apparently as important as environmental factors in the interpretation of foraminiferal distributions.

Most Recent marine samples from the Atlantic provinces contain diverse assemblages of *Elphidium*, (BIO Report 65-13). This genus, represented by seven species in the Atlantic area, is commonly the most abundant form at all stations.

Warm-water faunas suggest that lagoons and shallow water seas have been predominant in the area since 12,000 B.P. (Before Present) and that the warm-water fauna migrated northward and established in these shallow lagoons approximately 12,000 years ago.

G. A. Bartlett

Atlantic continental shelf and slope

Grab samples and cores of bottom sediments were taken with a view to correlating sedimentary and faunal parameters with variations in submarine topography. Staining of the faunal content was done at sea, and a certain amount of sea chemistry was also carried out. In an attempt to assess the total environment, X-ray and

spectrochemical analyses and some wet chemical analyses are being undertaken in the laboratories of BIO and Queen's University. This work will serve as research material for the writer's Ph.D. dissertation.

C. J. Yorath

Hydrography

R. C. Melanson

A. L. Adams	R. C. Lewis
R. C. Amero	W. R. MacKay
D. J. Brooks ¹	J. G. Martin ²
R. M. Cameron	L. I. Murdock
T. J. Carew	C. J. Pellerin
E. J. Comeau	J. M. R. Pilote
P. L. Corkum	J. W. F. Pritchard
F. L. DeGrasse	W. J. Probert
S. S. Dunbrack	L. D. Quick
R. M. Eaton ¹	J. G. Shreenan
V. J. Gaudet	T. B. Smith
M. A. Hemphill	M. G. Swim
A. D. Kenney	R. G. Wallis
G. H. King	K. T. White
C. J. Langford	R. K. Williams
R. B. Lawrence	G. M. Yeaton
D. D. LeLievre ¹	

T. M. Calderwood,
J. A. Gasparac¹
N. E. Fenerty¹

} Illustrations, Draughting
Photography Group

General

The Hydrographic Service in BIO is responsible for chart, tide and current surveys within the East Coast Region, defined as Canada's Atlantic seaboard, Gulf of St. Lawrence east of Pointe des Monts, Hudson Bay and the Eastern Arctic. Charting was undertaken by four DM&TS vessels, while a major current survey was conducted by a chartered vessel. Three shore-based parties were also established to carry out surveys of inshore areas. One major project, "Tail of the Banks", originally assigned to the *Baffin*, was cancelled due to major malfunctions in the gear boxes of the ship's main propulsion system. One ship, CSS *Maxwell*, was available only for a 3-month period due to a 3-month training commitment in the Great Lakes. Six small surveys in areas easily accessible from BIO were performed by hydrographers on rotation. The Tides and Currents group installed 16 new tide gauges, made annual inspec-

¹ Joined BIO in 1965.

² Joined BIO in 1965.

tion of 15 permanent gauges and conducted a major current study in the Bay of Fundy. With the exception of the "Tail of the Banks" project, the main objectives for 1965 were met and Table 2 gives a summary of work accomplished (p. 46).

The unit responsible for hydrographic technical records is now properly organized, the photographic services are progressing well, and the illustrations-draughting service, with a staff of two people, is better able to cope with the workload.

BIO again exhibited a display at Lunenburg, N. S. during the Annual Fisheries Exhibition. It was a combined effort of hydrography and oceanography, and as in the previous year, a special mention was given by the judges.

At the commencement of 1965, there were 31 on staff. During the year, three hydrographers and one draughtsman transferred from Ottawa, one instrument technician for the Inshore Tides

and Currents group was obtained, one photographer was engaged, one man resigned, and three survey technicians were engaged and transferred to Ottawa for training. The result was a staff total of 36 at year end. Eleven summer students, plus one Colombo Plan student, were employed during the survey season

Hydrographic Surveys

Mr L. P. Murdock, as Hydrographer-in-Charge of the CSS *Acadia* conducted standard charting surveys in the following areas from May 20 to October 31 (Fig. 8) :

- (a) Long Point to Beaver Point, Prince Edward Island,
- (b) Naufrage Harbour, Prince Edward Island,
- (c) Main Tickle--Notre Dame Bay, Newfoundland,
- (d) Sir Charles Hamilton Sound and Change Run, Newfoundland.

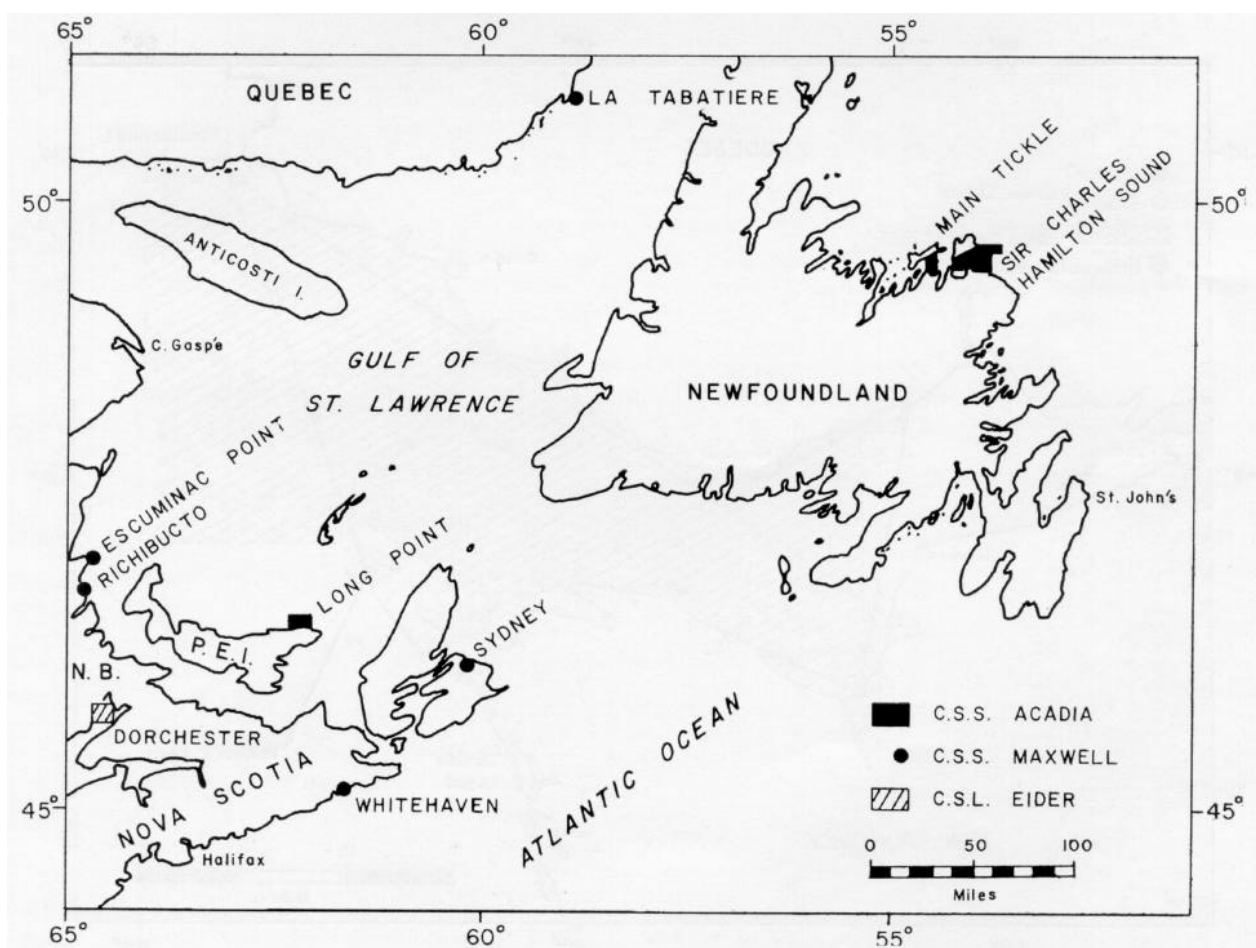


Fig. 8. Areas in which shoal examinations and conventional navigational charting surveys were conducted by CSS *Acadia*, CSS *Maxwell* and CSL *Eider*.

The main Prince Edward Island project was to complete the inshore surveys along the north coast of the Island from Long Point to Beaver Point. The Naufrage Harbour project was to produce an up-to-date survey of the small boat harbour since it is the only available shelter in the immediate area. Decca fixed-error calibrations of Chain 6 were also made for the area surveyed. Both of these projects have been completed. The Main Tickle project arose from a request by the Province of Newfoundland for data needed in a feasibility study of placing a causeway between New World Island and Twillingate Island. The survey was completed and the results submitted to the Newfoundland Department of Highways. The survey of Sir Charles Hamilton Sound is a continuing project to provide up-to-date charts of this sheltered passage and is presently about 50% completed.

Mr D. D. LeLievre, as Hydrographer-in-Charge of the CSS *Kapuskasing*, continued chart-

ing Chaleur Bay and approaches from May 18 to October 29 (Fig. 9). This is a continuing project, commenced in 1964 and is presently about 85% completed. The purpose is to provide detailed charts to satisfy the needs of the increasing number of ships operating in the area because of the industrial development underway along both the north and south coasts of this Bay. Hi-Fix in hyperbolic mode was used for the major portion of positioning, thus allowing the ship and four sounding launches to utilize the chain simultaneously. This is the first time that the Hydrographic Service has undertaken a major survey of this kind. It was found that positioning accuracy was excellent throughout the area of survey and a great deal of charting was accomplished by adopting such a positioning mode. A chartered Hiller helicopter proved valuable in establishing horizontal control, installing Hi-Fix Chains, and assisting in the calibrations. This season's work will allow Chart 4486, Chaleur Bay, to be published in the not too distant future.

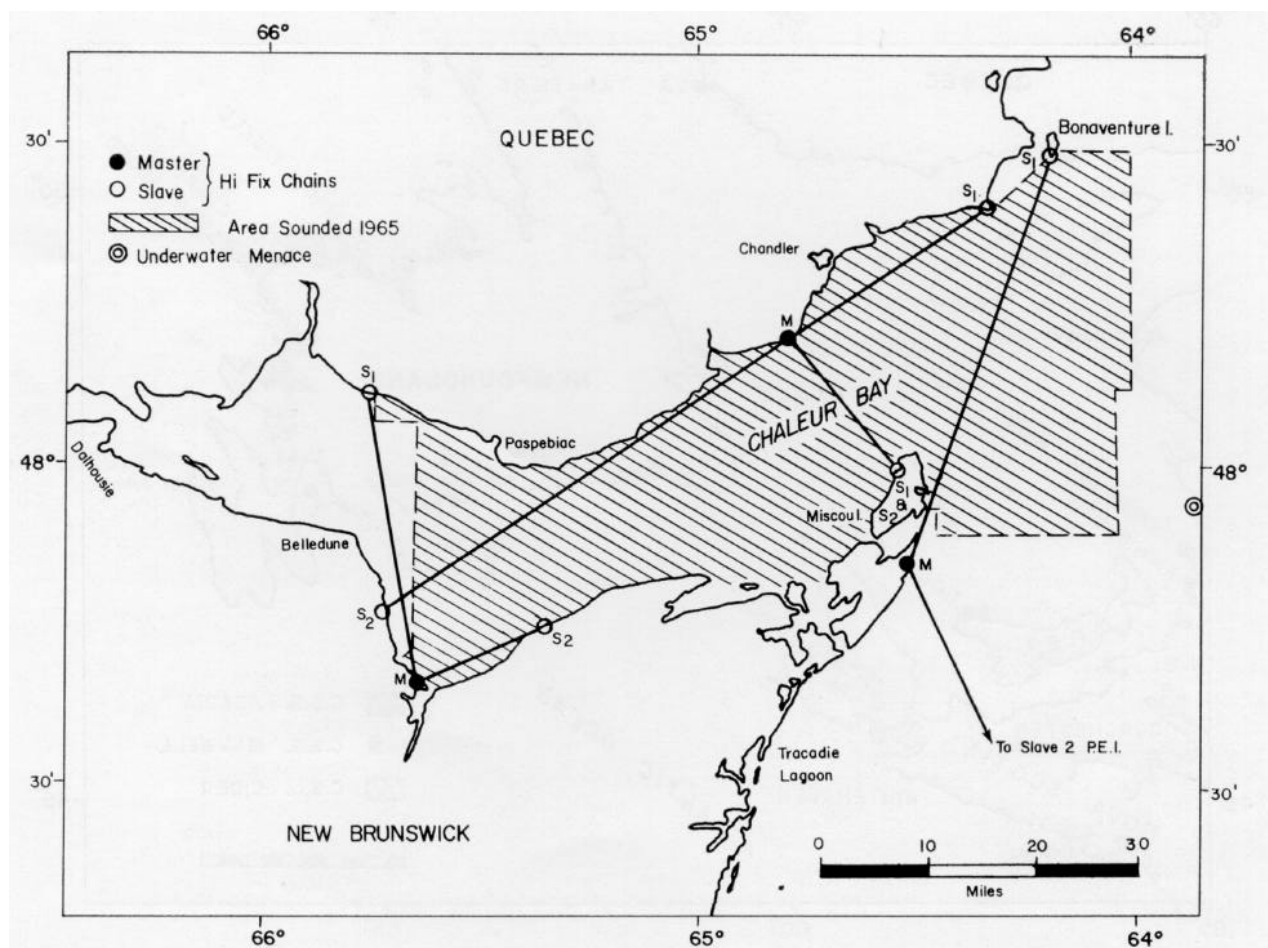


Fig. 9. Bay of Chaleur charting survey conducted by CSS *Kapuskasing* indicating coverage in 1965.

Mr R. C. Amero, as Hydrographer-in-Charge of the CSS *Maxwell*, conducted the following surveys from May 3 to July 14 (Fig. 8):

- (a) Whitehaven Harbour, Nova Scotia (shoal examination),
- (b) Sydney Harbour, Nova Scotia (International Piers),
- (c) Escuminac Point, New Brunswick (shoal examination),
- (d) Richibucto, New Brunswick (shoal examination),
- (e) La Tabatière, Quebec.

A shoal examination was carried out in Whitehaven Harbour to verify the existence of a shoal dangerous to shipping: a least depth of 5 ft at chart datum was discovered. This project was based on a request from our Chart Production unit, where a new publication of a chart of the area was being held until the shoal's existence could be clarified. Another shoal examination was conducted off Escuminac Point. This arose through a request from the US Naval Oceanographic Office. A report of this menace to navigation was made by the Master of the steamer *Trinacria* in May, 1888. An area of 2 sq miles was given a good sounding coverage, but no indication of the shoal was found. Shoal examinations were also conducted along the channel ranges leading into Richibucto Harbour. The areas in question were covered by sweeping. The existence of one shoal was confirmed while the second suspected shallow spot was disproved. A stretchline survey was conducted of the International Piers at Sydney, N. S. The purpose of this survey was to make a plan of the major wharf completed in 1964. A standard charting survey was conducted of La Tabatière Harbour and approaches. This survey was warranted because oil tankers occasionally call at this port.

Mr F. L. DeGrasse, as Hydrographer-in-Charge of the CSS *Baffin*, was assigned to charting the Tail of the Banks. However, due to a major malfunction in the ship's propulsion system, which would not allow the survey to go forward, Mr DeGrasse was placed in charge of a shore party conducting surveys along the coast of Nova Scotia and New Brunswick. Work was undertaken on the following projects from May 14 to October 30 (Fig.: 10) :

- (a) Halifax Harbour to Jeddore Rock, Nova Scotia,
- (b) Sheet Harbour approaches-Spry Bay, Nova Scotia,

- (c) Tusket Islands, Nova Scotia,
- (d) Cape Dorchester, New Brunswick.

Assistance was provided to surveys in Halifax Harbour undertaken by the regional office (p. 42). Horizontal and vertical control was established between Halifax Harbour and Jeddore Rock to facilitate the drawing of an accurate photogrammetric plot for future charting. Photo interpretation was also completed for previously established control in the Jeddore Rock to Nichol Island area. Horizontal and vertical control was established for producing an accurate photogrammetric plot of the shoal-infested area between Sheet Harbour and Liscomb. Shoal examinations were conducted and additional information gathered to complete outstanding field sheets in the Sheet Harbour area. Horizontal and vertical control was established in the difficult area of Tusket Islands to facilitate drawing an accurate photogrammetric plot for the proposed 1966 survey. Horizontal and vertical control was established in the Cape Dorchester area to facilitate a high priority charting survey that had to be completed in 1965 (CSL *Eider* survey). All of these projects were supported during all or part of the time by a Bell helicopter. Future surveys will be expedited considerably as a result of the control work done this season.

Mr R. C. Amero, in charge of the CSL *Eider* shore party from July 19 to October 29, conducted surveys of the following areas (Fig. 8):

- (a) Shepody Bay, New Brunswick.
- (b) Cape Dorchester, New Brunswick.

A survey of these areas was made in accordance with a request by the New Brunswick Development Board, as deep draft ships will soon commence calling at the Westmoreland Chemical Park now under development at Cape Dorchester. During the course of the survey, two uncharted shoals were discovered in the ship channel and reported for inclusion in the Notice to Mariners. This was a very difficult area to survey due to the large tidal range and extensive mud flats; however, the project was completed and the new information will be incorporated into a new chart edition.

Mr M. A. Hemphill, as Senior Hydrographer onboard CSS *Hudson* from July 16 to September 26, was charged with the following responsibilities:

- (a) Hudson Bay-bathymetry as compatible with the main marine geological/geophysical project,

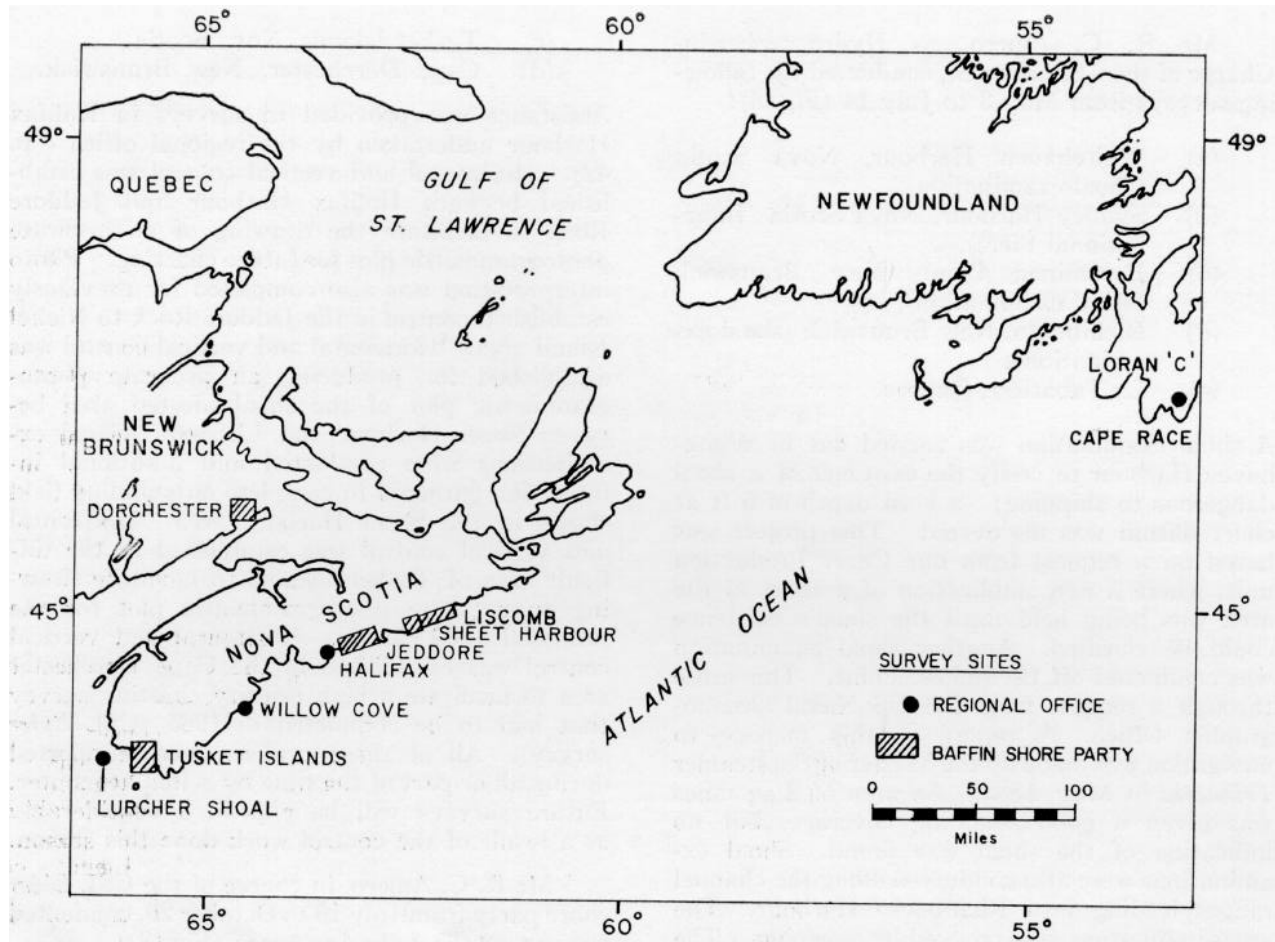


Fig. 10. Area in which conventional and special navigational charting surveys were undertaken by the Regional Office and *Baffin* shore party.

- (b) Hudson Bay-shoal examinations,
- (c) Churchill Harbour and approaches
Manitoba-general charting.

Throughout the cruise, all vessels participating in the program, *CSS Hudson* and *MV Theta* on charter to DM&TS, and the motor vessels *Polarhav* and *Brandal* on charter to Richfield Oil Ltd., kept a continuous record of bathymetry along their tracks. The vessels for the most part were positioned by Decca Lambda in hyperbolic mode. All echograms and track plotting sheets have now been collected from the different sources and processing is in hand. Over 20,000 miles of soundings have been obtained and will certainly assist in filling many of the gaps on the present charts (Fig. 6). A shoal situated in the centre of the Bay was located and examined. This peak was found to be slightly west of that position shown on Chart 7000.

Mr A. L. Adams was detailed by Mr. Hemphill to conduct a survey of Churchill Har-

bour and approaches, also to make a reconnaissance survey of that portion of Churchill River affected by tides. A considerable amount of new data was obtained; however, due to equipment malfunctions, the project area could not be completed in its entirety.

Field projects undertaken by the regional office (BIO) by hydrographers on rotation were as follows (Fig. 10) :

- (a) Halifax Harbour, Nova Scotia (revisory survey),
- (b) Willow Cove, Port Mouton, Nova Scotia,
- (c) Lurcher Shoal, Nova Scotia,
- (d) Cape Race, Newfoundland (Loran "C" Station).

Mr J. M. R. Pilote was in charge of carrying out revisory surveys in the vicinity of Halifax Harbour, with the assistance of *Baffin* staff. These surveys were made as the result of a re-

quest by the Halifax Pilotage Authority to verify depths over several shoals in the harbour approaches and along the leading lines entering the harbour. Additionally, assistance was obtained from *Baffin* staff in carrying out surveys of the floating dock and the Imperial Oil Jetty No. 1.

Mr T. B. Smith, assisted by Mr G. Yeaton, conducted a survey of the Loran "C" Station now under construction at Cape Race during an 8-day period in September. A request was made by the US authorities to have the transmitting and receiving antennae accurately positioned to facilitate drawing the chart lattice. Mr Smith, assisted by Mr R. Wallis from October 6 to October 20, also conducted a survey of the newly created harbour of Willow Cove. This resulted from a request, by local fishing interests who intend to have 100-ft-class fishing boats frequent the harbour.

A launch survey was commenced of Lurcher Shoal near Yarmouth, N. S. by Messrs J. R. Shreenan and N. Stuijbergen on September 25. The purpose of this survey was to prepare a de-

tailed plan of the shoal in order that test drilling could be carried out in anticipation of replacing the Lurcher Lightship by a permanent structure on the shoal. Unsatisfactory weather conditions made drilling impossible and sounding of the shoal a rather difficult task without the assistance of an escort vessel to stand by the 31-ft launch. On November 2 the *Maxwell*, with Mr P. L. Corkum in charge, went to Yarmouth to assist. The survey was carried out using Hi-Fix in the hyperbolic mode and was completed by November 12. The 31-ft launch was returned to BIO by *Maxwell* on November 15.

Inshore Tides and Currents Group

Current survey

Mr C. J. Langford, as Tidal Officer in charge of the chartered vessel *MV Theta*, conducted a major tidal current survey of the Bay of Fundy from June 10 to August 30 (Fig. 11). This was a combined effort in that personnel from the

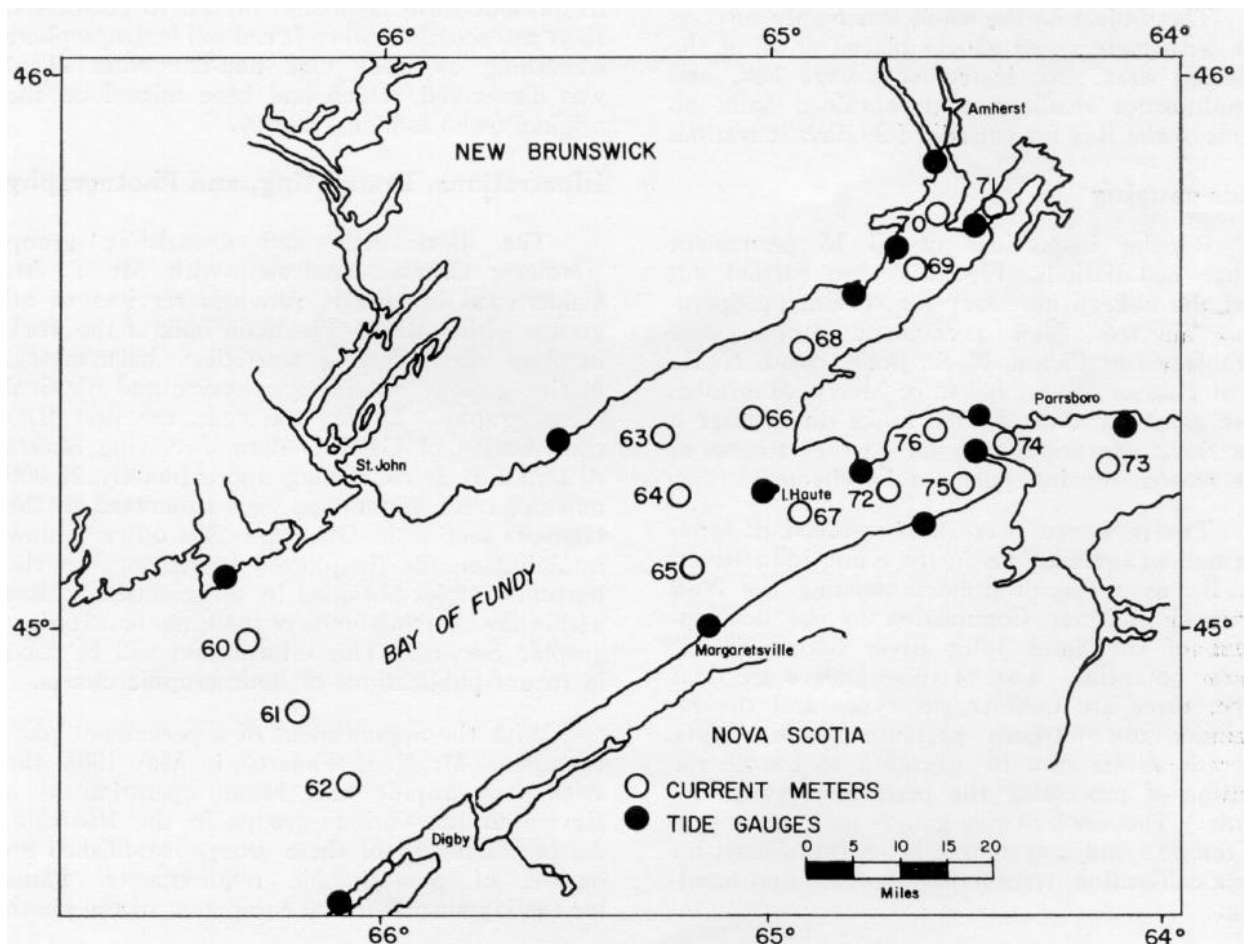


Fig. 11. Bay of Fundy current survey conducted by chartered vessel *MV Theta*, June 10 to August 30, 1965.

Current Survey group of Oceanographic Research installed and maintained most of the tide gauges. The purpose of this survey was to gather comprehensive field data on current and tidal regions for use in analytical studies of the probable effects of the emplacement of man-made barriers on the tidal behaviour of the Bay. These studies are part of a broad investigation, being carried out under the auspices of the Atlantic Development Board, into the electric power potential of the tides in the upper regions of the Bay.

Moored self-recording current meters were used for the long-term observations (15 days plus) and Kelvin Hughes direct reading meters for the short term (48 hr and less). Ottboro pressure tide gauges were used for all observations of the vertical tidal movement. The current meters were moored across three section lines in the main body of the Bay at the same time as others were moored at selected sites in the adjacent bays and rivers. Tide gauges (14) were installed at regular intervals apart around the entire Bay and in adjacent areas.

The project on the whole was highly successful, with meters and gauges placed at all of the selected sites. No instruments were lost, and simultaneous readings were obtained from all parts of the Bay for periods of 29 days' duration.

Tide gauging

Regular inspections of all 15 permanent gauge installations (Fig. 12) were carried out and the upkeep necessary for continuing operation effected. New permanent gauges were established at Pictou, N. S., Boars Head, N. B., Petit Passage, N. S., and Cape Merry, Manitoba. The gauge at Cape Merry broke down after a few days' operation, and due to the lateness of the season, repairs could not be effected.

Twelve gauges were also installed in semi-permanent installations in the Saint John River, N. B., as a special project assisting the New Brunswick Power Commission in the development of the Saint John River hydro electric power potential. Two of these gauges are float type, three are bubbler gas types and the remainder are Ottboro pressure types. Office procedures are now in operation to handle the routine of processing the permanent gauge records. The stock of tide gauges on hand is now in the 50's and a system is being established for their calibration, routine maintenance and handling.

Instrument Evaluation

Echo-sounder calibration

Mr J. M. R. Pilote continued experiments commenced in 1964, with a hydrophone for checking accuracy of echo-sounders. The objective of these experiments was to develop a system, using the hydrophone, which could be substituted for our present method of accuracy checks by lowering a steel bar below the transducers, thus permitting calibration to be carried out through a greater depth range. A Technical Report entitled "The Use of Hydrophone for Echo-Sounder Calibration in Depths Under Three Hundred Feet", recommending that the hydrophone be adopted for this purpose, is now being prepared.

Oblique echo-sounder

Personnel of the Hydrographic section took part in trials of the oblique echo-sounder, described in some detail on p. 49. Experience on the trials showed that while this equipment in its present form is mainly of use to geologists, there are occasions when it can tell hydrographers something as well. One non-dangerous shoal was discovered, which had been missed on the original (echo-sounder) survey.

Illustrations, Draughting, and Photography

The illustrations and draughting group (formerly Graphic analysis), with Mr T. M. Calderwood in charge, provides services to all groups within BIO. The main bulk of the work involves the following activities: bathymetry, marine geology, marine geophysics, and physical oceanography. During the year, the first BIO contribution of GEBCO data, involving Sheets A 1 and B 1, containing approximately 18,000 miles of track soundings, were submitted to the GEBCO section in Ottawa. This office is now retaining on file (in plotted form) data on the bottom samples obtained by all scientific cruises within the charting limits of the Canadian Hydrographic Service. This information will be used in future publications of hydrographic charts.

With the appointment of a permanent photographer, Mr N. E. Fenerty, in May 1965, the BIO photographic unit began operation as a service to the various groups in the Institute. An initial survey of these groups established an outline of photographic requirements. Plans for the layout and initial equipment of the photo

laboratory have been prepared and approved; acquisition and installation of equipment is under way. Throughout this planning stage, limited photographic service has been supplied from the existing inadequate facilities. The coming year will see a new laboratory and additional staff and equipment capable of meeting many more of the various demands placed upon this unit.

Proposed 1966 Hydrographic Field Program

(1) A Caribbean training exercise in the form of a survey of the coast of Antigua will be undertaken by the CSS *Baffin* during the period mid-January to early April. The purpose is to provide field training for new field personnel recruited into the Hydrographic Service during 1965.

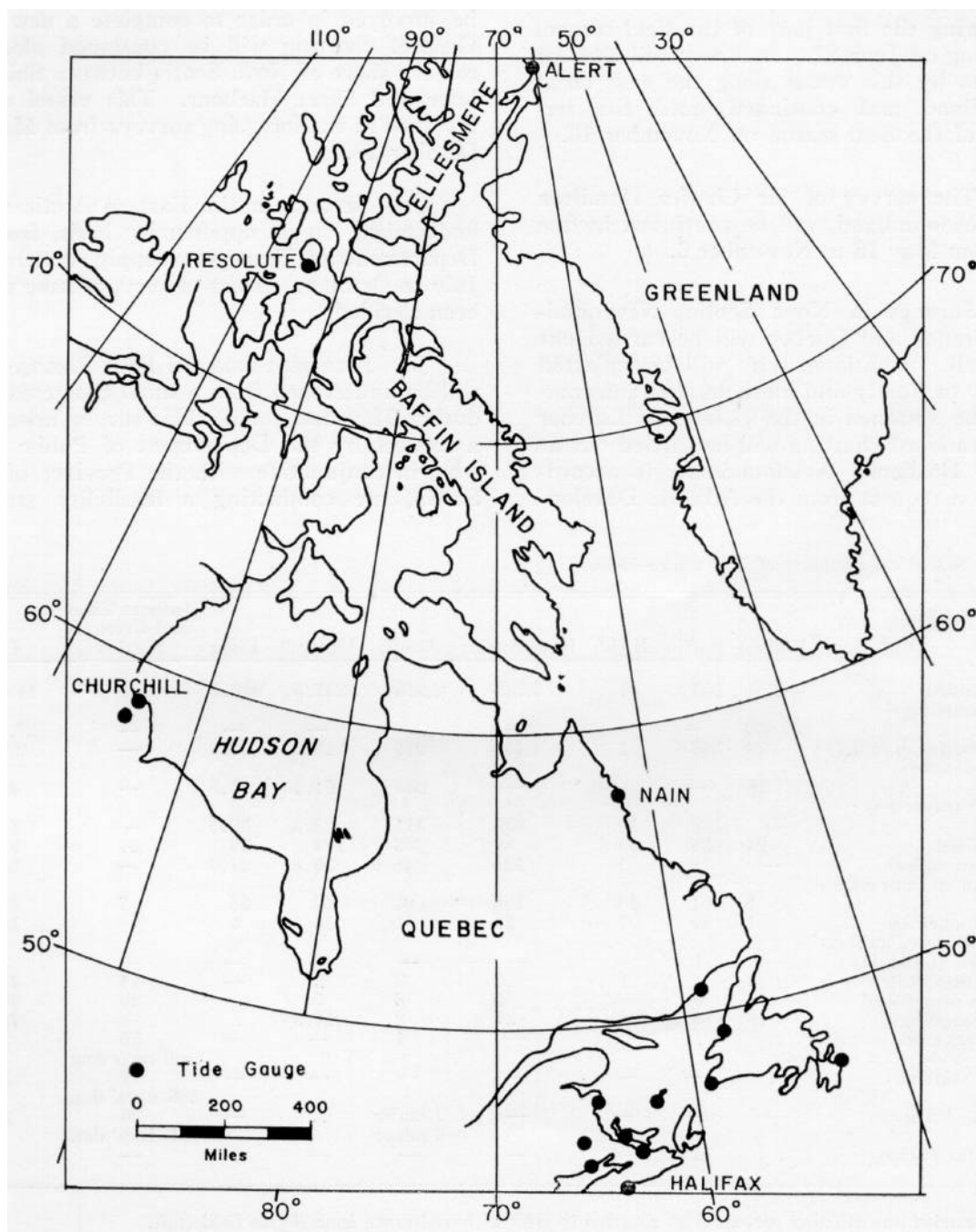


Fig. 12 Tide gauging locations in 1965.

(2) The "Tail of the Banks" survey will be conducted from the *Baffin* from May 16 to November 13, the purpose having three objectives, general charting, fisheries, and explorations. This will be a combined effort in that geophysical data will be collected in conjunction with bathymetry.

(3) The charting at the entrance to Chaleur Bay and Gaspé will be completed by the *Kapus-kasing* during the first part of the field season, commencing on June 27. A survey will then be undertaken by this vessel along the west coast Newfoundland and continued until the termination of the field season on November 13.

(4) The survey of Sir Charles Hamilton Sound, Newfoundland, will be continued by the *Acadia* from May 16 to November 6.

(5) Surveys in Nova Scotia, Newfoundland, Labrador and Quebec will be carried out by *Maxwell*. Additional data will be collected in the Bay of Fundy and more detailed information will be obtained in the vicinity of Lurcher Shoal. Standard charting will be carried out at Trepassey Harbour, Newfoundland, in accordance with a request from the Atlantic Develop-

ment Board. A small survey will then be undertaken in Harbour Grace, Conception Bay, Newfoundland. Upon completion of this work, a post-dredging survey will be made of Goose Bay Narrows, Labrador, for chart correction. A re-survey of the main waterfront in Cornerbrook, Newfoundland, will then be undertaken. The present gap in sounding coverage in the area of Natashquan Harbour and Approaches, P.Q., will be surveyed in order to complete a new chart. General charting will be continued along the eastern shore of Nova Scotia between Ship Harbour and Sheet Harbour. This vessel will be involved in the foregoing surveys from May 2 to October 28.

(6) Surveys in the Eastern Arctic will be undertaken, on an opportunity basis, from two Department of Transport supply vessels, from July to October. Areas of surveys have not yet been decided.

(7) A current study of Petit Passage, N. S. will be undertaken from a small chartered vessel during May and June. This survey arises from a request by the Department of Public Works who, in conjunction with the Province of Nova Scotia, are conducting a feasibility study of

TABLE 2. Statistical summary of field work -- 1965.

	Hudson	Baffin	H.Q. ^a	Kapus-kasing	Acadia	Maxwell	Eider	Inshore Tides and Currents Section	Total
N. miles sounded	257	158	31	7,263	2,926	257.5	903.1	64	11 859.6
Ship track sounding- (n. miles)	27,500	—	—	—	—	—	—	—	27,500
Area surveyed (sq. n. miles)	70	356	1	1,445	239	10.5	55.8	—	2,177.3
Area triangulated -- (sq. n. miles)	28	—	.01	—	280	64.4	55.8	—	428.21
Tellurometer traverse -- (n. miles)	—	242	10	386	111	23.3	39.5	—	811.8
Shoals examined	24	638	15	89	33	124	30	—	953
Coastlining (n. miles)	—	18	1	125	46.5	10.8	44.3	—	245.6
Triangulation stations estab- lished	8	91	16	106	90	64	35	7	417
Stations monumented	4	89	7	43	31	14	4	—	192
Conventional Decca calibra- tion stations (Lambda)	—	1	—	—	—	—	—	—	1
Tide gauges established	5	4	1	5	3	2	—	14	34
Bench marks established	1	9	—	5	6	5	—	40	66
Stretchline soundings	16	5.25	4	27	2	17.9	..	—	72.15
Current meters used	—	1	—	—	20	21
Moored obs. stations	—	—	—	—	—	—	—	self-recording 17	17
Anchored obs. stations	—	—	—	—	1 major 6 minor	..	—	586 days' data 20	27
Stadia traverse stations	..	4	—	—	—	—	—	11 days' data	4

^a Surveys carried out utilizing personnel on rotation in BIO with assistance from *Baffin* field staff.

blocking this passage with a causeway, and current data are required so that a proper assessment can be made of the effects such a blockage will have on the tidal flow.

(8) Annual inspections will be undertaken of all permanent and semi-permanent tide gauges within the region. A concentrated effort will be made to bring the existing installations up to standard. If time and funds permit, two permanent gauges will be established in the Arctic.

Engineering Services

The Engineering Services section has many and diverse activities which fall into two broad divisions: research, design, and development of instruments and equipment systems; and maintenance and operation of a wide variety of equipments. The descriptions of the various projects contained in the following pages emphasize the development of new equipment and instruments, but it is also realized that the routine maintenance and operation of the standard survey and research equipment is vitally essential to all phases of the laboratory's programs. The efforts of those involved in such maintenance work are rewarded by the accounts of successful experiments and cruises elsewhere in the report. Before moving on to the project reports, it seems appropriate to pause for an assessment of the organizational and training implications of the growing use of increasingly complex equipment in oceanographic research and survey, or the impact of technology on oceanography.

The Impact of Technology on Oceanography

The past year has seen a considerable expansion in the number of staff in Engineering Services, as well as in other divisions of BIO. Engineering Services presently overhauls, and frequently operates, mechanical and electronic aids to survey and research activities. Despite the considerable increase in staff, the quality of the work performed by Engineering Services has not greatly improved, in the opinion of those using the aids. The standards of maintenance have not always been perfect; good results have not always been achieved with new and sophisticated equipment: equipment still breaks down at sea and in the field. It is perhaps fitting to examine the existing organization of BIO, which provides only one of a variety of possible methods of meeting the demands of modern technology, to consider whether it can be improved to minimize these shortcomings.

Two years ago the staff comprised 40 research, 26 in survey, supported by 27 in Engineering Services. The total value of electronic instrumentation used was around \$350,000 for research and \$750,000 for survey. Present staff total 75 in research, 36 in survey, and 48 in Engineering Services, and instrument values are about \$1,000,000 each for research and survey. The rapid increase in the use of sophisticated equipment will undoubtedly continue in the coming years, but it must be matched by an equivalent growth in the technological ability of BIO; and this growth is required both for the maintenance of equipment and for its operation. Maintenance staff are barely keeping pace with the increase in equipment, and the level of technical competence required is steadily growing. The increase in technical competence needed for successfully using the equipment is not keeping pace with the equipment. This can be met either by technological training of the scientific and research staff, or by increasing still further the technical support staff. Some research and survey workers undoubtedly consider that they would prefer to incorporate electronic technicians within their individual groups, and it is clear that technologists will be required for this purpose. The technician pool system presently in existence allows junior technicians to investigate a number of work disciplines before deciding where their inclinations lie, and permits a flexible response to the varying demands for technician support.

It is clear that new staff recruited to BIO, in all areas of activity, both research and survey as well as support, should be selected from those applicants who have some training in modern technology — for in order to obtain good results from equipment, it is necessary to understand precisely the principles of operation and to a limited degree the details of operation. The principle that the research scientist must be fully familiar with the technical details of the equipment with which he works has been accepted for many years by those working in disciplines such as nuclear physics, and it must be recognized now by oceanographers. One implication of the present technological revolution is that university training in oceanography should emphasize electronics, digital computer programming, and mechanical engineering as applied to oceanography as major courses. The impact of technology on oceanography is being felt, but the connection between the effect and the course is not always realized.

R. L. G. Gilbert

Electronics Instrumentation Laboratory

C. S. Mason

A. S. Bennett¹
R. Cassivi
J. A. Dimmers¹
B. B. Hartling¹

D. R. Harvey¹
P. H. Jollymore¹
H. MacPhail

Additional personnel who have joined in the past year have enabled a considerable increase in the amount of work which can be handled. However, the effect of the increase will be more evident in the ensuing year, once all are firmly established. In 1965, the main effort of the group has been towards digital systems, although the design of other instruments has commenced. As in past years, a great deal of time has been spent assisting and advising others about instrumentation and in providing a maintenance service for specialized equipment. In the future, the maintenance and refurbishing of such equipment will become entirely a duty of electronic maintenance, and additional skilled technicians will be acquired for this purpose. The major projects of the past year are described below.

Geodal systems

Geodal, a semi-automatic geophysical data logging system installed on CSS *Hudson*, has been expanded and now records very low frequency radio transmissions, and Decca coordinates, both used in position fixing. In addition the magnetometer and gravimeter outputs and GMT time are recorded. Each parameter is recorded at least once per minute in both analogue and digital form, and the data is stored in a format suitable for digital data processing. The *Hudson* system worked almost faultlessly during the spring geophysics cruise (p. 25) when some design personnel were aboard to assist in the operation. It continued with only one minor failure during the Hudson Bay cruise, with no technical personnel trained in the system, on board. The *Hudson* installation has been described in a paper presented to the Ocean Science and Ocean Engineering Conference of the Marine Technological Society (BIO Contribution No. 35). The equipment was used to assist in the gathering of data presented to the International Upper Mantle Symposium on the world rift system. Two additional geodal systems, which recorded

magnetometer, gravity, and time data only, were also operated this summer on a routine basis and gave little trouble. Most of the inboard electronics for the shipboard magnetometers, which form part of each geodal installation, has been replaced and an Internal Note (BIO 65-3) describes a new switching circuit for the magnetometer signal.

Buoy magnetometers

During the course of a marine magnetic survey it is desirable to measure time variations of the earth's magnetic field: these measurements also have intrinsic interest. An Internal Note (BIO 65-2) has been written to describe in detail reasons why four self-recording buoy magnetometers were acquired in 1965. These instruments, commercially built, were delivered in early February. Each instrument was designed to record a value of the total force of the earth's magnetic field once every 5 min for a period up to one month. Automatic operation in a remote location either on land or in a moored buoy was intended. After additional re-design at BIO, the equipment was tested at sea in March, and although sparse data was obtained, the instruments proved unsuitable for installation as sea magnetic observatories. Rebuilding and testing of the equipment has continued throughout the year, and it now appears that the magnetometers will be suitable for use as land stations without attendant personnel. It is planned to design a new instrument suitable for use at sea.

During the March testing, *Hudson* failed to recover one instrument, left in a pressure container in about 100 fathoms of water, when the surface line parted. The instrument was recovered 2 months later by the charter ship MV *Theta* by dragging and recovering a groundline. Unfortunately, the magnetometer had failed after several days of intermittent operation.

Data processing system

Assembly has commenced of a data processing system for transferring data by multiplex recording of two or more FM modulated carriers from magnetic tape onto paper tape in a digital form. Discriminators for separating nine different carriers (IRIG channels 3-12) will be provided and the output of one, two, or more dis-

¹ Joined BIO in 1965.

criminator will be recorded by a 150 digit/second punched paper tape reperforator. Three decimal digits may be recorded for each input parameter with an accuracy of 0.5%; the maximum sampling rate will be 50 readings/second of one input, 25 for two, and so forth. Much of the equipment acquired for the system has barely met manufacturers' specifications and considerable time has been spent to determine the overall accuracy. At present nearly all the equipment is working, and a parallel to serial coupler for the paper punch output has been assembled. Because of the unavailability of a suitable FM filter discriminator unit, particularly for field applications, design of a suitable unit has begun.

Institute plotter

The plotting table, supplied as part of an automatic shipboard depth plotting system, has been recovered and the remaining portion put aside. A description of the condition of the original commercially-built shipboard system is given in BIO Internal Note 65-9, and the reasons for abandoning all the system but the plotter are outlined therein. The table still achieves the accuracy specified by the manufacturer. A new system, in which the table will plot points and symbols as it is instructed by a punched tape, is now under construction. The table, which will be Institute-based, will form part of an overall data processing system consisting of an automatic shipboard data recording system of the Geodal type, a shipboard computer where available, the Institute computer, and the rebuilt plotting table.

C. S. Mason

Biodal

A new digital data acquisition system is being designed which is intended eventually to replace the digital recording system at present in use. The new system is similar to the existing Geodal installations (p. 48) in that data is recorded on punched paper tape, but it is more flexible and capable of indefinite expansion of recording capacity. The design will incorporate improvements and refinements suggested by operating experience with Geodal. The new system will be capable of recording any parameter which can be presented in digital form. It is intended that this system will become a standard recording facility on BIO ships for use by scientists and hydrographers. It is being designed in such a way that maintenance at sea by BIO technicians will be a matter of easy routine. The basic paper tape recording unit will record a maximum

10 five-digit parameters in addition to date and time, and as many recording units as are necessary may be controlled by one master clock. Each recording unit identifies itself by punching symbols on the tape. It is hoped to start construction of the prototype early in 1966.

A. S. Bennett

Support to air-sea interaction

The writer has recently been seconded to the air-sea interaction group to assist in bringing their field equipment into a reliable and trustworthy state. The main problems under investigation are the transducer excitation and transducer output discriminators for the anemometers, and engineering the "Stable Platform" transmitter station into a prototype form, suitable to carry out additional tests.

J. A. Dimmers

Wave recording

The wave recording program this year has been almost entirely concerned with instrumentation. The field program has been the joint responsibility of the National Research Council and the Department of Transport, as has the analysis of the resulting data. A total of about 50 wave recording accelerometer buoys and radio transmitters have been supplied for the field program, together with 15 complete receiving stations. Some progress has been made with intercomparison between the BIO wave recorder and the NRC staff wave recorder at Point Pelee, and results are expected very shortly.

Oblique echo-sounder

Professor W. D. Chesterman of the University of Hong Kong provided both his services and the Hong Kong University Kelvin-Hughes horizontal echo-sounder for evaluation trials this spring. The equipment was installed on CSS *Kapuskasing* under the direction of Mr K. Wang, a student at Hong Kong, and experimental evaluation made of its application to hydrographic survey and geological research. The equipment is basically similar to that described by A. R. Stubbs in the International Hydrographic Review of July 1963, with minor additions and improvements. The use of this form of asdic depends mainly on the interpretation of differences of tone on the damp paper record: an acoustically hard bottom, such as rock or shingle, gives a dark record, while poor reflectors like mud or sand show up as lighter areas. Changes in gradient also vary the tone, but to

a much lesser extent. Considerable experience is needed to make a correct interpretation of the record. The degree to which this sounder can be relied on to detect submarine features is affected by water conditions. For instance, the marked thermocline which often occurs on the east coast of Canada bends the sound rays sharply downwards, limiting the range drastically, and concentrating the sound so that details may be masked even in the small area illuminated. A knowledge of underwater sound propagation is needed to appreciate these limitations.

The trials lasted for approximately 3 weeks and involved a considerable number of BIO staff. Evaluations of the equipment from the "users" point of view are given in p. 35, 44, and 90, of Part B of this report. It appears that modifications could be made to the equipment to overcome most of the difficulties encountered during the trials. By increasing the length of the towing cable, and also modifying the deck handling gear, the transducer could usually be placed below the thermocline, with very beneficial results. Remote control of the angular depression of the transducer would enable the optimum setting to be quickly found. An improved control of the amplifier time-variable gain is technically feasible, and would enable better results to be obtained. For hydrographic survey reconnaissance, a system which scans both sides of the ship's track, which can operate at 12 knots, and which displays the data in an approximately true-scale form, is required. All these modifications are possible, and it is hoped to work towards a sophisticated equipment during the coming years.

R. L. G. Gilbert

Marine Electronics

A. S. Atkinson

F. Barteaux	K. MacAskill ¹
J. Betlem ¹	G. MacDonald
C. Campbell ¹	A. Parsons ¹
V. Coady	C. Polson
J. Cournoyer	G. Roze
R. Dawson	W. Shearman ¹
W. W. Goodwin	H. B. Sutherland
J. Haight ¹	G. Vezina
P. LeBlanc ¹	G. Weber

The Marine electronics group, formerly known as Electronic maintenance, has increased its staff considerably during the year and the duties and responsibilities have been delegated to four sub-groups.

The Electronic positioning systems unit, with Mr Sutherland in charge, is responsible for the operating efficiency of the BIO Decca systems. The existing Decca 12F, 12F Lambda and Hi-Fix chains were refurbished during the off-season period and are at present undergoing their annual overhaul. In addition the unit has been busy with the conversion of obsolete Decca Navigator equipment to higher operating frequencies, with a view to increasing our equipment potential without expenditure for new units. This program will provide a short range portable system, a complete long range 12f system and spare equipment for existing long range systems. It is planned that the portable system, as well as most of the spare units, will be available for the 1966 field season.

The work of the servicing unit during the winter months, under the supervision of Mr Goodwin, consisted of the removal, overhaul and installation of all the various types of echosounders, radiotelephones, receivers and other ancillary equipment, which amounted to some 85 complete installations. The summer months, in addition to field duty, were spent investigating and modifying existing test instructions, improving the laboratory facilities, installing and testing equipment for special projects, and providing maintenance service to various field parties.

The Ships' equipment unit, with Mr Shearman as senior technician, was formed in April and since that time has been concerned with the installation, maintenance, and servicing of all the electronic equipment permanently installed on BIO ships. Antenna systems on ships have been improved, new equipment installed and checked out, existing equipment refurbished (including the complete radio room on *Baffin*), and a system of standard maintenance procedures and fault analysis set up on all ships,

The establishment of a Standards laboratory by Mr Dimmers in July and taken over by Mr Betlem when he arrived in October, has provided

¹ Joined BIO in 1965.

a very useful facility. It provides a maintenance and calibration service for all electronic and electrical test equipment in use at BIO and aboard ships. A cataloguing system and a calibration schedule have been initiated as well as procedures for the receipt and inspection of incoming test equipment. Present equipment permits semi-automatic calibration facilities which provide permanent records of measurements for periodic routine checks and analysis.

Two training courses were conducted for the benefit of field staff: an introduction to Decca positioning systems given by H. B. Sutherland, and an introduction to Redifon single sideband equipment by J. Dimmers.

Special projects being conducted by this section are as follows:

(1) Provision of a system to be installed in the oceanographic well on CSS *Hudson* for lowering a transducer below the keel in an attempt to improve sounding performance in bad weather.

(2) Provision of voice communications between the Institute and BIO ships.

(3) Semi-automatic performance measurements on all ships' radars.

(4) The electronic portion of a load measuring block that will indicate the true strain on a wire rope — particular application being with oceanographic winches where loads often approach the working limit of wire ropes.

(5) Echo-sounder chart reader; a pointer is manually positioned on the record on a standard echo-sounder chart, and the depth, corrected for tide, is automatically printed on a separate record. The device is fully described in BIO Internal Note 65-8.

A. S. Atkinson

¹ Joined BIO in 1965.

Mechanical Design and Services

J. Brooke

Design office

R. N. Vine
D. Chamberlain¹
(Ships div.)
D. Doyle
(Casual)
W. J. Whiteway¹

Instrument machine shop

W. W. Hall¹
G. F. Connolly
R. J. Sawler

Depot workshop

R. Balfour

F. Armitage ¹	H. W. Marshall
P. R. Blackmore	W. A. Moore ¹
A. S. Gilhen	C. Newell
C. Grant	R. M. Smith
H. P. MacDougall	R. E. Underwood

This year is noteworthy for the increase in design staff and the number of projects handled. The energies of the section are still dispersed over many areas, ranging from large construction jobs such as the erection of an ancient cannon weighing 11 tons as a radiation shield for the marine radioactivity project, to the design and construction for the geophysics group of a miniature tape recorder for the heat flow probe.

In the design office and instrument shop many small jobs and several development projects have been started; most of the small jobs have been completed. Considerable time is still spent in advising BIO staff on mechanical matters, and it is expected that this type of service will continue.

The depot workshops have been involved with the repair and overhaul of launches, the maintenance and repair of many pieces of oceanographic equipment, and the construction of new equipment. In addition there has been the usual effort required on "house and grounds" maintenance, not the least being the many office and laboratory changes required for new staff and projects.

Contributions from this group consisted of: two papers, BIO Contribution Nos. 36 (Brooke) and 37 (Doe and Brooke), together with a display unit, which were presented at the Ocean Science and Ocean Engineering Conference in June; another paper, BIO Contribution No. 42 (Doe and Brooke) given at the First Canadian Micrometeorological Conference in April; and BIO Internal Note 65-17 by Connolly (Appendix A-1).

Major projects of the past year are described below.

Load measuring block

This block has been designed to measure directly, whatever the wire angle, loads on wire or rope passing around its sheave. It will also measure the amount of line paid out. The prototype is mechanically complete and tests will be conducted shortly after the electronic instrumentation is completed.

J. Brooke
A. S. Atkinson

Small tape recorder for sediment temperature probes

Various movements are being tested to produce accurate stepping of magnetic tape for recording digital data derived from measurements with the heat flow probe. The aim is to produce a recorder which will hold 180 ft of tape, recording digital data with a packing density of 50 bits per inch, and which physically can be contained within a 3-inch diameter pressure case. The length of the movement at present is approximately 4 inches.

J. Brooke

Rock core drill

Work has started on a prototype rock core drill; the immediate target is to enable cores at least 6 inches long to be taken from the ocean bed in areas where rock faces are free of sediment. The power unit is charged by lowering the rig to the required face and tripping to start; the hydrostatic pressure of the ocean provides the motive power. Lab tests have been conducted to establish the best rate of drilling, clearing water flow, and loadings. Recent sea trials show promise of good performance after some

modifications have been made to the standard hydraulic components.

J. Brooke

Bag type water samplers

A prototype small plastic water sampler has been constructed and is being tested as a preliminary to designing a much larger sampler. The marine radioactivity group has indicated that sterile-sealed clean containers having a one-sample life would be preferable for accurate results. The prototype has had one sea test and the results are being analyzed.

J. Brooke

Cape Island launch

"Cape Island" type hulls are available locally at reasonable cost and it was decided to obtain a launch 32 ft long and provide her with a linked power and steering system to make it possible to hold station for lengthy periods while handling gear overside for testing purposes. The existing hydrographic launches at BIO are not designed for this work and cannot be made to hold station for any length of time, nor do they have sufficient working space aft.

The new launch is powered by two 40 hp diesel engines with variable pitch propellers. A hydraulic-assisted linkage translates forward, back, port, and starboard movements of a central steering column into propeller pitch changes to provide speed and direction control.

Design work was completed in July and installation of engines and shafts is complete. Parts for the steering gear are 80% complete. Testing of the steering gear and the launch as a whole has yet to be completed.

R. N. Vine

Printed circuit card modules

These racks are not available commercially and are therefore to be made up at BIO as required. They will provide a standard and uniform holder for the printed circuit cards needed to make up various electronic units under development at BIO. They will fit standard racks and cabinets and are mounted on hinges to give easy working access. The modules may be

mounted singly or in multiples, joined by the hinges, with a common front panel. Three prototypes were constructed, the last one proving satisfactory. Tools were then made to ensure uniformity of production and the first module was completed by the target date.

R. N. Vine

Ships

Captain S. W. Howell¹

D. H. Chamberlain¹ Captain A. M. Holler
J. M. Higgins¹ G. Smith¹

The planned, and much needed, strengthening of the shore-based organization was implemented during the year by the appointment of three officers beginning with Captain S. W. Howell, formerly Director of Canadian Naval Auxiliary Vessels (civilian-manned) at National Defence Headquarters, Ottawa. Captain Howell took up the duties of Regional Marine Superintendent at BIO at the end of June.

In early July, Mr J. M. Higgins assumed the duties of Regional Engineer Superintendent. Mr Higgins is well known to many employees having served as Chief Engineer of the *Baffin* from 1956 to 1961. While with GTR Campbell and Company, Naval Architects and Marine Consultants, Montreal, he was on loan to the Department for a period as Supervisor of Ship Construction and Maintenance, and subsequently, assisted in the supervision of the construction of *Hudson* during 1963-64.

Also in July, Mr G. Smith, a qualified Naval Architect, formerly on the design and supervision staff of GTR Campbell and Company of Montreal took up the position of Regional Hull Superintendent. Mr Smith has had wide and varied experience of marine survey work for several commercial shipping companies and marine classification societies, and from 1961 to 1964 was in charge of supervision duties on behalf of the Department during construction of *Hudson* at Saint John, N. B.

Captain A. M. Holler, who in the past has carried out the duties of Sea Leader and Acting

Marine Superintendent, has been appointed Regional Operations Officer and is responsible amongst other duties, for the programming and coordination of Atlantic Region ship and launch employment, including vessels on charter.

Ship Operations

Five ships of the Marine Sciences Branch, DM&TS, are operated by BIO: their principal specifications are given in Table 3 and a composite portrait appears in Fig. 13.

During the year all ships, with the exception of *Baffin*, met their operational requirements, with only the occasional delay due to relatively minor defects.

Baffin, upon completion of her refit in April, commenced work on a major hydrographic survey of the Tail of the Grand Banks but after a brief period of operation was forced to return to base with defective propulsion gearing. Investigation revealed that wear of the bronze clutch units following 8 years' arduous service was such that replacement was essential. This requirement unfortunately made the vessel unoperative for some considerable time, due to the lengthy period required by the manufacturer to produce the necessary parts. However, the operating time lost was put to good use by allowing work to be completed on the installation of a flume stabilization system. This system is similar to that installed on *Hudson*, as well as on a number of large modern commercial vessels, and effectively reduces the vessel's roll in a seaway, thus providing a more stable platform for scientific work in all but the severest weather conditions. In addition, *Baffin* personnel were employed in general relieving duties and in operating launches for a shore-based party engaged in charting the Sheet Harbour area of the Nova Scotia coast. Leave was also granted to as many persons as possible. The *Baffin* became fully operational on November 15, 1965, and as there will be no refit required until late 1966 or early 1967, a full year of operation has been planned.

Early in 1965 the potential operating area of the *Maxwell* was further extended by fitting out the vessel to the requirements of the St. Lawrence Seaway Authority. This consisted of the fitting of Seaway navigation lights and the

¹ Joined BIO in 1965.

installation of an automatic self-contained sewage system, which effectively eliminates the pollution of navigable waters, harbours and canals by the vessel's wastes. The existing 15 kw generator was removed and replaced with a 38 kw unit to meet an increasing demand for electrical services on board.

Hudson completed her first full year of operations very satisfactorily. However, experience has shown the need for a certain number of alterations which will add significantly to her operational and scientific capability. Among the main items planned for the next refit period are:

- (a) installation of an additional evaporator to meet an increased need for fresh water, both for laboratory requirements as well as normal ship's services;
- (b) extension of the foredeck gallows for deep water coring;
- (c) repositioning of ventilators and other obstructions on the foredeck to clear the forward working area;
- (d) foredeck section of the bulwarks starboard side to be made portable to facilitate over-the-side operations;

- (e) installation of cooling system for portable oceanographic winches to prevent overheating;
- (f) improved access to the General Purpose Laboratory.

In addition to these five research vessels, four other ships were programmed in whole or part through BIO. One of these, *CNAV Sackville*, is assigned by the Royal Canadian Navy to the Fisheries Research Board in BIO. The MV's *Theron* and *Theta* were under charter for 115 and 161 days respectively. Through the courtesy of the Marine Branch of the Department of Transport the icebreaker *CCGS Labrador* was engaged for 55 days on Institute work in the Arctic. The relative operational statistics for all nine vessels are given in Table 4.

Launches

All launches, 31 in number, were fully employed from both the major vessels and various shore bases during the season.

The 37-ft launch *Needlik* operating from *CSS Hudson* was lost in 99 fathoms of water in Hudson Bay on Friday, August 13, 1965; the

TABLE 3. Principal specifications of BIO, DM&TS ships.

Name of vessel	Built	Length	Breadth	Draft	Displacement	Master
<i>CSS Acadia</i>	1913	182'-0"	35'-7"	13'-6"	1,350 tons	Capt J. W. C. Taylor
<i>CSS Baffin</i>	1957	285'-0"	49'-6"	17'-3"	4,420 tons	Capt. W. N. Kettle
<i>CSS Hudson</i>	1963	293'-6"	50'-0"	20'-6"	4,660 tons	Capt. W. J. Vieau
<i>CSS Kapuskasing</i>	1943	222'-0"	35'-6"	12'-6"	1,250 tons	Capt. W. Thorne
<i>CSS Maxwell</i>	1961	115'-0"	25'-1"	7'-0"	230 tons	Capt. S. Baggs Capt. P. M. Brick (Relieving Master)

TABLE 4. Operational statistics

Name of vessel	Number of cruises	Days away from base	Mileage steamed
<i>CSS Acadia</i>	2	166	5,321
<i>CSS Baffin</i>	5	32	6,160
<i>CSS Hudson</i>	8	221	46,960
<i>CSS Kapuskasing</i>	4	223	21,951
<i>CSS Maxwell</i>	4	170	6,485
MV <i>Theron</i> (charter)	2	86	12,500
MV <i>Theta</i> (charter)	2	141	8,400
<i>CNAV Sackville</i>	10	157	23,330
<i>CCGS Labrador</i>	1	55 ^a	14,600 ^a

^a On BIO duty.

loss was caused by parting of the after fall while the launch was being hoisted inboard. Fortunately, no injury or loss of life was sustained in this accident, mainly because all normal safety precautions required when hoisting or lowering boats and launches were strictly observed by the *Hudson's* officers and crew. The cause of

this material failure has not yet been fully ascertained. Samples of the wire fall in use, tested after the accident, did not break until a 30-ton load was applied; the weight of the *Needlik* at the time of her loss was approximately 12 tons.

S. W. Howell

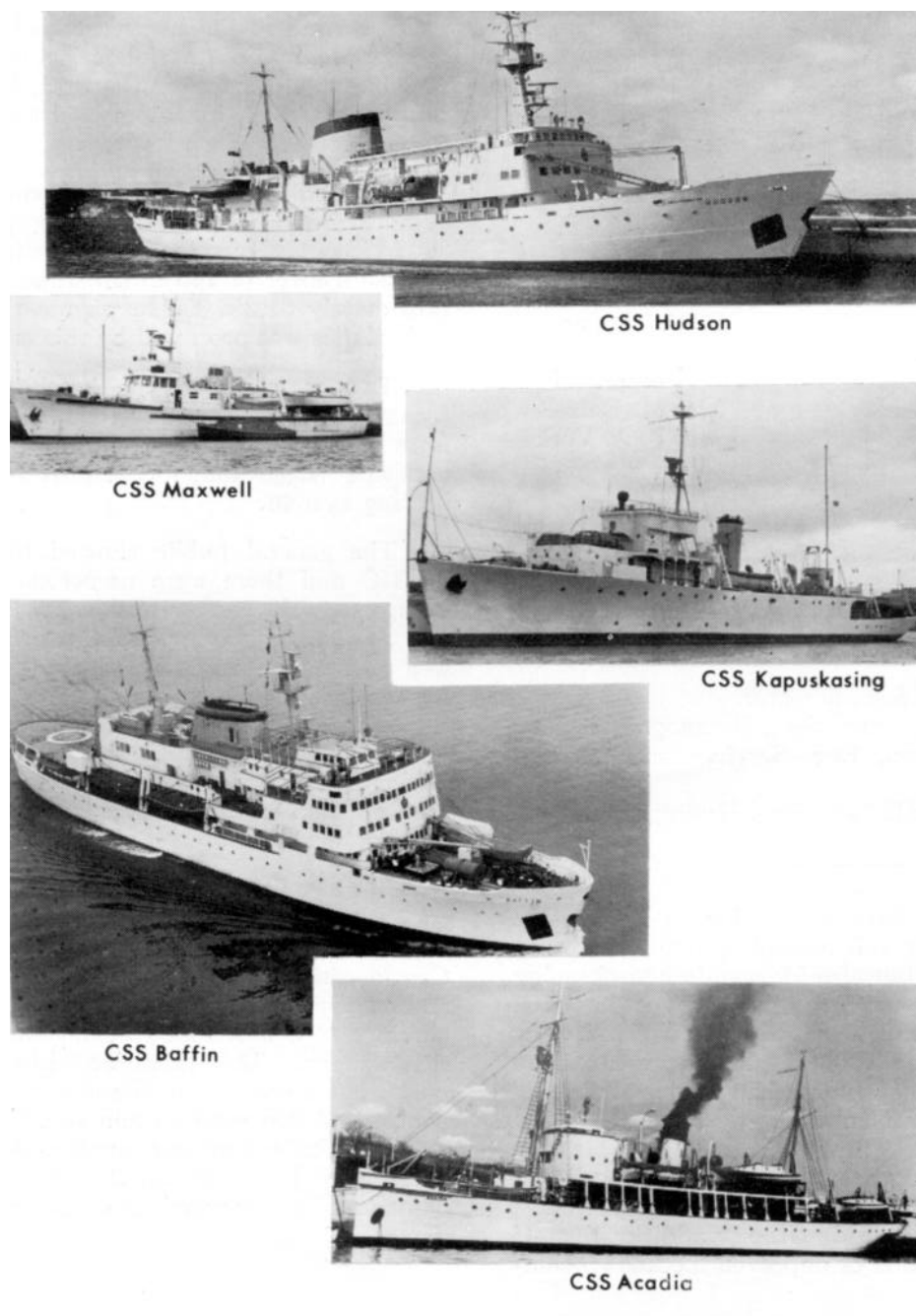


Fig. 13 Research and survey ships of BIO.

Administration

S. H. Scott

Library

Miss C. S. Allen
Mrs A. J. Cowan
Mrs G. H. Townsend²

Finance

V. W. Hilchey
Mrs J. Dickinson²
W. A. MacDonald¹
Miss F. G. MacLaren

Central Registry

Mrs C. E. Gallant
Mrs D. M. Fultz
Mrs S. J. Jones

Heating Plant

J. F. Greig
H. L. Gorman
G. E. Higgins
C. E. Rose

Ships

G. W. Booth
J. G. Arnold
F. W. Grant¹
G. Y. Hare
J. F. MacLean
R. H. Stone

Stores

B. G. Martin
M. W. Campbell
R. W. Fudge
S. P. Hartling
W. Lovett¹
G. Symonds
E. C. Tupper

Personnel

Mrs M. Dalzell
Mrs F. A. York

PBX

Miss I. A. Cunningham¹
Mrs S. G. Furlong

Miss B. A. Armsworthy, Sec., Reg. Marine Supt.
Miss C. J. Forsythe, Sec., Marine Geology and Admin.
Mrs V. C. Kerr, Sec., Director
Miss R. T. Mannette², Sec., Oceanographic Res.
Mrs J. Sim, Sec., Eng. Services and Oceanographic Res.
Mrs M. L. Smoth, Sec., Reg. Hydrographer

The Administrative section is responsible not only for the full administrative services to MSB personnel but also for certain housekeeping support to the several other groups in BIO. The continued rapid growth of staff throughout the Institute, see Table 1 (p. 12), presented the section with perhaps more than the usual number of challenging problems.

The resulting growth in incoming and outgoing correspondence, telex and telephone services was absorbed without additional staff by the introduction of improved methods includ-

ing a common file system with headquarters, a Xerox copier and a direct telex line to Ottawa. The addition of two persons permitted the staff of the accounts group to keep up with its heavy load; as an example of this load, purchase requisitions processed amounted to approximately \$3,000,000. A stores group headed by Mr Martin was established during the year and a clean-up of 2-3 years' backlog of records concerning receipts, issues, stock cards, inventory, etc. is being completed. A program of rewarehousing, palletizing, reshelving, a stock location system, issue and receipt of material, inventory and audit has been started and is well on its way.

Mr Booth, in charge of personnel and other administrative services, including pay, for the 300 officers and men in ships, reported that there was a turnover of 165 in ships' personnel. Approximately \$1,250,000 in payments for wages and salaries was processed by this group.

Two members of the heating and maintenance staff received letters of commendation from the Deputy Minister and awards for an excellent suggestion for improvement to the heating system.

The general public showed much interest in BIO and there were numerous requests by groups to visit the establishment. During July and August regular guided tours were held for well over 1,000 tourists. These were conducted by two senior high school students provided by the City of Dartmouth. An "open house" in February for senior high school and university students attracted about 1,200 visitors, a greater number than in the previous year inspite of inclement weather.

In recognition of the basic importance of a good library in a research organization, the BIO library is supported jointly by MSB and FRB. Consideration is being given to further ways and means of ensuring its growth from small beginnings to a first rate specialist library of marine science. The Librarian, Miss Allen, reports that accessions to the library included 716 books, and 908 reprints and serial publications. The book collection now numbers 3,337 volumes and is used jointly by all BIO staff and by students and faculty members of Dalhousie University.

S. H. Scott

¹ Joined BIO in 1965.

² Left BIO in 1965.

Appendices

Appendix A-1

Publications and Reports

Publications

- BAILEY, W. B., J. BUTTERS and R. R. WEILER. Experiments in oceanographic forecasting. Paper submitted to Military Oceanographic Forecasting seminar held in Dartmouth, N. S., Sept. 27-30, 1965.
- BARRETT, D. L. 1965. Lancaster Sound magnetic survey. *Cdn. Jour Earth Sci.* (in press), BIO Contribution No. 46.
- BARTLETT, G. A. 1965. Foraminifera distribution in Tracadie Bay, Prince Edward Island. *Geol. Surv. Canada Paper* (in press), BIO Contribution No. 47.
- BECK, V. N. 1965. Tests of a miniature electrical humidity sensor. *Trans. Cdn. Micromet. Conf.*, Toronto, April 12-14, 1965 (in press--Cdn. Met. Serv. of Canada), BIO Contribution No. 41.
- BROOKE, J. 1965. Time release system for delayed bottle sampling. Submitted to *Oc. Sci. & Oc. Eng. Conf.*, Washington, D. C., June 14--17, 1965 (in press--Mar. Tech. Soc./Amer. Soc. of Limn. & Ocean.), BIO Contribution No. 35.
- DOE, L. A. E. 1965. Physical conditions on the shelf near Karachi during the post-monsoonal calm, 1964. *Oc. Sci. & Oc. Eng. Conf.*, Washington, D. C., June 14-17, 1965, vol. 1, p. 278-292, Mar. Tech. Soc./Amer. Soc. of Limn. & Ocean, BIO Contribution No. 33.
- DOE, L. A. E., and J. BROOKE. 1965. A moored stable platform for air-sea interaction studies. *Limn. & Ocean. Supp.* Vol. X, No. 86, Nov. 1965. BIO Contribution No. 37.
- DOE, L. A. E. 1965. Air-sea interaction studies at the Bedford Institute of Oceanography-general program. *Trans. Cdn. Micromet. Conf.*, Toronto, April 12-14, 1965 (in press--Cdn. Met. Serv. of Canada), BIO Contribution No. 38.
- DOE, L. A. E. 1965. A series of three-component thrust anemometers. *Trans. Cdn. Micromet. Conf.*, Toronto, April 12-14, 1965 (in press--Cdn. Met. Serv. of Canada), BIO Contribution No. 39.
- EWING, G. N., A. M. DAINY, J. E. BLANCHARD and M. J. KEEN. 1965. Seismic studies on the eastern seaboard of Canada: the Appalachian system I. *Cdn. Jour. Earth, Sci.* (in press), BIO Contribution No. 44.
- FORD WM. L.,¹ and G. HATTERSLEY-SMITH 1965. On the oceanography of the Nansen Sound fiord system. *Arctic (Jour. Arctic Inst. N.A.)* Vol. 18, No. 3, Sept. 1965.
- LONCAREVIC, B. D., and C. KEEN. 1965. Crustal structure on the eastern seaboard of Canada: studies on the continental margin. *Cdn. Jour. Earth Sci.* (in press), BIO Contribution No. 45.
- LONCAREVIC, B. D., and D. R. BOWER. 1965. Sea gravimeter reliability test, Baffin 63. *Pub. Dom. Obs.*, Ottawa, BIO Contribution No. 49.
- LOUCKS, R H, 1965. Discussion of theory for air-sea interaction measurements. *Trans. Cdn. Micromet. Conf.*, Toronto, April 12-14, 1965 (in press--Cdn. Met. Serv. of Canada), BIO Contribution No. 43.
- MARLOWE, J. I. 1965. Probable Tertiary rocks from a submarine canyon of Nova Scotia. *Marine Geology* (in press), BIO Contribution No. 32.
1965. Mineralogy as an indicator of long-term current. Fluctuations in Baffin Bay. *Cdn. Jour. Earth Sci.* (in press), BIO Contribution No. 48.
1965. Sedimentology of the Prince Gustaf Adolf Sea area, District of Franklin. *Geol. Surv. of Canada Bull.* (in press), BIO Contribution No. 50.

¹ Submitted for publication prior to joining BIO staff.

- MASON, C. S., E. C. BULLARD and J. D. MUDIE. 1964. Curious behaviour of a proton magnetometer. *Proc. Camb. Phil. Soc.* (1964) **60**, 287-293. BIO Contribution No. 30.
- MASON, C. S., and R. B. RODEN. 1964. The correction of shipboard magnetic observations. *Geophys. Jour. Roy. As. Soc.* (1964) **9**, 9-13, BIO Contribution No. 31.
- MASON, C. S. 1965. A geophysical data logging system for shipboard use. Submitted to *Oc. Sci. & Oc. Eng. Conf.*, Washington, D. C. June 14-17, 1965. BIO Contribution No. 36.
- MORGAN, M. R.¹ 1965. An examination of the sea surface temperature distribution in a selected area off the Scotian Shelf throughout 1963. Paper submitted to Military Oceanographic Forecasting seminar held in Dartmouth, N. S., Sept. 27-30, 1965.
- PELLETIER, B. R. 1964. Marine geology in Arctic Canada and Hudson Bay. *Ency. of Earth Sci.*, edited by Rhodes Fairbridge. (in press). BIO Contribution No. 26.
- PELLETIER, B. R. 1964. Development of submarine physiography in the Arctic Archipelago and its relation to crustal movements. *Royal Soc. of Can.* (in press). BIO Contribution No. 29. Also BIO Report 64-16.
- POTTIE, B. G. 1965. A fast response thermistor thermometer. *Trans. Cdn. Micro-met. Conf.*, Toronto, April 12-14, 1965 (in press-Cdn. Met. Serv. of Canada), BIO Contribution No. 40.
- SRIVASTAVA, S. P.² 1965. Method of interpretation of magnetotelluric data when source field is considered. *J. Geophys. Res.* **70**, p. 945-959. Cdn. Contrib. to Intl. Upper Mantle Project No. 100.
- ² 1965. Theory of the magnetotelluric method for a spherical conductor. *Geophys. J. of RAS* (in press). Cdn. Contrib. to Intl. Upper Mantle Project No. 101.
- ² 1965. Theory of the magnetotelluric method for non-uniform conductors. *J. Geomagnet. and Geoelect.* vol. **17**, No. 3/4, 507-515. Cdn. Contrib. to Intl. Upper Mantle Project No. 102.
- SRIVASTAVA, S. P.,² and E. R. NIBLETT 1965. Magnetotelluric two and three layer master curves. *Dom. Obs. Pub.* (in press). Also Cdn. Contrib. to Intl. Upper Mantle Project.
- WEILER, R. R.,² and A. A. MILLS. 1965. Surface properties and pore structure of marine sediments. *Deep Sea Res.*, **12**, p. 511-529 (1965).
- WESTPHAL, K. O. 1965. Series solution of freezing problem with the fixed surface radiating into a medium of arbitrary varying temperature. Submitted to *Intl. Jour. Heat & Mass Transfer*. BIO Contribution No. 34.

¹ Mr Morgan was a member of Oceanographic Services for Defence but not of DM&TS.

² Submitted for publication prior to joining BIO staff.

BIO Reports

- | | | |
|-----------|---|--|
| BIO 65-1 | K. O. Westphal | On the freezing of water column under the influence of radiation cooling. |
| BIO 65-2 | G. T. Needler | Series solutions for a class of heat conduction problems with a phase change. |
| BIO 65-3 | G. A. Bartlett | Preliminary investigation of benthonic foraminiferal ecology in Tracadie Bay, Prince Edward Island. |
| BIO 65-4 | L. A. E. Doe
R. H. Loucks
V. N. Beck
B. G. Pottie
J. Brooke | Review of air sea interaction studies at the Bedford Institute of Oceanography. |
| BIO 65-5 | A. E. Collin | Oceanographic observations in Nares Strait, northern Baffin Bay, 1963 and 1964. |
| BIO 65-6 | R. J. Leslie | Ecology and paleoecology of Hudson Bay foraminifera. |
| BIO 65-7 | W. I. Farquharson | Tidal heights in Bay of Fundy. |
| BIO 65-8 | C. R. Mann
A. B. Grant
T. R. Foote | Oceanographic results of cruise S-64 between the Scotian Shelf, Grand Banks of Newfoundland and the Gulf Stream. |
| BIO 65-9 | A. C. Grant | Distributional trends in the Recent marine sediments of northern Baffin Bay. |
| BIO 65-10 | R. G. Pirie | Petrology and physical chemical environment of bottom sediments of the Rivière Bonaventure-Chaleur Bay area, Quebec, Canada. |
| BIO 65-11 | W. I. Farquharson | Tidal stream and current surveys evaluation of data. |
| BIO 65-12 | R. J. Leslie
B. R. Pelletier | Bedrock geology beneath Hudson Bay as interpreted from submarine physiography. |
| BIO 65-13 | G. A. Bartlett | Preliminary notes on Recent species of Elphidiidae in shallow waters of the Atlantic provinces of Canada. |
| BIO 65-14 | L. H. King | Use of a conventional echo-sounder and textural analyses in delineating sedimentary facies-Scotian Shelf. |
| BIO 65-15 | J. I. Marlowe | Sedimentology of the Prince Gustaf Adolf Sea area, District of Franklin. |
| BIO 65-16 | C. R. Mann
A. B. Grant
T. R. Foote | Atlas of oceanographic sections--northwest Atlantic Ocean--February 1962-July 1964. |
| BIO 65-17 | | Fourth Annual Report. |

BIO Internal Notes

BIO Internal Notes, formerly known as Institute Notes, are unpublished, unedited notes intended for internal circulation. They are encouraged as a first step in the preparation of a manuscript or as a first record of work, which may be unfinished or incompletely considered. External distribution, if any, is at the author's discretion.

BIO 65-1	W. I. Farquharson	Current data obtained from ocean moorings 1964.
BIO 65-2	C. S. Mason	The Barringer buoy magnetometers.
BIO 65-3	C. S. Mason	A proton precession and magnetometer switching circuit.
BIO 65-4	S D. Smith	A seminar on air sea interaction study presented at UBC.
BIO 65-5	M. E. MacLean A. E. Collin	Oceanographic observations in Davis Strait.
BIO 65-6	R. L. G. Gilbert	Remote-controlled launches.
BIO 65-7	R. L. G. Gilbert	To recover or not to recover --
BIO 65-8	R. L. G. Gilbert A. S. Atkinson	Echo-sounder chart reader.
BIO 65-9	B. B. Hartling C. S. Mason	Report on CAE plotter.
BIO 65-10	R. H. Loucks	A note on response characteristics and spectral densities.
BIO 65-11	R. L. G. Gilbert	Notes on research projects at Hudson Labs.
BIO 65-12	R. L. G. Gilbert	Notes on the Westinghouse horizontal echo-sounder.
BIO 65-13	J. M. R. Pilote	Suggested horizontal distance measuring instrument for large scale hydrographic surveys.
BIO 65-14	J. Brooke R. L. G. Gilbert C. S. Mason	Electronic and mechanical instrumentation at B.I.O.
BIO 65-15	A. B. Grant	Investigation of deep ocean salinity, Gulf Stream, Tail of Banks.
BIO 65-16	H. B. Sutherland	An electronic aid in seismic operations.
BIO 65-17	G. F. Connolly	Extra line stowage bag for subsurface buoy.
BIO 65-18	S. P. Srivastava	Part A -- A proposed electro magnetic model to investigate the effect of the coast on the diurnal magnetic variations recorded in the eastern coast of Canada. Part B -- Possibilities of recording telluric currents at sea.
BIO 65-19	W, D. Forrester G. T. Needler	A weakness in the CODC OCEANS II program.
BIO 65-20	G. J. Gibson C. R. Mann	Canadian east coast standard sections.
BIO 65-21		Summer Assistants' reports 1965.

Appendix A-2

Lectures and talks

The following is a partial list of scientific presentations by members of staff:

- | | |
|-------------------|---|
| Barrett, D. L. | Discussed magnetometer surveys in Lancaster Sound, Arctic Archipelago at the Upper Mantle Workshop, Ottawa in February 1965. |
| Bartlett, G. A. | Seminar on micropalaeontology to the Geology Department, Mount Allison University, Sackville, N. B. |
| Buckley, D. E. | Seminar on sedimentological studies of Malpeque Bay, Prince Edward Island, to University of Southern California, Los Angeles, California. |
| Doe, L. A. E. | Seminar on "Program of air sea interaction studies at the Bedford Institute of Oceanography" to Institute of Oceanography, Dalhousie University, Halifax and to Institute of Oceanography, University of British Columbia, Vancouver, B. C. |
| Ewing, G. N. | Presented paper entitled "Deep Crustal Structure in the Gulf of St. Lawrence area" to the Upper Mantle Workshop, Ottawa in February 1965. |
| Ewing, G. N. | Presented paper entitled "Seismic studies within the Appalachian System on the Eastern Seaboard of Canada" at the Annual Meeting of the American Geophysical Union, Washington, D. C. |
| Gilbert, R. L. G. | Talk entitled "The Research Ship — a new look" to the Society of Naval Architects and Marine Engineers in Saint John, N. B. |
| Loncarevic, B. D. | Presented paper entitled "Gravity anomalies and crustal structure — Coast of Cape Breton" at the XVII Colston Symposium, Bristol, England in April 1965. |
| Loncarevic, B. D. | Presented paper entitled "Mid-Atlantic Ridge between 45° N. and 46° N." at the International Upper Mantle Symposium, Ottawa in September 1965. |
| Loncarevic, B. D. | Presented two papers entitled "Shipborne gravimeter reliability" and "Bouguer anomaly map on the mid-Atlantic Ridge" at the International Gravity Commission meeting in Paris, France in September 1965. |
| Loncarevic, B. D. | Seminar on "Detailed investigations on the mid-Atlantic Ridge" to the Geology Department, Dalhousie University, Halifax in November 1965; and to the Institute of Earth Physics, University of Toronto in December 1965. |
| Mann, C. R. | Seminar on "Long and short term changes in the ocean" to graduate classes at McGill University, Montreal. |
| Mann, C. R. | Public university lecture on "The Gulf Stream" at McGill University, Montreal. |
| Marlowe, J. I. | Block of lectures on carbonate geochemistry to Department of Geology, Dalhousie University, Halifax. |
| Marlowe, J. I. | Seminar on "Water circulation and mineralogy in an Arctic island sea" to the Institute of Oceanography, Dalhousie University, Halifax. |

- Pelletier, B. R. Seminar on "Regional sedimentation" to Geology Department, Mount Allison University, Sackville, N. B.
- Pelletier, B. R. Talk on "Marine geology program at BIO" to Mount Allison University, Sackville, N. B.
- Pelletier, B. R. Seminar on "Paleocurrents" to Geology Department, Queen's University, Kingston, Ont.
- Pelletier, B. R. Talk on "Marine geology projects at BIO" to Queen's University, Kingston, Ont.
- Pelletier, B. R. Presented paper entitled "Sedimentation in Arctic waters" to the combined convention of the American Association of Petroleum Geologists and the Society of Economic Palaeontologists and Mineralogists, New Orleans, USA.
- Pelletier, B. R. Symposium on crustal and oceanographic studies in the Arctic Islands to the Arctic Zone meeting of the Upper Mantle Workshop in Ottawa.

Aside from these scientific lectures to outside groups, many of the staff reported on their work to BIO seminars. Staff members also addressed service clubs, university and high school student groups and the public through television and radio, on various aspects of the work of the Institute.

Appendix A-3

Affiliation with Dalhousie University

Close and highly valued working relationships are maintained with those Dalhousie departments interested in marine research and especially with the Institute of Oceanography of Dalhousie. Particular value is attached to the honorary faculty appointments granted by the University to Drs Doe, Loncarevic and Mann.

Dr Mann gave a graduate course in fluid mechanics in the Department of Physics, Dr Loncarevic contributed 24 lectures to a graduate course on the physics of the earth and Dr Doe with Dr R. W. Trites, FRB offer an introductory course in oceanography.

Appendix A-4

University Faculty and Students on Seasonal Staff, 1965

<u>Name</u>	<u>University or Institute</u>	<u>Allocation in BIO</u>	<u>Remarks</u>
Hooper, Prof. K.	Carleton	Marine Geology	Faculty member
Bishop, D. D.	Mount Allison	Marine Geology	Graduate
Bishop, W. E.	Memorial	Electronics Instrumentation	
Black, D. W.	McMaster	Marine Geology	
Boudreau, H. A.	Dalhousie	Hydrography	
Clarke, J. W.	N. S. Land Survey	Inshore Tides & Currents	

<u>Name</u>	<u>University or Institute</u>	<u>Allocation in BIO</u>	<u>Remarks</u>
Clarke, R. A.	Toronto	Phys. Oceanography	Graduate
Davies, P. V.	Eastern Ont. Inst. of Tech.	Hydrography	
Dawe, Miss R. S. A.	Dalhousie	Marine Geology	
Deas, A.	U.B.C.	Marine Geophysics	
Doe, W. E.	Dalhousie	Marine Geophysics	
Douglas, K. A.	Coll. of Tech. St. John's, Nfld	Hydrography	
Dunfield, Miss S. C.	Queen's	Marine Geology	
Finley, J. P.	Dalhousie	Phys. Oceanography	
Forsyth, D. A.	Queen's	Marine Geology	
Fowler, W. K.	Dalhousie	Marine Geology	
Gillis, R. J.	U.N.B.	Marine Geology	
Gougeon, E. J.	Carleton	Frozen Sea Research	
Guptill, L. D.	Dalhousie	Phys. Oceanography	
Hammond, G. R.	Eastern Ont. Inst. of Tech	Inshore Tides & Currents	
Herzer, R. H.	Queens	Marine Geology	
Hiltz, P. A.	N. S. Land Survey	Hydrography	
Howard, E. G.	N. S. Land Survey	Hydrography	Graduate
Johnson, E. C.	N. S. Inst. of Tech.	Mechanical Design	
Krauel, D. P.	McMaster	Phys. Oceanography	
Kuehnel, R. O. W.	Dalhousie	Marine Geophysics	Graduate
Lampman, B. T.	N. S. Inst. of Tech.	Marine Electronics	
Lovekin, T. A.	Eastern Ont. Inst. of Tech.	Current Studies	
McArthur, B. A.	Memorial	Marine Geology	
McCammon, B. W.	McMaster	Marine Geology	
MacDonald, J. W.	N. S. Inst. of Tech.	Marine Electronics	

<u>Name</u>	<u>University or Institute</u>	<u>Allocation in BIO</u>	<u>Remarks</u>
McFarlane, R. S.	Eastern Ont. Inst. of Tech.	Inshore Tides & Currents	
MacGillivray, W. H.	N. S. Inst. of Tech.	Marine Electronics	
McKinnon, M. B.	N. S. Tech. Coll.	Mechanical Design	
MacLellan, M. A.	N. S. Inst. of Tech.	Marine Electronics	
Macnab, R. F.	Dalhousie	Marine Geophysics	
Mehlman, D.	N. S. Land Survey	Hydrography	
Miller, C. G.	Coll. of Trades & Tech.. Nfld.	Hydrography	
Moodie, T. B.	Carleton	Air-Sea Interaction	
Rock, H. W.	Carleton	Mechanical Design	
Sarty, D.	Dalhousie	Marine Geology	
Shearer, J.	Carleton	Marine Geology	Graduate
Sourkes, A.	McGill	Frozen Sea Research	Graduate
Stewart, J. J. McG.	Dalhousie	Marine Geology	Graduate
Starr, J. G.	Carleton	Electronics Instrumentation	
Thompson, W. E.	N. S. Inst. of Tech.	Mechanical Design	
White, R.	N. S. Land Survey	Hydrography	Graduate
Wise, Miss P. J.	Queen's	Marine Geology	Graduate
Yorath, C.	Queen's	Marine Geology	Graduate

The foregoing list of 31 university and 17 institute of technology students is an indication of the considerable importance attached to the program of seasonal employment of students. The primary objectives are to introduce them to the work of BIO and to provide a preliminary appraisal of them as potential permanent staff. Another consideration is their significant value as assistants to the regular staff in carrying forward both field and laboratory projects during the busy summer season. Every effort is made to place students in work pertinent to their studies: science students assisting scientists on research projects, surveying students on hydro-

graphic survey parties, and other technical students on hydrographic survey parties, and other technical students in appropriate positions. Five of the university group were on their second tour, an increase over the previous year.

Each was requested to submit a short report describing his work and was invited to include any remarks he wished to make about working conditions. Reading these reports makes evident their great variety. Many are narratives describing the work in general terms and listing the places where field work was carried out. Some contained brief analyses of the problems

on which the author worked, giving an idea of how they had tackled them. A number of the students elected to comment on their views of BIO. The most common remark was one of dissatisfaction with the pay policy, particularly for overtime and statutory holidays, but a number also stated that the other working conditions helped overcome this. Some reports expressed the wish that the writers could have received more advance information about the projects on which they were put to work. Some preferred to spend all their time on one project while others liked a variety of duties. Both opinions were expressed by some people whose summer experience was of each type. The course of summer lectures which was presented to introduce the students to the various fields of work at BIO produced a variety of remarks: some favourable, and some critical. A few students

who had returned to BIO for a second year remarked that they found the lectures an improvement over those of the previous year; this suggests that maturity and experience were required to absorb the material presented. In general most of the students appear to have found their work interesting and enjoyable, and quite a number expressed a desire to return, either for another summer or permanently, on completion of their courses. The staff in charge of the students were well satisfied for the most part with the calibre of these young people. This year's experience as reported by both staff and students confirms again not only the long-term value of the program but also highlights the need for administrative improvements, notably in the system of pay as casuals and in the processes of selection and assignment to projects.

Appendix A-5

Directory of professional and senior technical staff as at December, 1965:

Wm. L. Ford	Director	B.A., M.A., British Columbia, Ph.D., Northwestern, Illinois.
L. A. E. Doe	Senior Oceanographer	B.A., M.A., Toronto, Ph.D., New York.
R. L. G. Gilbert	Engineer-in-Charge	B.A., M.A., Ph.D., Cantab.
S. W. Howell ¹	Regional Marine Superintendent	Cert., Master (F.G.).
R. C. Melanson	Regional Hydrographer	Prov. Land Surveyors Cert.
B. R. Pelletier	Head, Marine Geology	B.Sc., McGill, M.Sc., McMaster, Ph.D., Johns Hopkins.
S. H. Scott	Administrative Officer	3 years Eng., Dalhousie.
R. C. Amero	Hydrographic	Prov. Land Surveyors Cert.
A. S. Atkinson	Engineering	B. Eng., Dalhousie & N. S. Tech
W. B. Bailey	Oceanographic Research	B.Sc., Acadia.
R. Balfour	Engineering	Voc. School Engineer.
D. L. Barrett	Oceanographic Research	B.A., M.Sc., Dalhousie.
G. A. Bartlett	Marine Geology	B.Sc., Mount Allison, M.Sc., Carleton, Ph.D., New York.

¹ Joined BIO in 1965.

J. Butters	Oceanographic Research	Cert., Master (F.G.).
A. S. Bennett ¹	Engineering	B.A., Ph.D., Cantab.
J. J. Betlam ¹	Engineering	3 years Tech. School, Holland - instrument making; Elect. & Math. Dip.-Tech. School, Holland; 7 years corres. courses in electronics --Holland.
P. H. Bridge	Oceanographic Research	B.A., M.A., Cantab.
J. Brooke	Engineering	P. Eng. (Ont.).
D. I. Buckley	Marine Geology	B.Sc., Acadia, B.Sc., Hon.. Acadia, M.Sc., Western Ontario.
T. M. Calderwood	Hydrographic	Ott. Tech. School Dip.
R. M. Cameron	Hydrographic	3 years Mount Allison Civil Eng.
A. R. Coote	Oceanographic Research	B.A.. M.Sc.. British Columbia.
P. L. Corkum	Hydrographic	
F. L. DeGrasse	Hydrographic	2 years Civil Eng., Mount Allison.
J. A. Dimmers ¹	Engineering	Dip., Adelaide.
D. Dobson	Oceanographic Research	Cert., Master (F.G.).
S. S. Dunbrack	Hydrographic	Prov. Land Surveyors Cert.
R. M. Eaton	Hydrographic	
J. A. Elliott	Oceanographic Research	B. Eng., Saskatchewan, M.Sc., British Columbia
G. N. Ewing	Oceanographic Research	B.Sc., St. Francis Xavier, M.Sc., Dalhousie.
W. I. Farquharson	Oceanographic Research	
T. R. Foote	Oceanographic Research	2 years Mount Allison.
W. D. Forrester	Oceanographic Research	B.A., Toronto, M.Sc., British Columbia.
V. J. Gaudet	Hydrographic	Prov. Land Surveyors Cert.
G. J. Gibson ¹	Oceanographic Research	B.Sc.. Alberta.
A. B. Grant	Oceanographic Research	
A. C. Grant ¹	Marine Geology	B.A., Acadia, B.Sc., Dalhousie, M.Sc., New Brunswick.

¹ Joined BIO in 1965

W. W. Hall ¹	Engineering	Nat. Cert. of Mech. Eng.
B. B. Hartling ¹	Engineering	Voc. School, Advanced Elect.
RI. A. Hemphill	Hydrographic	
J. M. Higgins ¹	Ships	1st and 2nd Class Cert., Competency.
A. M. Holler	Ships	Cert., Master (F.G.).
A. D. Kenney	Hydrographic	2 years Pre-Eng., Acadia.
F. K. Keyte	Oceanographic Research	B.A., Sydney, Australia, B.A., Hons., Alberta, M.A., Toronto.
L. H. King	Marine Geology	B.Sc, Acadia, Ph.D., M.I.T.
K. RI. Kranck ¹	Marine Geology	B.Sc., McGill, M.Sc., Uppsala, Sweden.
C. J. Langford	Hydrographic	3 years Holcomb Tech. Eng., Merchant Navy Naval School.
D. J. Lawrence ¹	Oceanographic Research	B.Sc., M.Sc., Dalhousie, Ph.D., Queen Mary College.
J. R. N. Lazier	Oceanographic Research	B.A., Toronto, M.Sc., British Columbia.
D. D. LeLievre ¹	Hydrographic	Prov. Land Surveyors Cert.
E. L. Lewis	Oceanographic Research	B.Sc., M.Sc., Ph.D., London.
B. D. Loncarevic	Oceanographic Research	B.A., B.Sc., M.A., Toronto, Ph.D., Cantab
R. H. Loucks	Oceanographic Research	B.Sc., (Hons.), M.Sc., British Columbia.
R. M. McMullen ¹	Marine Geology	B.Sc., Saskatchewan, M.Sc., Alberta, Ph.D., Reading, England.
H. W. MacPhail	Engineering	1 credit Elect Eng.
C. R. Mann	Oceanographic Research	B Sc., M.Sc., New Zealand, Ph.D., British Columbia.
J. I. Marlowe	Marine Geology	B.Sc., Florida State, Ph.D., Arizona.
C. S. Mason	Engineering	B.Sc., M.Sc., Western Ontario, Ph.D., Cantab.
C. D. Maunsell	Oceanographic Research	B.A., M.A., British Columbia, Ph.D., California (Berkeley).
L. P. Murdock	Hydrographic	5 credits on B.Sc.
G. T. Needler	Oceanographic Research	B.Sc., M.Sc., British Columbia, Ph.D., McGill.
I. M. H. Pagden	Oceanographic Research	B.Sc. (Hons), Ph.D., Exeter.

¹ Joined BIO in 1965.

J. M. R. Pilote	Hydrographic	Course in navigation--Tech. Inst., Rimouski.
W. J. Probert	Hydrographic	Prov. Land Surveyors Cert.
L. D. Quick	Hydrographic	Cert., Master (F.G.), 2 years Navigation.
C. Quon	Oceanographic Research	B.Sc., M.Sc., Alberta.
R. F. Reiniger	Oceanographic Research	B.Sc., Saskatchewan, M.Sc., Toronto.
R. C. Richards	Oceanographic Research	B.Sc.. British Columbia.
C. K. Ross	Oceanographic Research	B.Sc., M.Sc., Toronto.
H. Sandstrom	Oceanographic Research	B.A., Toronto, M.A., Ph.D., California
J. G. Shreenan	Hydrographic	B.Sc., (Forestry). New Brunswick. 1 year Teacher training.
G. Smith ¹	Ships	Nat. Cert. Architecture, Oxford School.
S. D. Smith	Oceanographic Research	B.Eng., McGill.
T. B. Smith	Hydrographic	Prov. Land Surveyors Cert.
S. P. Srivastava ¹	Oceanographic Research	B.Sc., (Hons), IIT, Ph.D., British Columbia.
H. Steeves ¹	Oceanographic Research	B.Sc.. New Brunswick.
M. G. Swim ¹	Hydrographic	1 year Acadia.
H. B. Sutherland	Engineering	2 credits Math. Dalhousie.
G. Vilks	Marine Geology	B.Sc., McMaster.
R. N. Vine ¹	Engineering	
R. R. Weiler ¹	Oceanographic Research	B.A., M.A., Toronto, Ph.D., Dalhousie.
K. O. Westphal	Oceanographic Research	Dip. (Hons), Wurzburg, M.A., Toronto. Ph.D.. British Columbia.
R. K. Williams	Hydrographic	

¹ Joined BIO in 1965.

Part B

**The Annual Report for 1965 of the Atlantic
Oceanographic Group, Fisheries Research Board of Canada**

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Part B

The Annual Report for 1965 of the Atlantic Oceanographic Group, Fisheries Research Board of Canada

Director's Remarks

With the steadily growing world need for food, it is a reasonably objective for fishing interests to aim at taking as high a total yield from the sea as is technically and economically possible. Recent years have seen major increases in man's attempts to exploit the world's fish resources and resulting increases in the total yield. However, an important part of the increased yield has not come from the grounds traditionally fished, nor has it consisted of the kinds and sizes of fish and other marine forms which have always been the mainstay of fisheries. Instead, it has depended heavily on catches from newly discovered grounds and on newly developed methods of catching and marketing species once discarded as of no value, or relatively unknown except to biologists. Landings of species such as cod, haddock, and halibut, long most important to countries fishing in the Northwest Atlantic, have increased relatively little, or in local situations have even decreased in importance.

As the world's fishing fleets have grown, it has also been found that the average individual vessel requires better equipment, greater efforts and longer hours of fishing to catch the same amount it could when competition was less keen. Hence, even while total yield has grown, so too has the cost of fishing, often at a faster rate. This, combined with any indication of declining yield, is a clear reason for concern, since it is difficult not to believe that we are already approaching the limit of new fishing grounds and that we may soon reach a practical limit to the new species which can be economically caught and used for human food.

The present high demand for marine fishery products and the certainty that even greater quantities will be needed in the future, make it essential that the meaning of these recent trends in yield, and the potential for future production, be understood. If the indications of slowing increase or even decrease in yields from traditional fisheries are reflections of a general phenomenon, there is undoubtedly need for re-

strictive regulations aimed at limiting ourselves to those rates of fishing which will ensure the maximum long-term yield commensurate with acceptable economic returns. On the other hand, if the declines are not signs of an overall limit in the rate of production of valuable forms, it is essential that fishing interests be free to continue development of what has always been regarded as one of the potentially richest sources of the food needed by mankind. It is the ultimate task of research in fisheries oceanography to provide information on production systems in the sea which will permit us to decide between these alternatives.

Problems of Management in Open-Sea Fisheries

The phenomena of slowing increases in total yields and increasing costs of fishing, appear to characterize the development of any fishery and are not in themselves a sign of overfishing. In fact, fears of the possible consequences of "overfishing" based on this kind of evidence were expressed over 300 years ago--before any substantial fisheries existed--and even then resulted in enforcement of restrictions on fishing. Today almost all of the great sea-fisheries are subject to some sort of regulation and extensions of regulations are accepted as inevitable consequences of further fishing development. The restrictions that exist have taken different forms in different areas, and claims-and counter-claims have been made for their success. However the complexity of the fish communities and of the effects of the environment, together with the difficulty of using changes in catches to measure changes in abundance or productivity have posed formidable problems in collection and interpretation of relevant data. Therefore the validity of the claims for successful management, or of the predictions of the long-term effects of fishing, have yet to be firmly established in any particular area.

For want of the information needed to assess the effects of exploitation and management, industry, government, and scientists, have been forced to resort to theoretical formulations largely

based on analogy with experience gained in management of small water bodies or on land. This experience covers a wide range. On the one hand, park areas or preserves have been set up, where significant interference by man is prohibited. This helps to ensure that the present state of these areas is preserved on account of their recreational, study or general cultural values; but protective management of this type is not designed for "production" in the usual sense. On the opposite extreme are farm lands and pond areas where the application of knowledge evolved from detailed studies and experiments, have led to highly complex and profound manipulation and resulted in rates of production which are now many times higher than was thought possible under natural conditions a century ago. The methods of management evolved for controlling exploitation of terrestrial resources have clearly demonstrated their worth. The continued imposition of controls on open-sea fisheries apparently stems from expectations of equal success by the application of similar methods.

Unfortunately, despite the successful record of terrestrial and fresh-water management, there are serious doubts that this experience provides a reliable basis for guiding the exploitation of the sea. On land, and even in small bodies of fresh water, man has to do with a relatively stable, two dimensional, environment containing rather immobile plants and animals. Not only is it possible to enumerate and study these situations in detail, but the numbers and kinds of plants and animals in them can be largely controlled and manipulated. The basic fertility of the soils and water can be controlled, and rather precise calculations of the productive capacity and results of particular manipulations can be made, within the limits imposed by changing climates. The sea presents an essentially different situation. The sea surface and sea floor are important interfaces near which many important biological and physical actions occur. But the system is essentially three-dimensional and the whole water mass is subject to a dynamism foreign to terrestrial experience or scales of measurement. The contained life is complex, subject to rapid temporal changes and in most cases highly mobile. Even the pasture, in the form of phytoplankton zones in the broad ocean currents, refuses to remain in one place for long.

With such different physical and biological conditions in the sea, it is reasonable to expect

that the requirements for manipulation as well as the results of management are likely to be very different from those on land. In the open sea, there is no likelihood of "farming" or cultivation in the usual sense and there seems no need for it; the "fields" of the sea are being continuously re-fertilized without man's intervention. In most cases man cannot corral and husband the animals in the sea. Efforts in this direction seem largely superfluous since with a few notable exceptions, such as marine mammals and possibly sharks, most marine animals confined to the open sea appear potentially capable of producing large numbers of eggs and larvae and of sustaining their reproduction naturally despite heavy fishing of the parent stocks. Such properties suggest that instead of restriction of the basic exploitation and carefully calculated manipulation of the environment, there may be in the sea a system requiring highly selective but sometimes heavy exploitation if we are to take full advantage of the productive potential which exists.

Special Problems of Near-Shore Fisheries

One of the most important factors dictating differences in our approach to terrestrial and oceanic production systems is the time and geographic scale of the phenomena involved. In the same way, considerations applicable to the open-sea are not necessarily appropriate to small bays, estuaries or near-shore areas, though all are marine environments. Water movements in these "fringe" areas are restricted, and the quality of the water in them strongly influenced by the character of the adjacent land masses. Physical characteristics, re-fertilization processes, production-potential and pathways of energy flow in them are subject to terrestrial influence and may be vastly and rapidly altered, accidentally or intentionally, by man's activities. Special problems thus emerge which are more nearly comparable to those on land; dangers of pollution are immediate, and cultivation by planned manipulation is already possible and practiced on varying scales. Special studies of inshore areas are therefore desirable from the point of view of their special potentiality, analogous with that already realized on land.

This variety of marine situations makes complete generalization of problems of management a false simplification. It may, nevertheless, reasonably be expected that biological and physical systems in the smaller near-shore areas

will share many of the features of the open sea. In this sense, near-shore or coastal areas may be regarded as microcosms which provide models of the larger marine environment. Since the areas are also open to detailed study and offer opportunity for testing hypotheses by experimental manipulation, they are especially valuable for the scientific study of marine production processes. Judicious application of the knowledge gained from the study of such "microcosms" makes the study of vast oceanic areas a far less formidable undertaking than it would otherwise be.

Present Knowledge and Future Needs

It is obvious that the choice of the appropriate philosophy and methods of using the marine environment depends upon a highly developed body of knowledge of the system as a whole. At the present, we have no such information for the open sea, nor indeed for any part of it. It is even questionable whether such knowledge yet exists for the smaller more accessible fresh-water systems in lakes and ponds. What is more, the research required to bring our knowledge to this level is costly and time consuming. Man pursues it, partly because of the challenge of such a vast unknown area so near at hand, but perhaps more importantly because he can see that full use of its resources could have as profound an influence on his life and culture as did the use of petroleum when he learned to extract it from the land. Fortunately the technological advances which have made possible the recent profitable expansion in fisheries exploitation and yield are rapidly being matched and complemented by advances in the technology of the marine sciences. Applications of much of it are still in their exploratory stages, and much remains to be done. But the information already made available gives added reason to pursue investigations of the system and its potentialities.

Scientific studies of the past 10 years have shown that the production of fish from the oceans, even at its present record high rate, is only a tiny fraction of the total energy from the sun which is fixed in organic material forming the basis of the marine food chains. Within the past 5 years there have been major discoveries of new and surprising pathways by which this energy is made available to the larger and more complex forms of marine life which man can harvest. There have been new developments in knowledge of the physical structure and dynamics

of the sea itself, of the ways in which these factors influence the distribution and behaviour of marine life and in the instruments necessary for finding and fishing the larger marine organisms, all vastly increasing the efficiency of man's harvesting efforts. New insights into the complexity of the structure and organization of the marine communities have also been gained, together with new notions of the types of interventions which might be expected from intervention by fishing. Finally, it has been found that, except where the environment itself is drastically altered, exploitation activities on the present scale or on the scale likely to be supported in the near future, do not appear to impair the basic productivity of the system, although they may alter the composition and character of the biological populations produced.

Such findings do not yet provide a sufficient basis for fisheries management, although they would appear not to support the age-old arguments that restrictions of fishing are the best or only way to ensure continuation of the kinds and amounts of food harvest which are needed. Any well based management scheme obviously requires additional knowledge of the marine community as a total production system. Moreover, the knowledge is needed in a detail which rivals or exceeds that used by the farm manager when he makes the decision as to whether the raising of cows, pigs, sheep, or a combination of them on a given piece of land is likely to yield him greatest benefits, or by the forester, who must ensure when he calculates his harvest from a given stand that his practices will not result in the replacement of the trees by species that are useless to him. At the present state of our knowledge of the sea, little seems certain except that its total production capacity is very great indeed, and that the potential production cannot be realized if the fish are left in the sea to die of old age. Yet it is ill-advised to harvest existing "crops" too quickly if there is real danger that thereby they will be replaced by a "field of weeds".

Each period in the development of our complex civilization poses problems of its own. In our exploitation of the sea our experience suggests that we are faced with several such major problems. One of the first is the continued technological development of means of economically harvesting and using these natural resources for food and other products needed by man. A second is the discovery of the meaning

of the changes in fishery yields in relation to increasing exploitation, and their implications for future yields. Another is the discovery of the mechanisms and pathways controlling the production system. Only with such information can it be hoped to prepare the way for that type of selective, controlled, and possibly heavy exploitation, which appears necessary for a continued increase in the yield from natural resources. In marine areas near the coast, there is the additional need to prevent inadvertent pollution and to promote and exploit opportunities for cultivation.

The Fisheries Research Board's Atlantic Oceanographic Group at the Bedford Institute of Oceanography

It is with an eye to the solution of some of these challenging problems of production in marine environments that the Fisheries Research Board (FRB) has begun the expansion of the Atlantic Oceanographic Group (AOG) as an independent marine research laboratory associated with the Marine Sciences Branch of the Department of Mines and Technical Surveys (DM&TS) in the Bedford Institute of Oceanography (BIO). The studies of the new laboratory will be focused on those physical and biological processes underlying marine, especially fisheries, production. In broad terms this is the study of how the energy of the sun becomes transformed into usable nutrient materials, and how these can be harvested by man. This is an objective shared with marine research laboratories elsewhere; it is hoped that contributions to the common pool of information by this new addition will help with the early development of the knowledge needed.

The Fisheries Research Board's association with other groups and government departments in BIO seems especially opportune. The Institute provides special opportunities for exchange of information and facilities which enables general use to be made of new technological achievements in fishing, electronics and physical oceanographic measurements. Even more important is the juxtaposition of scientists in both biological and physical disciplines with a common interest in the study of the sea. The association has already resulted in many interdisciplinary discussions, sharing of scientific knowledge, and has led to the planning of joint programs. At the same time, the developing association with the staff of the Institute of Oceanography at Dalhousie University in par-

ticular, as well as other marine-oriented research institutes of the Halifax area, will help ensure that the knowledge gained will be widely based and provide well-founded insight into the marine production system.

Summary of Research Programs

With such background and prospects a brief statement of the research projects in progress is presented here. More detailed summaries by individual investigators are appended. They cover a wide range of topics, but taken together they indicate something of the scope of the individual researches necessary to support a broad program of the sort implied above. In what follows the reports have been arranged under two primary headings corresponding with the commonly distinguished biological and physical sciences, and entitled here: **biological** and **environmental** oceanography.

Biological oceanography

Biological oceanographic studies underway at the laboratory may be considered as falling into two main areas. The first of these is the description of pathways and measurement of amounts and rates of transfer of energy in the biological communities. Such studies pose special problems, initially, in the identification of parameters which will be meaningful in the terms usually used to describe physiological and behavioural characteristics of animals and which can be readily measured by available techniques. The reports given below consider the usefulness of relations among growth, food, and metabolism to describe the energy systems of individual fishes, and to lead to predictions of the amount of energy channelled into "production" processes. The possibility of establishing the form of the functional relationships among these quantities by laboratory study, and the possibilities of field applications are also considered. Parallel with these studies of interactions at the higher trophic levels are the studies of the base of the food chains, in the vast field of primary-secondary trophic interactions. Important contributions to an understanding of energy exchange in this part of the system may be made by combined use of laboratory and field measurements of phytoplankton organisms and their predators. As is pointed out in the reports, studies of the dinoflagellates which produce identifiable metabolic substances and pass them on, unaltered, to their predators may prove particularly

rewarding and are being developed with this in mind.

The second main area of biological oceanography is the study of the structure and degree of organization of the biological system in nature. It is these features of the system which control the availability of the energy for transfer, either as food for plants and animals or as catches for fishing vessels. Information on this subject may be most readily developed with respect to the fish populations and fishing vessels, and is in any case relevant to an understanding of factors determining fishing efficiency and success. Some of the information available on the structure of local fish populations has been assembled and the first analyses of these data as well as preliminary consideration of methods required to assess their significance in characterizing the system are reported. Further progress in studies of the bottom communities is also reported. The sea floor is undoubtedly the site of major energy transformations and transfers, although the special sampling problems involved have hindered adequate descriptions of the communities themselves for many years. Studies reported below, using a standard sampling device, have revealed some diagnostic characteristics of the species structure of communities in the bottom sediments as well as significant relationships between the biomass of the dominant species and substrate characteristics.

Environmental oceanography

Studies of environmental oceanography are being conducted in three main areas along those lines which are most strongly associated with the biological studies. The first is the study of the physical properties of sea water and its energy load, in relation to local circulation and distribution patterns. Studies in the Gulf of St. Lawrence area in particular have shown features of the local circulation of surface waters which appear likely to be significant in the understanding of the distribution and abundance of many organisms and which may indicate important sites of local production. Similar phenomena have been observed and studied in estuarial areas where they seem especially likely to influence the distribution and movements of the larger anadromous fishes such as salmon. The second area is the study of chemical properties of sea water. While much has been written about the importance of the sea as an environment for plants and animals, surprising gaps exist in our knowledge of its basic chemical properties. Researches reported below have been

devoted to filling some of the gaps most obvious from the point of view of biological systems, such as the solubility of calcium carbonate at temperatures below 15°C and the determination of activity coefficients for some of the most common ion complexes. The third important area is the study of the geology and geochemistry of the sea floor. Information on most of our important production areas has been meagre. The reports summarized below record the development of background information on broad features of the geology and geomorphology of the Gulf of St. Lawrence, indicating the origin and areas of deposition of the sediments. The results have given valuable information on persistent features of the general circulation. The character of the sediments has been found to be correlated with the distribution of bottom organisms in certain areas. Work on the chemical activity of the sediments has begun as a basis for understanding more of the nature of both the physical and biological energy exchanges at this important interface.

Future programs

It will be obvious that while present studies already cover a wide range of scientific specialties, the problems faced in a study of production processes and how to take advantage of them require an even broader range. The competence of the Dartmouth laboratory to carry its share of the tasks facing fishery science depends not only on substantial strengthening of research capacity in the fields already represented, but extensions into other fields. Recognizing these needs it is planned that future activities will be expanded into the mathematical and physical sciences, with immediate attention to physical oceanography and instrumentation.

Past work of AOG has centred on developing knowledge of the environment in areas where there are important fisheries, particularly in the Gulf of St. Lawrence. In the new programs in general fisheries oceanography, it is hoped to take full advantage of this background. Where possible, special biological and physical field studies will be developed in the Gulf. A particular advantage of this plan is the interest also being shown in studies there by other marine research institutes in eastern Canada, hence the possibility of cooperative programs on a rather wide scale. Investigations are already underway there by the FRB Biological Station at St. Andrews, N. B. and its sub-station at Eglarville; the Department of Fisheries of the Province of Quebec, Station de Biologie at Grand Rivière;

the Institute of Oceanography at Dalhousie; the Marine Research Centre of McGill University and by several sections of the Marine Sciences Branch of DM&TS in BIO. The area is too large to permit any of these organizations to contemplate synoptic surveys over a long period of time, but the cooperation by these laboratories in special research projects should soon give a broad understanding of the Gulf as a production system.

Information on a marine system of the size of the Gulf of St. Lawrence or even larger is essential to long-range objectives in fisheries oceanography. However, information on marine systems is needed in a detail which will not be quickly available from areas of this size. It is therefore proposed, in addition, that the staff of the Dartmouth laboratory will devote a considerable part of its initial effort to the study of St Margaret's Bay, a small bay near the laboratory. Proximity to the laboratory not only facilitates its study by the permanent staff, but will make it possible to use the bay and facilities employed there in the training of term assistants and university students whose time for field observations may be rather restricted. The bay is large and deep enough to suggest that it may be a microcosm representative of certain features of larger marine systems, and at the same time provide us with useful knowledge of opportunities for manipulation or management of near-shore areas.

L. M. Dickie

FRB Staff List

Director and administration

L. M. Dickie, B.Sc. (Acadia), M.Sc. (Yale).
Ph.D. (Toronto) (from 1 July, 1965).

M. Blaxland (from 2 August, 1965).

Hilda K. Gamester

Sandra H. M. Rushton

Sylvia M. Smith (from 1 October, 1965).

Environmental oceanography

R. W. Trites, B.Sc. (UNB), Ph.D. (UBC).

D. H. Loring, M.Sc. (Acadia), Ph.D. (Manchester).

R. F. Platford, M.Sc. (UBC), Ph.D. (Saskatchewan).

B. L. Blackford, B.Sc. (Acadia), M.Sc. (MIT), (to 8 September, 1965).

T. C. Platt, B.Sc. (Nottingham), M.A. (Toronto), (from 22 June, 1965).

G. B. Taylor

C. J. Bayers

C. C. Cunningham

R. J. Lahey

T. A. Grant

W. B. Fraser

S. R. McHughen (from 25 May, 1965).

Biological oceanography

A. Prakash, B.Sc. (Delhi), M.Sc. (Allahabad), Ph.D. (UBC).

Vivien M. Brawn (Srivastava), B.Sc. (Reading), M.Sc. (Durham), Ph.D. (UBC) (from 2 August, 1965).

E. Kott, Ph.D. (Toronto), (from 28 July, 1965).

D. L. Peer, B.Sc. (UNB), M.Sc. (Saskatchewan).

M. Hodgson, B.Sc. (Dalhousie).

R. J. Bentley, B.Sc. (Reading), (from 8 November, 1965).

Alma M. Holland, B.Sc. (Memorial), (from 14 September, 1965).

Summer assistants

C. Purcell

B. Pottie

T. Dafoe

Judith Wood

D. J. G. Nota, M.Sc. (Leiden), Ph.D. (Utrecht).

1965 Publications of FRB Staff

Scientific journals

- BRAWN (SRIVASTAVA), V. M. 1965.¹ Alexander's method of determining swim-bladder volumes modified for living physoclist fish. *J. Fish. Res. Bd. Canada*, **22** (6): 1555-1558.
- DICKIE, L. M.,¹ and J. E. PALOHEIMO. 1965. Heterogeneity among samples of the length and age compositions of commercial groundfish landings. *Res. Bull. int. Comm. Northw. Atlant. Fish.*, No. **2**, p. 48-52.
- DICKIE, L. M. 1965.¹ Difficulties in interpreting trends in cod and haddock landings from the eastern Scotian Shelf. *Ibid.* No. **2**, p. 80-82.
- DUMBROWSKI, H., C. G. I. FRIEDLAENDER, R. KUHN and D. H. LORING. 1965. Bacteriological investigations of Carboniferous rock salt from Pugwash, Nova Scotia. *Ecologiae* (in press) p. 967-974.
- LORING, D. H. 1965. Resume of geological investigations by the Atlantic Oceanographic Group. *Maritime Sediments* **1**: 7-8.
- NOTA, D. J. G., and D. H. LORING. 1964. Recent depositional conditions in the St. Lawrence River and Gulf. *Marine Geology*, **2** : 198-235.
- PALOHEIMO, J. E., and L. M. DICKIE. 1965.¹ Food and growth of fishes. I. A growth curve derived from experimental data. *J. Fish. Res. Bd. Canada*, **22** (2): 521-542.
- PLATFORD, R. F. 1965. Activity coefficients of the sodium ion in sea water. *J. Fish. Res. Bd. Canada*, **22**: 885-889.
1965. Activity coefficients of sodium chloride in sea water. *J. Mar. Res.* **23**: 55-62.
- PLATFORD, R. F., and THOMAS DAFOE. 1965. Activity coefficient of sodium sulfate in sea water. *J. Mar. Res.* **23**: 63-68.

Manuscript reports or unrefereed publications

- BLACKFORD, B. L. 1965. Some oceanographic observations in the southeastern Gulf of St. Lawrence--summer, 1964. *Fish. Res. Bd. Canada*, MS Rept. (Oceanogr. and Limnol.), No. 190.
1965. Results from a current meter moored in Kouchibouguac Bay June and July, 1964. *Fish. Res. Bd. Canada*, MS Rept. (Oceanogr. and Limnol.), No. 196.
- LORING, D. H., and R. J. LAHEY. 1965. Rapid silicate analyses of marine sediments. *Fish. Res. Bd. Canada*, MS Rept. (Oceanogr. and Limnol.), No. 189, 56 p.
- MACINTYRE, W. G. 1965. The temperature variation of the solubility product of calcium carbonate in sea water. *Fish. Res. Bd. Canada*, MS Rept. (Oceanogr. and Limnol.), No. 200.
- PLATT, T. 1965.¹ Computer analysis of beam handling system for a linear accelerator. M.A. Thesis, Univ. of Toronto.
- PRAKASH, A. 1965. Physiological ecology of the causative organisms including mechanism of toxin accumulation in shellfish. In Rept. of the Joint Sanitation Seminar on North Pacific Clams. Alaska Dept. Health and Welfare and U.S. Public Health Service, Sept. 1965, Juneau, Alaska (in press).

¹ Articles submitted for publication prior to date that staff member joined AOG.

Investigators' Summaries of Current Research

Biological Oceanography

Effects of food and temperature on the relation between metabolism and body size

In an earlier publication ("Food and growth of fishes. I. A growth curve derived from experimental data" J. E. Paloheimo and L. M. Dickie, 1965. *J. Fish. Res. Bd. Canada*, **22**: 521-542) we have noted that it is possible to describe the growth of fishes, $\Delta W/\Delta t$ in relation to the experimentally measurable variables, body size (W), food intake (R), and total metabolism (T). The experimental evidence of the nature of the relation between T and W , and its dependence on R and temperature are reviewed in a paper now in press. Making use of the basic energy equation $pR=T+\Delta W/\Delta t$, where p is a term for correction from ingested to utilizable energy, we calculate an index of T as the difference between the energy equivalents of R and $\Delta W/\Delta t$ for comparison with results of oxygen consumption studies. Application to a number of published experimental results suggests that with constant food availability, the index of metabolism, T , from feeding experiments, shows the same rate of change with body weight, W , as has been found by oxygen consumption studies under standard conditions. That is, the two sources of data provide estimates of a common γ in the relation.

$$T = \alpha W^\gamma$$

where α and γ are the fitted constants for the curve.

When fish are fed on a "maintenance" diet, the value of α calculated from the food consumption, appears to correspond with that characterizing the "routine" metabolic level in oxygen consumption studies. Higher α levels result from higher levels of food availability and at *ad libitum* feeding α approaches levels known in oxygen consumption work as "active" metabolic levels. Temperature effects in the experiments were estimated from multiple regression analyses and showed an elevation of α with increasing temperature. The long-term effect of temperature on α was comparable with that predicted by the Krogh correction at *ad libitum* feeding, but was

significantly lower when food was limited, as at "maintenance" feeding.

From a survey of effects of different designs of feeding experiments on these metabolic parameters, it appeared that apparently aberrant values of the weight exponent γ may instead be mistaken interpretations of gradual changes in the level of metabolism α . That is, within limiting conditions of standard or active metabolism, changes in temperature or manipulations of the food supply by the experimenter elicit adaptative responses in the level of metabolism. These show up as effects on γ when the changes are gradual, hence confounded with body-size changes during growth.

If it can be shown that relations similar to those found under controlled conditions apply in the natural environment, this type of formulation permits us to judge the relative intakes of food of different sizes and species if their metabolic level and growth are known. Such information is essential to an understanding of the relative abilities of animals in a community to make use of their energy resources.

J. E. Paloheimo
L. M. Dickie¹

Relations among food, body-size and growth efficiency in fishes

Our earlier studies have indicated conservatism in the response of the relation between total metabolism and body-size in fishes to changes in the level of food availability and temperature. This suggests that a similarly definable relation may exist between these variables and the remainder of the energy system represented by growth. Our further investigations of the relationship between growth and feeding appear to verify this. From them we conclude that the logarithm of the gross growth efficiency, defined as the ratio of the energy equivalents of growth to food intake, decreases linearly with increase in the food energy intake.

Data from experiments reported in the literature suggest that this growth-efficiency relationship is affected by a number of factors. For a

¹ Member of staff of FRB Biological Station, St. Andrews, N. B.

particular type of food, and a constant level of temperature and food availability, the rations intake is highly correlated with body size although during a given growth period the range of body size is the greater. In such cases, log growth efficiency can be predicted from either rations intake or body size. In experiments where the feeding level is varied so that there is no longer a correlation between rations and body weight, log growth-efficiency can be predicted only from the rations. Differences in temperature level within the usual temperature range of the species appear to affect the long-term growth efficiency only indirectly through their effects on the rate of rations intake, and not to otherwise alter the partitioning of the energy flow into metabolism and growth. Short-term temperature fluctuations or encounters with temperature extremes may lead to more complex effects. Changes in factors such as salinity appear to affect the basic distribution of energy and may differ with body size, hence alter both the slope and position of the growth-efficiency lines.

While there is little specific information on the effects of other factors the data available suggest that the type of food is the single most important factor controlling parameters of the growth-efficiency line. Within wide limits, changes in caloric contents or nutrients per unit weight of food may be relatively unimportant. However, increases in particle size are associated with marked decreases in the slope of the efficiency line, and may affect its position as well. Such results, viewed in conjunction with experimental data relating the success of grazing to the variance of the food distribution, lead to the conclusion that the food-particle-size effects arise primarily from differences in the food intake per unit metabolic expenditure for searching and ingesting food particles.

Such findings are in keeping with the conclusions of other investigators that food is the most "potent" factor determining growth efficiency, and that production processes are in general independent of body size. They suggest furthermore that in the growth efficiency curves we are dealing with one sensitive manifestation of the integrative-regulatory mechanisms by which fish maintain themselves in a particular environment. As such, information on growth efficiency curves may be used to characterize the position of life history stages of various species in the natural production chains.

J. E. Paloheimo
L. M. Dickie

Red blood cell parameters as indicators of metabolic level of fish

If the energy dynamics of natural fish population are to be studied, a field technique to measure the level of metabolism must be developed. The standard laboratory method of measuring oxygen consumption is impractical for free swimming animals collected in nature from deep water. However, the blood is one of the main oxygen transport systems in the body and the long-term level of oxygen consumption may be reflected in values of certain blood parameters, such as cell number and size, or in the biochemistry of the red blood cells, and remain unaffected by responses of short-term stress conditions to which fish are subjected during capture.

If water temperature is kept constant, oxygen consumption appears to be determined by: (1) the body weight of the fish; i.e., metabolism (T) as expressed by oxygen consumption is related to weight (W) by the expression $T = \alpha W^\gamma$ where γ is a constant and α is the level of metabolism and, (2) by varying the amount of food taken by the fish. In case (1) it appears that if fish of different weights are fed metabolically equivalent diets, α is likely to be constant; in case (2) feeding of fish of the same weight on different amounts of food should result in different values of α . Changes in some of the blood parameters or biochemistry of the blood cells may be related to these changes in level of metabolism.

The parameters at present under consideration for experimental study are: number of cells/unit blood volume, mean cell volume of red blood cells, carbonic anhydrous activity/rbc, and [Zn]/rbc. It is intended to study changes in these parameters in relation to changes in level of metabolism determined by accepted methods in experimental tanks. If they show suitable stability it may be possible to estimate the level of metabolism of populations in the field by analyzing blood samples.

Edward Kott

Fish physiology and behaviour

Studies reported in the preceding summaries suggest that certain characteristics of energy uptake and utilization in fishes are sensitively reflected in their physiological and behavioural adaptations. The implications of such relationships for understanding processes underlying

natural production point to a need to examine their functional form, particularly the effects of searching and grazing activities, food availability and food consumption on metabolic levels and growth. Experimental analyses of some of these factors, and their relations in marine fishes are planned. However, they require special equipment and facilities not at present available at BIO. During recent months attention has therefore been directed to a review of the literature and to the design of a suitable laboratory building and provision of a reliable sea water supply of suitable quality. Preliminary plans for the building and sea water supply are complete and construction is expected to begin soon. Studies of salinity and temperature distribution in Bedford Basin are underway, to determine the depth to the sea water intake. Specifications of major components of laboratory equipment have been determined through the generous cooperation of staff at FRB, Biological Station, St. Andrews, N. B. An evaluation of a new commercially produced oxygen probe and meter for monitoring oxygen consumption by fish in tanks and to determine oxygen levels in the sea has also been completed.

V. M. Brawn (Srivastava)

Physiology and ecology of marine dinoflagellates

One of the principle problems associated with the understanding of production processes in the sea lies in our lack of knowledge of the efficiencies of transfer of the energy fixed by photosynthesis in the phytoplankton to the zooplankton, and of the factors which determine the rates of the transfer. Limitations at this stage may in large measure account for the failure of scientists to be able to correlate indices of production at the higher trophic levels with the knowledge of production rates at the lower, especially primary trophic levels. Manipulations of laboratory cultures of the dominant plant and animal forms provide a potentially important source of such information. Among them the dinoflagellates are an especially important group. With this in mind, work in the culture of marine dinoflagellates is being continued and expanded, with particular attention to those responsible for producing "shellfish toxicity".

Four species of *Gonyaulax* from the Bay of Fundy, California, British Columbia and Ply-

mouth, U.K., have been brought into unialgal cultures and are being maintained in enriched sea water media in our laboratory. Examination of the major physico-chemical and biological factors which favour growth of *Gonyaulax* in the laboratory cultures as well as in nature has been completed. Future work is contemplated to examine the role of micronutrients in addition to comparative general physiological and ecological studies.

Particular attention has been given to the pattern of toxigenesis during the entire growth phase in unialgal nonaxenic cultures of *Gonyaulax tamarensis* and *G. catenella*. There is experimental evidence to show that the former carries a three to ten times higher poison load per cell than the latter. Toxigenesis appears to be a clonal trait and apparently a continuous process throughout the growth phase of a culture. The relationship between the levels of toxin and the numerical abundance of *Gonyaulax* is now fairly well established.

Of particular importance in understanding energy exchanges at these lower trophic levels is the question of the rates of reproduction of the primary producer relative to the effects of grazing on them by zooplankton. Our field and laboratory observations have provided indications that tintinnids exert a substantial grazing pressure on dinoflagellates population and thus may play an important role in determining the size of standing crops and life history of the blooms. There is also some indication that these grazers are selective in their feeding. Meaningful estimates of grazing rates by zooplankton under particular conditions could be made using toxicity levels in the predator and prey as a measure of energy transfer. Such techniques require monospecific cultures of grazers but so far our attempts to culture tintinnids in enriched sea water or artificial media have been unsuccessful. Additional work is contemplated in this direction.

A. Prakash

Frozen sea water and water quality

The study of frozen sea water grew largely out of interest in the problem of assays of quality of natural sea water which in certain seasons and certain areas supports faster growth of plankton species than in others. Preliminary studies have shown that major nutrient com-

ponents of sea water do not undergo significant changes in quality when particulate-free sea water is frozen immediately after collection and stores in the dark at temperatures below -20°C over a period of several months. However, we have reason to believe that previous work in this field has not sufficiently recognized the importance of removing organic as well as inorganic detrital elements prior to freezing.

In experiments in which we have used particulate free frozen sea water collected during different seasons from one location in the Bay of Fundy as a growth medium for *Gonyaulax* cultures, we have found growth rates comparable to those found in nature during the season of collection. It therefore appears that the biological growth potential of sea water with regard to dinoflagellates is not lost by this treatment implying that none of the important growth factors has been significantly altered. Further possible applications of the method to bioassay of water quality are being explored.

A. Prakash
M. Hodgson

Heterogeneity among commercial samples of fish populations

Landings of commercial vessels provide a source of more extensive, hence potentially more representative samples of the characteristics of fished populations than are afforded by any other sampling system available. However, before such data can be confidently used to provide indices of relative abundance of sizes and ages, as a basis for calculating growth and mortality rates it is necessary to establish the reliability of estimation of these characteristics. Prior to the time that the senior author joined the staff at BIO, the co-authors carried out such a study on commercial groundfish records collected and compiled over a 14-year period by the staff of the Biological Station, St. Andrews, N. B. Detailed results are published as shown in the publication list. It is expected that studies of similar nature will be extended to other population sampling data in an effort to more clearly explain the results.

Basically, the method used in analysis was the x^2 test comparing deviations of length and age compositions of individual samples or groups of samples from their general mean. However, because the calculations of numerous x^2 values

for many comparisons are time-consuming and cumbersome we used instead the system of information statistics which is asymptotically equivalent to the x^2 statistic. The system has the advantage of additivity of the sub-set values. Hence sub-totals may be used to calculate approximate x^2 values within and between sub-sets for an analysis of the sources of variation among samples.

In summary, the calculations for length distributions showed that the x^2 to degrees of freedom ratios were generally high (about 4.0 to 35.0), indicating that the differences among samples were greater than would be expected from random variations in successive samples from a homogeneous population. Analyses by subsets indicated significant differences between seasons of collection, and fishing grounds, as well as differences in the relative importance of these variables from year to year. However, stratification of the samples into the finest possible unit sub-divisions showed significant heterogeneity remaining within these units. There also appeared to be an increase in the measure of heterogeneity with increases in the numbers of samples taken.

While we do not have an adequate understanding of the degree to which sampling of the individual vessel catches contributes to the overall heterogeneity, our measures did reflect the influence of fishery and population changes detected in other data. Furthermore, the measures of heterogeneity are roughly comparable to similar measurements made from research vessels where the deck sampling program is carefully controlled. It therefore appears that the measures are reflecting real biological heterogeneity of population elements, relative to the sizes of areas effectively searched by fishermen. This conclusion is supported by the fact that more sampling turned up more such sources of variability.

Such results suggest that a rather extensive sampling program is required before records taken from commercial catches can give a reliable picture of the population composition. They also indicate, however, that there must be considerable complexity in the organization of the fish populations, possibly resulting from direct aggregations or schooling by size, or from differential response by size to unevenly distributed environmental conditions. They imply a greater importance of such biological heterogeneity in

community dynamics and availability of fish for capture than has sometimes been recognized by fisheries ecologists.

L. M. Dickie
J. E. Paloheimo

Schooling in predator-prey relations

Numerous observations have shown that clusters or schools are a common feature of animal and plant communities. Attempts to understand their significance have included observations of the differences in physiology and behaviour of isolated and grouped animals. While there are large differences, the results suggest no unequivocal direct relation to survival of prey and predator or to the role of clustering in the community trophic relations. Direct observations of the interactions of groups in a variety of predator-prey systems suggest that groupings may at times be advantageous and at others disadvantageous: the complexity of effects seeming to defy simple generalization. A theoretical conceptualization of such systems seems appropriate as a basis for guiding further study.

Earlier formulations of predator-prey systems such as those of Nicholson and Bailey and of Ricker have tended to ignore the effects of schooling. Studies such as those of Neyman on schooling and catching of fish have assumed that the school size is fixed, an assumption not supported by observations in nature. We have developed a method of studying predator-prey models based on statistical renewal theory which avoids these limitations.

In this system the prey schools can be considered as either discrete clusters or as dense schools comparable to either discs or balls. Cluster or disc size, as well as the numbers of individuals per cluster or disc is variable, and the system also takes into account the fact that after encountering its prey the predator may take appreciable time to attack and consume or digest it before resuming its search.

The model shows several features which appear relevant to interpretation of natural observations. Excluding possible effects of fatigue or starvation, and assuming unlimited "storage" capacity on the part of the predator, schooling of the prey does not affect the predator's catch so long as a school is detected only from the same distance as is a single prey. Since clusters are more readily detected, grouping or

clustering increases the predator's total take per unit volume. Where the predator has a limited storage capacity, the predator's take reaches a maximum at intermediate school sizes, and the model suggests a criterion for deciding when schooling is or is not advantageous to prey survival.

J. E. Paloheimo
L. M. Dickie

Benthic communities of the Magdalen Shallows

Results of initial studies, designed to characterize and measure the biomass of mud and sand bottom communities in the southwestern Gulf of St. Lawrence were described in last year's annual report. Further quantitative samples of benthic fauna of this area were obtained from 12 stations occupied in July, 1965 by the CNAV *Sackville*. Four of the stations were in the area southeast of the Magdalen Shallows, the remainder to the west of the Magdalen Islands.

Sorting and identification of two of the samples taken in the southeast area this year have been completed as have further samples from the 1964 collection. The results confirm previous indications that there are major station-to-station differences in the biomass (wet weight/m²) in communities dominated by the Amphipod *Harpinia* sp and the Cumacean *Diastylis rathkei*. A correlation between the combined biomass of these two organisms and the mean diameter of sediment particles, which appeared last year on the basis of preliminary analyses, is supported by study of additional samples from the area. The relationship appears however, to be independent of the total biomass estimated for the stations. No similar relationship has been found in apparently similar although shallower bottom-type communities in Northumberland Strait. Major differences in communities of the two areas might perhaps be expected from the differences in the range and stability of the water temperature between the two situations, however, further sampling studies are necessary to test the significance of these preliminary observations.

D. L. Peer

Northumberland Strait causeway area benthic fauna

The reasons for particular relationships between bottom communities and the nature of

the substrate are poorly understood, except in terms of broad behavioural and structural adaptations of some of the principal species comprising them. For further understanding the investigator is often dependent on comparisons between different types of areas, or observations of particular areas over a long enough time period to include significant changes in the environment and community. Opportunities to study areas abruptly altered by major engineering developments are therefore a valuable potential source of information. One such opportunity is presented in the proposed construction of a nine-mile causeway across Northumberland St., linking Prince Edward Island with the mainland.

From October 13-15, 1965, benthic fauna samples were taken at 12 stations located in the Cape Tormentine area of Northumberland Strait. These are intended to provide a guide for a subsequent comprehensive survey in conjunction with lobster investigations at FRB, Biological Station, St. Andrews, N. B. Studies of the bottom sediments have been undertaken by staff of the Geological Survey of Canada in BIO. This cooperative program will be designed to provide baseline information on the aquatic community and its environment and to follow at least major changes subsequent to the construction of the causeway.

The preliminary survey was designed only to indicate the general nature and complexity of the communities as a basis for setting up an adequate sampling system. Multiple samples were taken with a Van Veen grab sampler and washed through a 0.2 inch mesh; only relatively large organisms were retained. The samples have not yet been examined in detail, although earlier sampling at the Western end of Northumberland St. and off Richibucto during 1964 indicated two types of sand bottom communities there. The inshore community in shallow water (5-6 fathoms), was characterized by the polychaetes *Leiochone dispar* (Verill) and *Sthenelais limicola* (Ehlers) with occasional specimens of *Nephtys ciliata* (Müller) *Ammotrypane aulogaster* (Rathke), *Ophelia limacina* (Rathke), *Scoloplos robustus* (Verill). A sand bottom community further offshore contained the following species of polychaetes none of which were found in the inshore community: *Prionospio* sp, *Axiothella* sp, *Arcteobia anticostiensis* (McIntosh), *Scoloplos armiger* (Müller), *Aglaophamus circinata* (Verill), *Nephtys caeca* Fabr *Nereimyra punctata* (Müller).

D. L. Peer

Environmental Oceanography

Physical oceanography of the southern Gulf of St. Lawrence

In 1964, non-tidal currents in the south-eastern Gulf of St. Lawrence were observed by the use of parachute drogues and transponding drift buoys. Relative geostrophic flow was calculated from a network of oceanographic stations occupied during the survey. The results obtained by the two methods agreed well.

Cyclonic gyres were observed in the surface layer of the area. These appeared to form locally and move along with the general flow. The gyres have a very significant upwelling effect on the thermocline beneath them. Because of this the moving gyres represent a potential mechanism for producing large fluctuations in the bottom temperature of near-shore areas.

In 1965 similar studies were undertaken in the southwestern Gulf of St. Lawrence, west of the area examined in 1964 (Fig 14). Drogues were set in the surface layer, the thermocline, and near bottom. Only the drogues in the surface layer moved significantly. The surface layer drogue movements indicated a general southeasterly set across the Magdalen Shallows extremely weak currents in the region just to the north of North Point, PEI and evidence of a clockwise gyre southeast of North Point. This gyre appeared to be a wake phenomenon produced by the configuration of PEI.

Analysis of the data is continuing.

B. L. Blackford
R. W. Trites

Laboratory models of circulation

Over the past 2 years the principles of electrical analogs and their use in solving simplified forms of the hydrodynamic equations have been studied. Work was terminated in September owing to the resignation of the staff member carrying out this investigation to permit him to continue with university studies.

Construction of the three-dimensional model discussed in the 1964 annual report was completed in the spring of 1965. This rectangular prototype was built to the scale of the Atlantic Ocean so that results from it could be compared to the results obtained from other workers using dif-

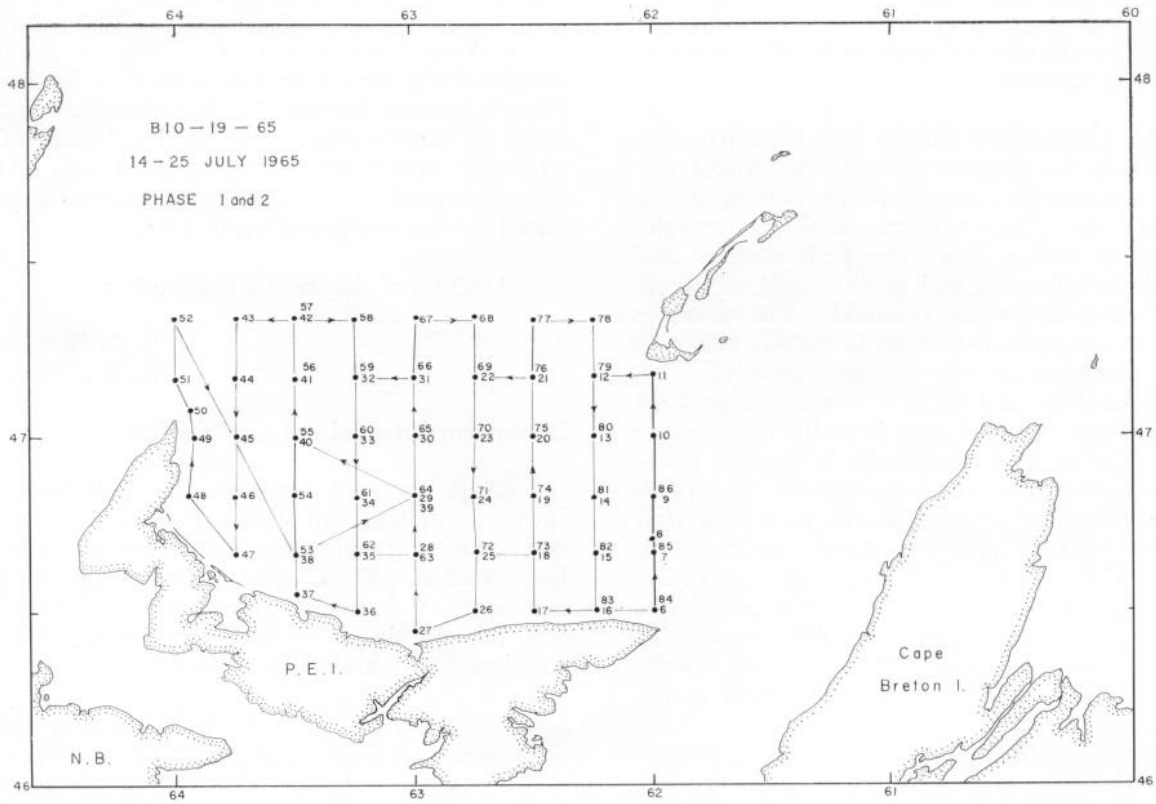
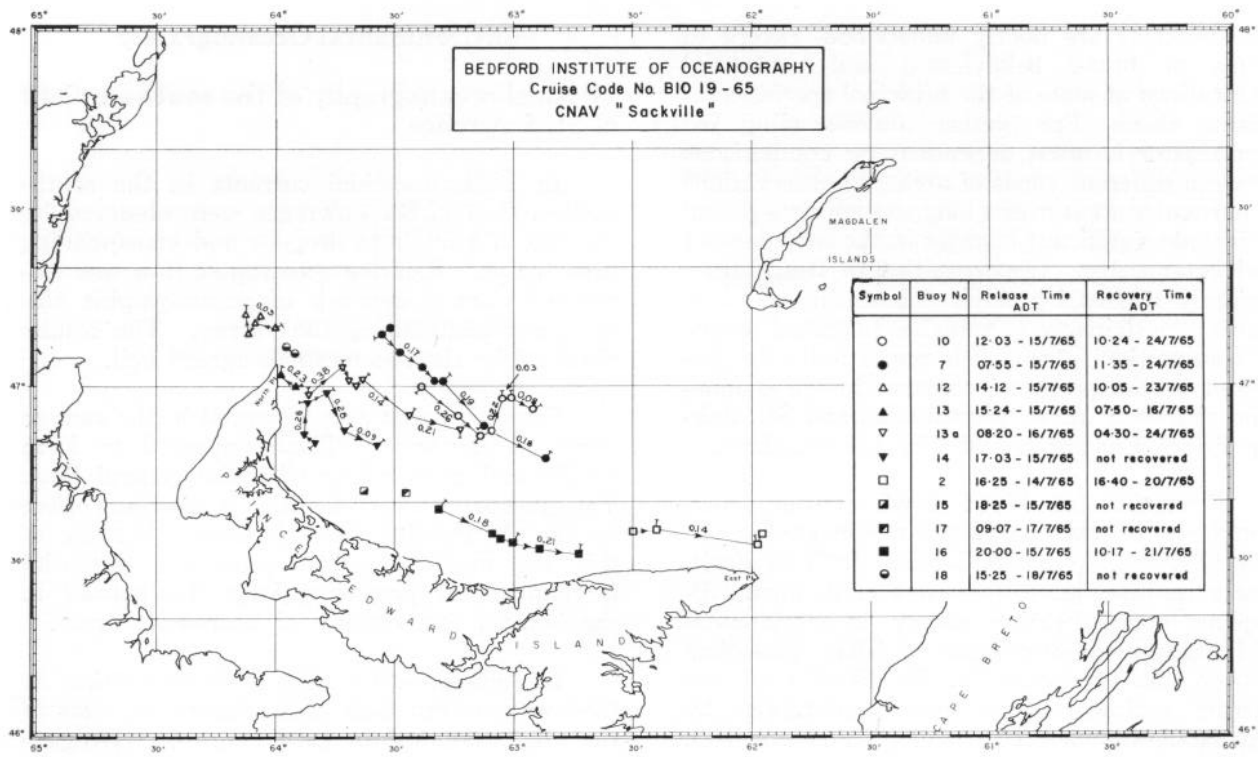


Fig. 14. Oceanographic station locations and drogue tracks, southwestern Gulf of St. Lawrence, July, 1965.

ferent methods. The model consisted of four layers in the vertical direction and a grid spacing of 1,000 km in both horizontal directions.

Only very preliminary results were obtained. The grid spacing was found to be entirely inadequate and should be decreased by at least an order of magnitude. This would mean an increase of three-orders of magnitude in the number of components. The model was observed to reproduce Ekman type spirals with an applied surface wind stress. Furthermore, the depth of penetration was greater for the small latitudes, as would be expected. The investigations did not progress to the point where the effects of boundary conditions and density structure could be studied.

B. L. Blackford

Physical oceanography of the Margaree estuary

Physical Oceanographic studies of Margaree Harbour and approaches, in Cape Breton, were initiated in July, 1965 to complement the biological studies of salmon stocks in the Northeast and Southwest Margaree rivers (Fig 15). The aim of the study is to gain knowledge and understanding of the way in which the fresh and salt water mix and move seaward. It is thought that this may be an important factor that will influence the time of entry of salmon to the river. The Margaree is known as a "late run" salmon river. Relatively few salmon enter the river prior to September. This is contrasted with the Cheticamp River, only about 15 miles to the northeast, in which salmon, in considerable numbers enter earlier in the year.

Field studies were commenced in mid-July and continued until the end of August. Two tide gauges were installed, one outside the breakwater at the mouth of the Harbour, and the other about 13 miles up-river from the breakwater, in order to determine the slope through the estuary and to compute the intertidal volume. A framework with two Braincon current meters was laid in the Channel (depth approx 16 ft) between the breakwaters. Only one of these functioned satisfactorily. Temperature and salinity were measured at a network of 13 stations extending from a position just seaward of the breakwater to a point about 2 miles "up river". The area outside the Harbour was considered only superficially. Limited temperature

and salinity measurements were taken, and several dye experiments were carried out using Rhodamine B and a Turner fluorometer. The dye patches usually moved away rapidly and dissipated quickly.

The Cheticamp Estuary was examined only casually, but there is little doubt that the oceanographic mechanism contrasts markedly with that of the Margaree. At one period in August the mouth of Cheticamp River was completely closed from the sea, as the result of storm action. A few days later the water level inside rose several feet above mean sea level. Eventually the mouth reopened. The size of the opening appears to bear a relationship to the fresh water discharge, and possibly is maintained in such a way as to limit the amount of salt water that can penetrate "up river" from this point.

The data collected have been only partly processed. When the analysis has been completed, it should provide a good basis for continuing studies.

R. W. Trites

Physical oceanography of Pictou Harbour and approaches

Limited physical oceanographic studies were undertaken in the Pictou area to determine present flushing characteristics, as well as to predict conditions which might prevail after a causeway is constructed. A pulp mill is under construction at Abercrombie Pt. (Fig 16) and a causeway is to be built from this point to the north side of the harbour, making a fresh water lake out of the Middle and West River estuaries.

A 2-day survey of temperature and salinity distribution in June, 1965, combined with calculations based on the tidal prism and low tide volume, indicated that the concentration of effluent from the pulp mill in Pictou Harbour might, under some conditions, exceed tolerable limits. As a result, attention was next focussed on the area outside the Harbour, particularly in Pictou Roads and off Boat Harbour.

In September, a Braincon current meter was installed a short way seaward from the mouth of Boat Harbour and operated successfully for 30 days. A recording anemometer was installed in the area as well. A series of dye experiments was carried out, using Rhodamine

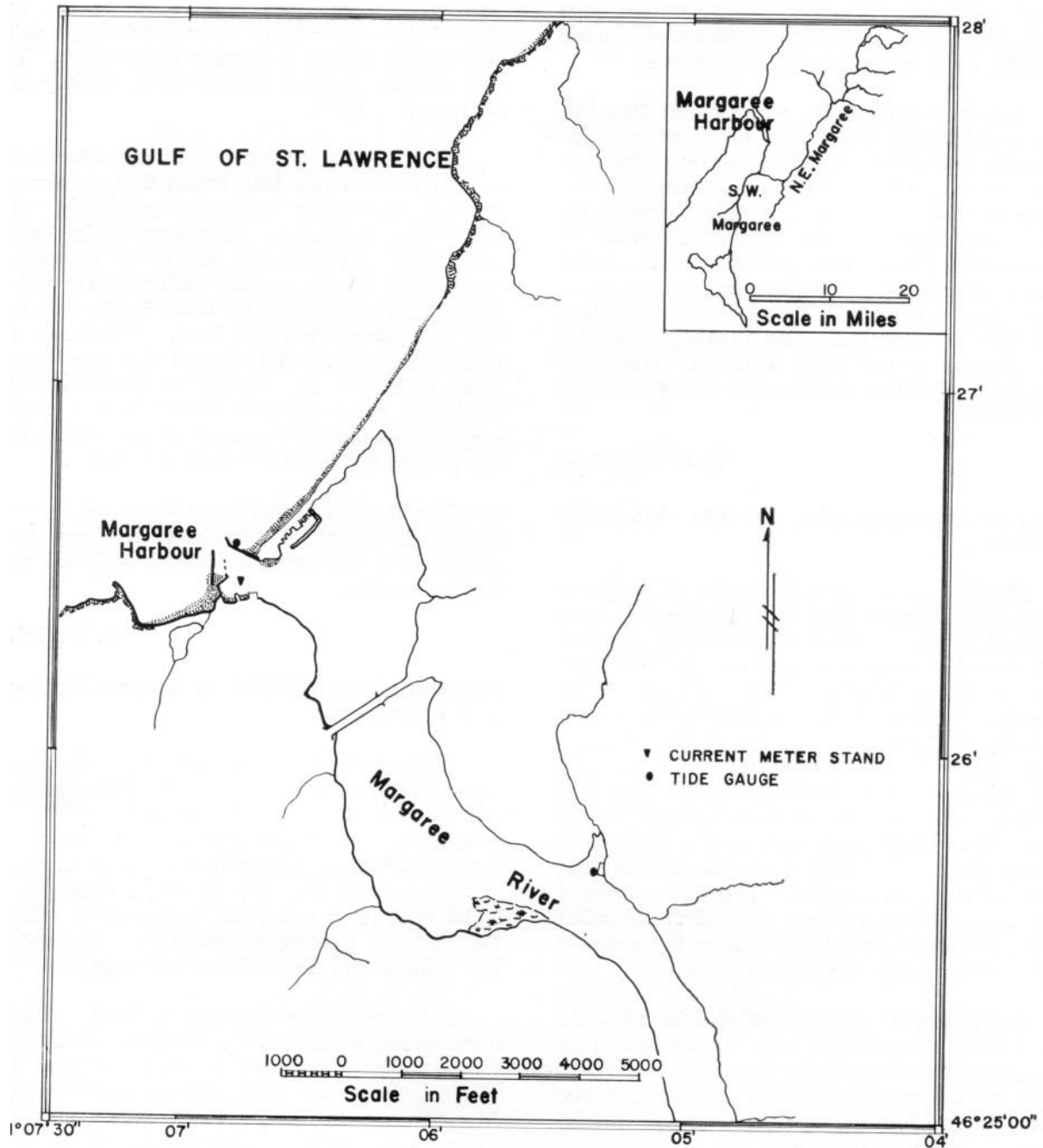


Fig. 15. Margaree Harbour, Cape Breton, N. S.

B and a Turner fluorometer. Patches of dye were followed for varying periods up to 12 hr. Salinity and temperature measurements were taken at a network of stations several times during the survey. Processing of data and analysis are incomplete at present.

R. W. Trites

The solubility product of calcium carbonate in sea water

The program described in the 1964 annual report, and designed to measure the low temperature solubility product of calcium carbonate in sea water, is now complete. No values for temperatures below 15°C exist in the literature

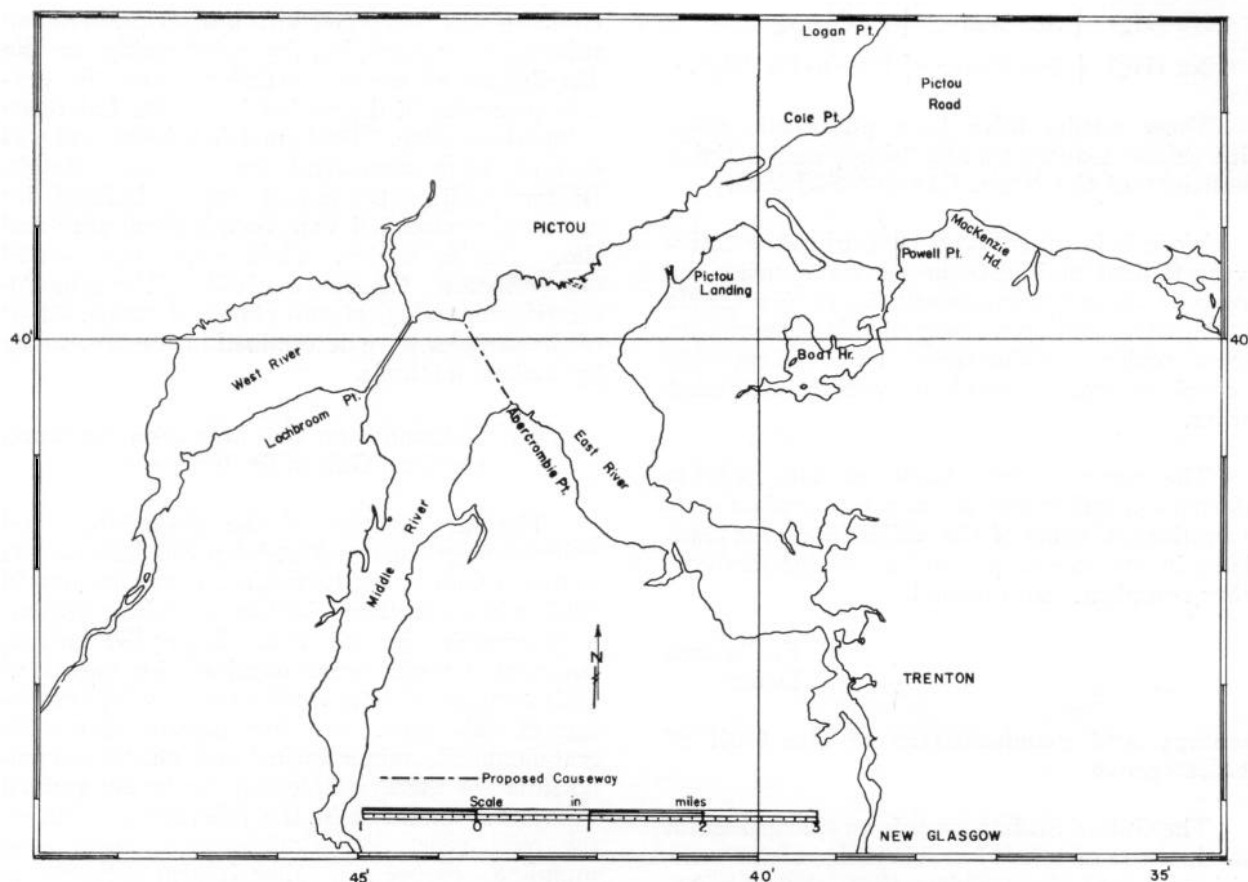


Fig. 16. Pictou Harbour and approach area.

for comparison, but the results agree with those of most other workers in the range 15° to 30°C. The results, which are listed below, will be published soon.

Temperature	Solubility Product X 10 ⁶	
	Calcite	Aragonite
30°C	0.51 ± 0.04	0.86 ± 0.04
25	0.54	0.90
20	0.57	0.94
15	0.60	0.98
10	0.63	1.02
5	0.67	1.06
0	0.70	1.10

These results will allow a more accurate estimate of the extent of oceanic saturation with the two crystalline forms of calcium carbonate than has previously been possible.

This work formed part of the thesis of W. G. MacIntyre who has recently been awarded a PhD in Oceanography from Dalhousie University, Halifax, N. S.

W. G. MacIntyre
R. F. Platford

Activity coefficients in sea water

Knowledge of the development and functioning of chemical systems in the sea depends on information on ionic activity. However, the basic data have not been available for the complexes occurring in sea water. During recent studies the activity coefficient of sodium chloride and sodium sulfate have been measured using the following cells:

Na (Hg) | Sea Water | AgCl-Ag

Na (Hg) | Sea Water | PbSO₄-Pb (Hg).

These results have been published, along with values deduced for the "single ion" activity coefficient of the Na⁺, Cl⁻ and SO₄ ions.

Work is in progress on measuring the activity coefficient of MgSO₄ in sea water using the isopiestic vapor pressure method. A very simple sea water is best for a study of this type and its use is under investigation. This will provide a check on values which have been estimated earlier.

The measurements made to date provide information which can be used to calculate concentrations of some of the major inorganic complexes in sea water. Extensions of the study to other complexes are planned.

R. F. Platford
T. Dafoe

Geology and geochemistry of the Gulf of St. Lawrence

The Gulf of St. Lawrence is an epicontinental marginal sea of somewhat triangular shape comprising an area of approximately 57,000 sq miles. There are two openings to the ocean: the straits of Cabot and Belle Isle. From the St. Lawrence river system which extends inland some 2,000 miles, the Gulf receives the drainage of approximately 500,000 sq miles. Pleistocene glaciation and present climatic conditions set the Gulf and River of St. Lawrence apart from most of the other sedimentary environments where detailed studies have been carried out. In 1962, AOG initiated a series of investigations on the sediments in the river and gulf of St. Lawrence. The progress of these investigations in 1965 is summarized in the following paragraphs:

- (a) Recent depositional conditions in the St. Lawrence River and Gulf (excluding the southern and northeastern portions of the area)

Since the 1964 annual report, a study of the recent depositional conditions in the St. Lawrence river and Gulf excluding the southern shelf area, and northeastern corner, has been completed, and published. This investigation, which was carried out in conjunction with Dr D. J. G. Nota of the State Agricultural University, Wageningen,

Holland, was concerned with a description of the submarine topography, its relationship to the distribution of surface sediments, and the present processes of deposition in the St. Lawrence submarine valley. Bathymetric information was derived from acoustical surveys and charts. Bottom sediment samples were obtained by means of a modified Van Veen bottom grab and short gravity corers. Field work was carried out onboard CNAV *Sackville*. The granulometric, mineralogical and chemical compositions of the samples were determined in the laboratory by various methods.

- (b) Sediments on the Magdalen Shallows, southern Gulf of St. Lawrence

The investigation of the morphology and Sedimentology of the Magdalen Shallows in the southern Gulf of St. Lawrence, was continued in 1965, when additional bottom sampling stations were occupied in the area. Some 180 bottom sediment samples were obtained by means of grab samplers to supplement our previous coverage of this area. At the present time, the granulometric, mineralogical and chemical compositions of these samples are being determined by various methods in the laboratory. During the past year, acoustical surveys using echo sounding, sparker and subhorizontal asdic equipment have contributed valuable information on the microtopography, sediment distribution and thickness of the sediment cover in the area.

Data obtained from the acoustical surveys and bottom sampling show that several distinct sedimentary environments occur on the shelf around the Magdalen Islands. Sandstone bedrock with an intermittent veneer of sediments is the main characteristic of the sea floor north of Prince Edward Island and to the north and northwest of the Magdalen Islands. In contrast, the shelf areas west and east of the Magdalen Islands have almost continuous sediment cover with only local occurrences of bedrock.

- (c) Recent depositional conditions in the northeast Gulf of St. Lawrence

An investigation of recent depositional conditions in the northeast corner of the Gulf of St. Lawrence was initiated during a short cruise on board CSS *Baffin* in December, 1965. Some 90 bottom sampling stations were occupied between the west coast of Newfoundland and the coast of Labrador as far north as the Strait of

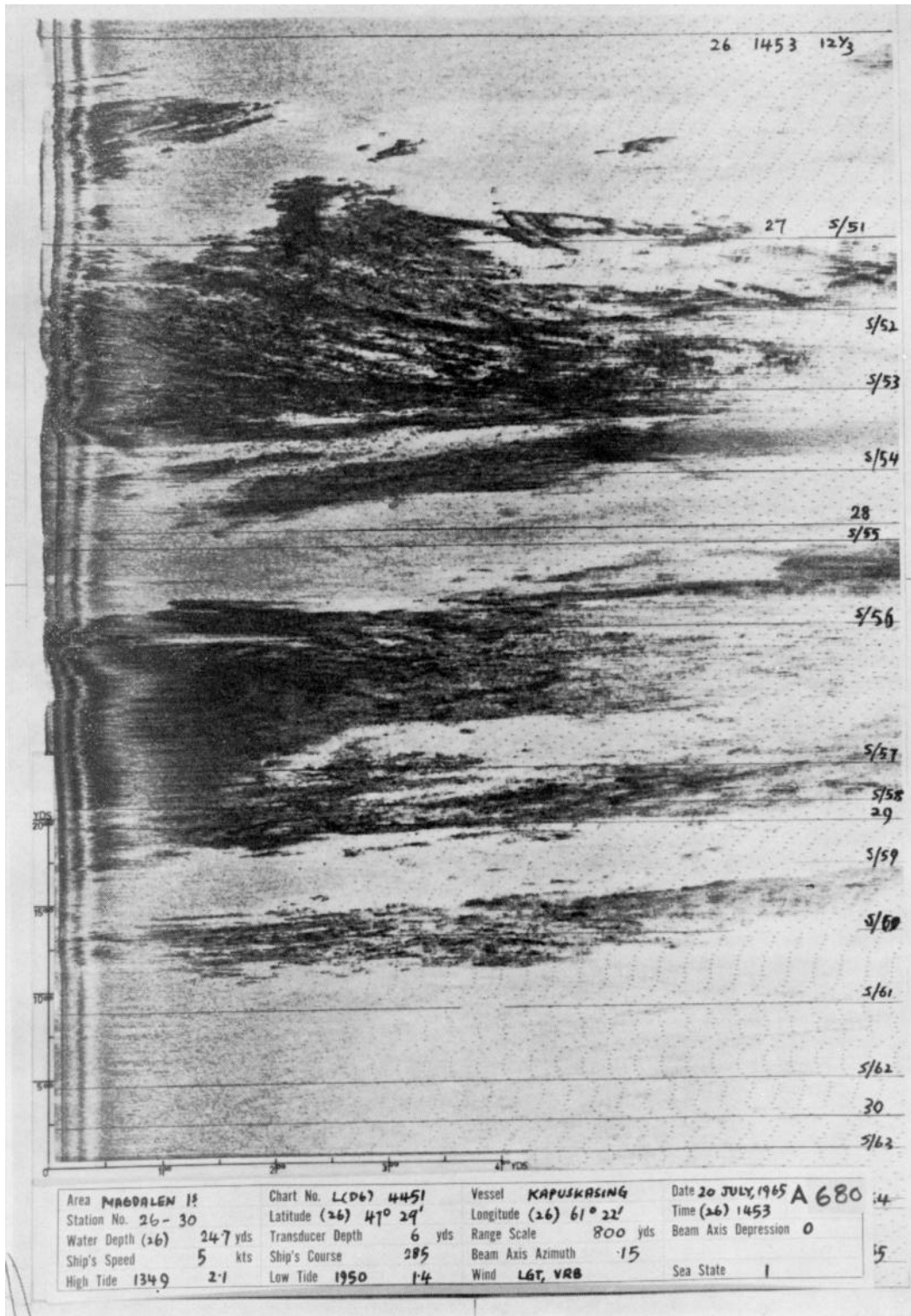


Fig 17. Photograph of Acoustical record of sea floor near Magdalen Islands, from Kelvin-Hughes-oblique echo-sounder equipment.

Belle Isle. Bottom sediment samples were obtained at most of these stations using the modified Van Veen bottom grab. Continuous echo sounding of the sampling lines provided detailed information on the submarine topography of this area. Analyses of this material will help complete our background information on the interrelationship of the sediment composition, submarine morphology sediment sources, present processes of deposition and depositional history of this area.

D. H. Loring

The geochemistry of recent sediments from the St. Lawrence River and Estuary

Geochemical studies of the major elements comprising the sediments in the St. Lawrence river and estuary were continued in 1965. The distribution of Al, Ti, Fe, Mn, Ca, Mg, and P have been determined in sediments from the mouth of the Saguenay river downstream to Pte. des Monts. In interpreting the results, consideration is given to such factors as facies, rates of deposition, sediment sources, and the physico-chemical environment. Although complete analyses are not yet available the results indicate that the majority of the elements are already present in the lattices of various primary silicate minerals when they enter the basin of deposition, and slight variations in the major element contents in the different sediments reflect little variation in the mineralogy of these deposits. The chemical composition of the sediments also indicates that this material was transported from its weathering site before chemical weathering had taken place to any appreciable degree. The chemical immaturity of these sediments is thought to be due to rapid reduction in the grain size of the source material by physical weathering during the Pleistocene Era and under present climatic conditions.

D. H. Loring

Oblique echo-sounder survey of the shelf around the Magdalen Islands

During the past year, detailed information on the microtopography and sediment composition of the sea floor on the shelf around the Magdalen Islands was provided by the use of the Kelvin and Hughes oblique echo-sounder equipment. This equipment was demonstrated by Professor Chesterman of the University of Hong Kong during a short cruise on board CSS *Kapus-kasing*. The results showed that a belt of the sea floor of about 800 yards in width could be examined in detail by a ship underway at speeds of up to seven knots and that the results could be available immediately on a continuous sheet of recording paper. The variations in the composition and topography, were indicated by variations in the intensity of the markings and could be readily interpreted given adequate calibration and standardization of the equipment. Echograms and bottom samples taken simultaneously with the acoustical records were used to confirm the interpretations. (see also p. 49).

One such acoustical record is reproduced in Fig 17. This striking pattern was produced by two large and several small rock formations protruding above the sea floor through a thin sand cover near the east coast of the Magdalen Islands. The dark linear pattern on the record was produced by rock edges facing the transducer while the white patches and lines are shadow zones behind these edges. The sand areas appear on the record as even light tones between the two main outcrops and on the upper and lower portions of the record.

D. H. Loring