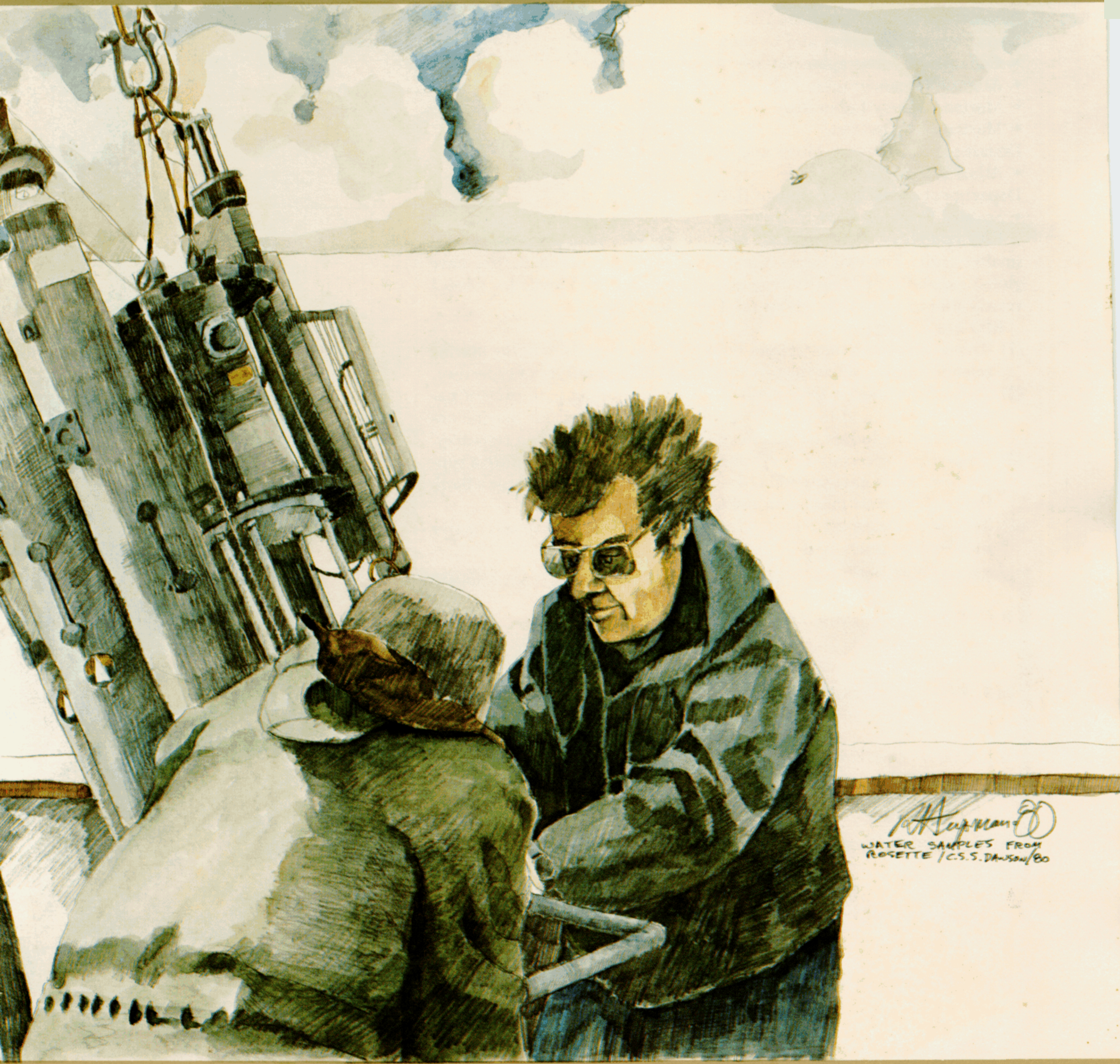
HOME

Bedford Institute of Oceanography

BIO REVIEW '81



Canada

The Bedford Institute of Oceanography (BIO) is the principal oceanographic institution in Canada; it is operated within the framework of several federal government departments; its staff, therefore, are public servants,

BIO facilities (buildings, ships, computers, library, workshops, etc.) are operated by the Department of Fisheries and Oceans, through its Director-General, Ocean Science and Surveys (Atlantic). The principal laboratories and departments are:

Department of Fisheries and Oceans (DFO)
- Canadian Hydrographic Service (Atlantic Region)
- Atlantic Oceanographic Laboratory
- Marine Ecology Laboratory
- Marine Fish Division

Department of Energy, Mines and Resources (DEMR)
- Atlantic Geoscience Centre

Department of the Environment (DOE)
- Seabird Research Unit

BIO operates a fleet of three research vessels, together with several smaller craft. The two larger scientific ships, *Hudson* and *Baffin,* have global capability, extremely long endurance, and are Lloyds Ice Class I vessels able to work throughout the Canadian Arctic.

BIO has four objectives:

(1) To perform fundamental longterm research in all fields of the marine sciences (and to act as the principal Canadian repository of expertise).
(2) To perform shorterterm applied research in response to present national needs, and to advise on the management of our marine enviromment including its fisheries and offshore hydrocarbon resources.
(3) To perform necessary surveys and cartographic work to ensure a supply of suitable navigational charts for the region from George's Bank to the Northwest Passage in the Canadian Arctic.
(4) To respond with all relevant expertise and assistance to any major marine emergency within the same region.

R.G. Halliday - *Chief, Marine Fish Division, DFO*

M.J. Keen - *Director, Atlantic Geoscience Centre, DEMR*

A.J. Kerr - *Director, Atlantic Region, Canadian Hydrographic Service, DFO*

K.H. Mann - *Director, Marine Ecology Laboratory, DFO*

G.T. Needler - *Director, Atlantic Oceanographic Laboratory, DFO*

D.N. Nettleship - *Canadian Wildlife Service, Seabird Research Unit, DOE*

Introduction

An essential element of any scientific or technical endeavour is communication of its results to those who need them, either to further the science or technology itself or to apply the results directly to the problems of the day. Hence this new BIO publication replaces the *Biennial Review* that was our principal medium of communication for many years but which evidently did not reach a wide enough audience and did not contain the information about BIO that many people have said they needed.

BIO Review will be published annually, but it will not be a typical annual report. It will review just one aspect of our multifaceted Institute and it will serve as an up-to-date guide for those who need to do business with us - the hydrographic community, scientists in other institutes, administrators in other federal and provincial government departments in Canada, the Canadian offshore and fishing industries, the manufacturers of oceanographic and hydrographic instrumentation, and the consulting companies. For this first issue of *BIO* Review, the choice of which topic to focus on was made almost automatically by the events of the last year or so, a period in which the Institute has become deeply involved in the environmental problems associated with frontier development of oil and gas reserves offshore and through the Arctic. New national policy for development of offshore and other Canada Lands resources, the requirements of the Federal Environmental Assessment and Review procedures, and the needs of the offshore industry for ocean data have all made BIO greatly more involved in the problems of the day than has hitherto been the case.

The first issue, therefore, is devoted to the ways in which BIO is responding to the calls on oceanography and hydrography arising from the main problems facing our nation at sea; it is our hope that this review will indeed facilitate the process, and make our data and expertise increasingly accessible to those who need it from month to month. For this reason, as well as reviewing the ways in which our work relates to today's problems, we also include a comprehensive and up-to-date guide to who does what, where, and why through BIO. This will be repeated each year and will we hope render BIO less 'faceless' than many have complained it has been in the past. Together with the establishment of an industrial liaison office - the BIOMAIL Office - this year, we hope that this publication will indeed help make BIO much more accessible.

The second issue of *BIO Review* will be published prior to the Joint Oceanographic Assembly to be held in Halifax in 1982 and will be devoted to the fundamental, long-term, ocean science that forms so large a part of the Institute's activities, and without which the work described in this first issue would not be possible. Subsequent issues will concentrate on other aspects of the BIO mandate, such as cartography and hydrographic surveying, or on narrower issues that could profitably be reviewed in greater detail such as the consequences of building a tidal barrage in the Bay of Fundy, or the oceanography, ecology, and geology of a region of special interest. In this way, we hope to make the work of one of the largest oceanographic institutions in the world more sensitive to the needs of those who support it.


Roger Belanger 6084-7

Alan R. Longhurst
Director-General
Ocean Science and Surveys (Atlantic)
Department of Fisheries and Oceans

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On the cover:
A painting by Nova Scotia artist Roger Hupman, who was commissioned to portray life and work aboard a BIO oceanographic research vessel. The painting is one of a series hung at various locations within the Institute.

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chapter 1

Ocean Climate

Climate, in particular ocean climate, has a major impact on various sectors of the economies of maritime nations including fisheries, agriculture, and transportation. The oceans absorb more than 80% of the incoming radiative energy that the earth receives from the sun. Their dynamics are critical to the way this energy is used to drive the major atmospheric and oceanic circulations and thus either maintain the global climate or contribute to its fluctuations.

In recent years, the study of climate has been receiving increased attention. In 1969, the World Meteorological Organization (WMO) established the Global Atmospheric Research Program (GARP), one objective of which is to study climate and the oceanic and atmospheric processes that control it. BIO, as have many institutions with deep-sea capability, has participated in several GARP experiments. One called the GARP Atlantic Tropical Experiment was concerned with atmospheric convection near the equator and its related oceanic interactions.

In 1979, WMO established a world climate program. Although many countries, like Canada, had already begun steps to set up their own climate programs, it was clearly recognized that climatic changes are truly international in nature and that it is essential to co-ordinate the all-too-meagre resources available for climatic research. In Canada, the international activities of our climate program are co-ordinated by a committee of the National Research Council and those of a strictly Canadian nature by the Canadian Climate Centre (CCC) of the Atmospheric Environment Service. The CCC is ensuring that not only does the Canadian Climate Program include those atmospheric and oceanographic research programs necessary to enhance our ability to predict climate but that it is responsive to the needs of agriculture, fisheries, forestry, etc., and that climatic information is applied, in ways that benefit all Canadians.

Oceanographers must play a key role in any program aimed at enhancing our ability to predict climate change. Not only is the atmosphere strongly coupled to the ocean but it is the ocean that has much the greater heat capacity and thus a much slower response time than the atmosphere. Heat stored in upper ocean waters may provide heat to the atmosphere many months after it was placed there by other atmospheric events. In this sense, the ocean serves as a long-term ‘memory’ for the atmosphere.

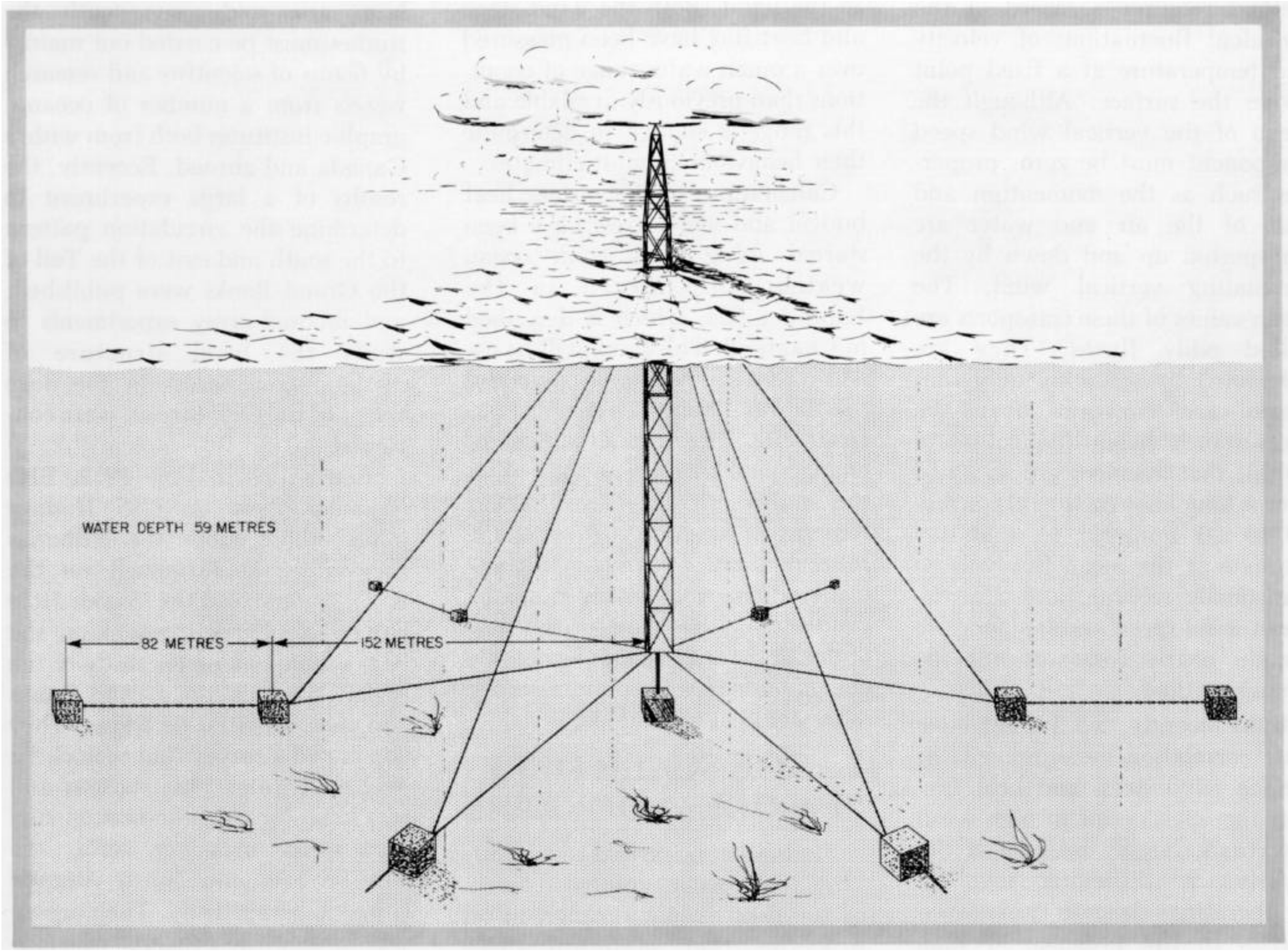
The North Atlantic Ocean has a relatively intense circulation and exhibits a full range of large-scale atmosphere-ocean interactions in need of study. At the equator, evaporation and radiative input create warm and saline surface waters while in the north cooling and ice formation create cold and heavy water that sinks in convective cells or flows out of the Arctic Ocean into the deep North Atlantic, This differential heating and cooling creates a large convective cell that transports warm water north where it loses its heat to the atmosphere and moderates climate, especially in Europe. Much of the warm water flows north with the Gulf Stream, which passes our shores where, before it turns north around the Tail of the Grand Banks and east towards the Azores, it acquires instabilities that are complex and difficult to define precisely.

These and many other features of the North Atlantic make it a key area for climate research and various programs at BIO are making a major contribution in this direction. The potential exists for future large-scale coupled atmosphere-ocean numerical models capable of predicting climate changes over many months and maybe even several years. Some of the programs discussed below investigate past and present climatic interactions and help meet this goal.

SURFACE AND MIXED LAYER OCEANOGRAPHY

Some of the Atlantic Oceanographic Laboratory’s climate-oriented work concerns the processes taking place at the ocean-atmosphere boundary and in the oceanic mixed layer, where the bulk of the changes in the ocean’s heat storage are evident. Questions being asked include: How are heat, salt, momentum, and gases transferred across the ocean surface, and how do they promote exchanges between the mixed layers and deeper ocean? What makes sea waves grow? What is the wave climate - that is the monthly and year-to-year wave-height distribution - of the North Atlantic Ocean? What factors control the formation, decay, and motions of the sea ice?

An extensive air-sea interaction study completed in 1980 is but one example of BIO’s work on these questions. This study, described below, has considerably enhanced our knowledge of the wind stress (or drag) and heat exchange (or flow) over the open ocean and the data collected can now be used to construct more accurate and com-

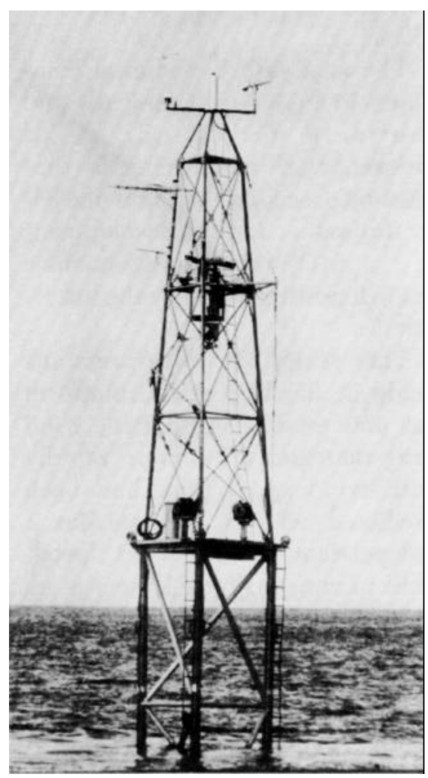


The BIO stable tower is used to make air-sea interaction measurements. Excess buoyancy from floatation tanks in the lower six sections of the tower stretches the restraining cables tightly. This stabilizes the tower and permits us to make wave and current measurements that are free of error introduced by the motion of the tower that supports the instruments. The upper portion is pictured at right.

plete models of the ocean's circulation and weather patterns. Understanding the mean values and seasonal distributions of wind stress and heat flux is also useful for predicting the effects of man-made or natural changes to the ocean and its climate.

For this study, a stable platform (see figure) was designed, equipped with turbulence, temperature, and wave height sensors, and moored off the entrance to Halifax Harbour from June 1976 to February 1978. The platform was situated in an area characterized by deep-water waves where it was exposed to the full fetch of the North Atlantic Ocean for winds from the south and east and to a minimum fetch of 10 km for winds from the west. It consists of a 47-m long floating tower, six floatation tanks, each weighing 60.5 tons, and a number of anchors and lines. When in position, the upper tower rises 12.5 m above mean water level. The instruments operated for 184 days recording data in runs of about 40 minutes' duration daily under normal sea conditions and more frequently during gale force winds. The tower's instruments were linked by a telemetry system to the BIO shore computer so that the tower could be operated unmanned during stormy conditions. A thrust anemometer (described in Chapter 7) was developed at BIO to measure turbulence even in the presence of rain and spray.

Data from the platform were analyzed by the eddy correlation method, which is the most direct means of establishing formulas derived from actual measurement to describe the wind stress and heat flux at the ocean surface. This



Stuart Smith 5208

method requires a record of the turbulent fluctuations of velocity and temperature at a fixed point above the surface. Although the mean of the vertical wind speed component must be zero, properties such as the momentum and heat of the air and water are transported up and down by the fluctuating vertical wind. The mean values of these transports are called eddy fluxes. They are calculated by assuming only that fluxes are constant over the measurement height (typically 5 to 20 m), that averages are obtained over a long enough time (typically 30 to 60 minutes) so that the estimate of the mean flux will be statistically reliable, and that the mean wind speed and temperature remain nearly constant over the averaging time.

Until recently, we did not have eddy correlation measurements of surface wind stress and heat flux over the open ocean in high wind conditions, largely because of the experimental difficulties involved in operating delicate turbulence sensors in the presence of high waves and spray and in maintaining sensors in a fixed position. Over a limited range of conditions (wind speeds up to 15 ms^{-1}), it was difficult to verify whether the drag and heat flux varied with the wind speed.

The availability of digital computers to analyze economically and routinely the hundreds of thousands of measurements that must be processed to obtain one eddy flux value, and the development of the BIO stable platform have made it possible to verify the uncertainties.

The series of measurements made at the BIO stable platform has now established that the wind drag increases a bit more rapidly with wind speed than had been predicted, whereas the heat flux is independent of the wind speed. Both parameters have lower values than we had earlier predicted perhaps because earlier data came from closer inshore where the surface waves are steeper and slower, and possibly more strongly coupled to the wind. Both the wind stress and heat flux have been measured over a much wider range of conditions than previously available and this range is enough to determine their behaviour in most climates.

Calculations of the surface heat budget and wind stress have been started using data from ocean weather ship *Bravo* in the Labrador Sea, which is described in Chapter 2. This work will be used to check the stable platform results off Halifax Harbour, to relate the surface heat budget to changes in sea water, and to extend the analyses to other areas. What remains to be done is to establish reliable values of sea surface evaporation over a wide range of conditions so that the contributions of the latent heat flux to the ocean's energy budget can be more reliably estimated.

LARGE SCALE DEEP SEA OCEANOGRAPHY

Studies being carried out on the large-scale oceanographic features of the deep ocean, the dynamical processes that maintain these features, the physical transport of various physical and chemical parameters, and the northern overflows of deep water and deep convection that significantly contribute to the deep sea balances, as mentioned above, are all relevant to the climate problem. Recent Atlantic Oceanographic Laboratory work on the circulation and dynamics in the northeastern North Atlantic Ocean is reviewed below. The work in the Labrador Sea, which is also of great importance to the understanding of ocean climate, is presented in the next chapter under the title "Focus on the Labrador Sea: Physical Oceanography".

Although the Gulf Stream is a much studied feature, modern investigations continue to turn up previously unsuspected characteristics of the variability over space and time of this major ocean current system. Describing in increasing detail the complexities of the Gulf Stream today requires synoptic and detailed coverage over a large area and consequently the studies must be carried out mainly by teams of scientists and research vessels from a number of oceanographic institutes both from within Canada and abroad. Recently, the results of a large experiment to determine the circulation pattern to the south and east of the Tail of the Grand Banks were published, and moored-array experiments to study the local structure of medium-scale eddies in the deep water of the Gulf Stream were continued.

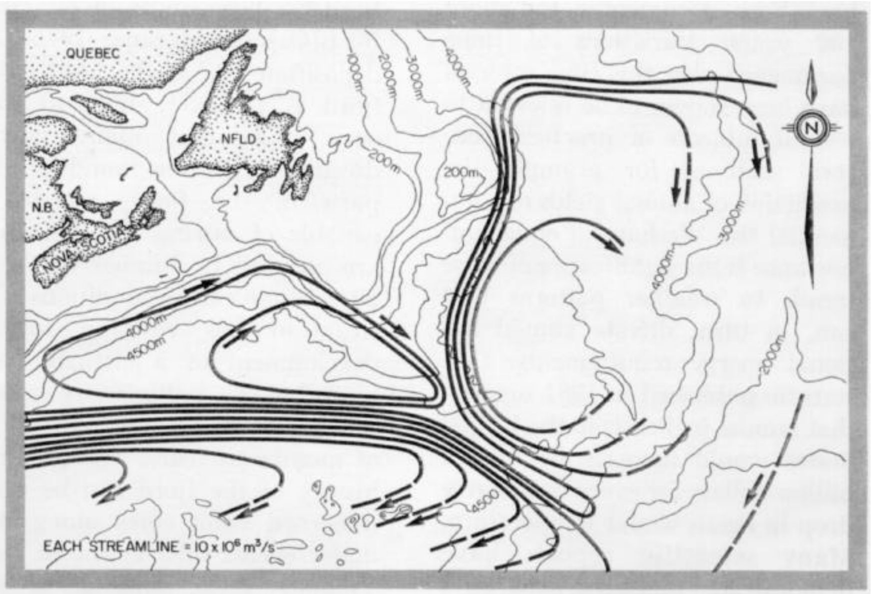
From April to June 1972, BIO oceanographers on CSS *Hudson* joined those from the Fisheries Laboratory at Lowestoft on the R/V *Cirolana* and the Woods Hole Oceanographic Institution on the R/V *Chain* in a major study of the region between the Grand Banks and the Mid-Atlantic Ridge. They conducted a survey that included a grid of hydrographic stations and two long lines of near-bottom current meter moorings across the Gulf Stream and North Atlantic Current, respectively. The purpose was to map the property distributions and current field in greater detail and with less ambiguity where the Gulf Stream apparently branches. The actual motion of the Gulf Stream at this point has been debated for many years. One hypothesis, advanced in 1962, claims that the primary current system there is not a branching Gulf Stream but portions of two separate (and nongeostrosphic) gyres. The differences between the two main theories are shown in the accompanying figures (p. 7).

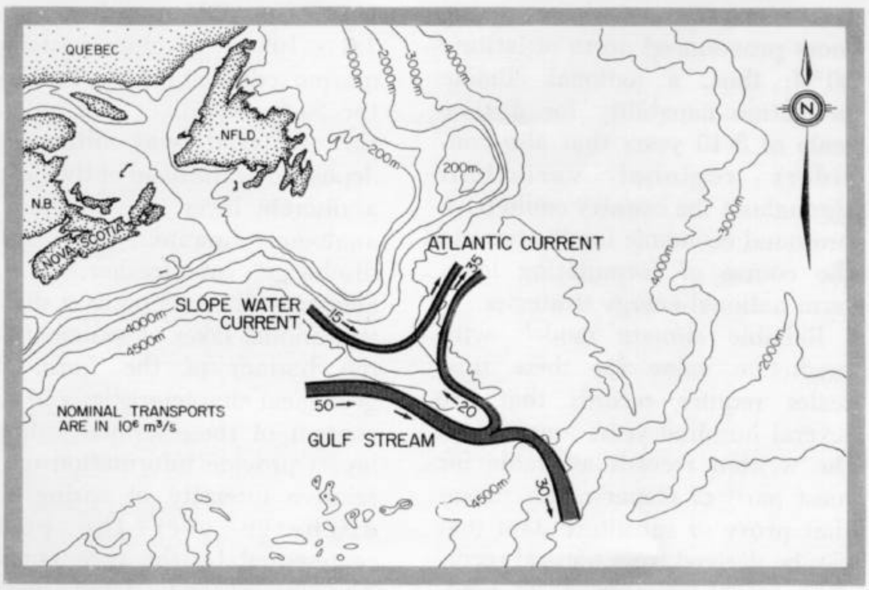
An extensive analysis of the data has now been completed and the results published (Clarke *et al.* 1980 - see Chapter 9). BIO scientists now have an extensive data set from the moorings and stations that has enabled them to display the property distributions of the Gulf Stream southeast of the Grand Banks in a series of horizontal maps and vertical profiles,

From the results of this study, we are now confident that a significant proportion of the Gulf Stream transport is carried east and north around the Tail of the Banks to form a part of the North Atlantic Current. We feel that the 1962 hypothesis is not the best one to describe the observed property distributions. Rather, given a moderate degree of lateral mixing, the observed properties are more consistent with a branching geostrophic field.

Another Gulf Stream study in which BIO participated has the ultimate goal of understanding the interaction between mesoscale eddies and the general circulation averaged over much longer times. A moored current meter experiment, the Gulf Stream Array, was conducted between December 1975 and May 1977 in co-ordination with the USA/USSR POLYMODE Program. Our study showed that currents at a 4000 m depth beneath the Gulf Stream at 55°W are dominated by eddies with periods of the order of 40 days, spatial scales of the order of 90 km, and maximum speeds over 0.5 ms^{-1}. The eddying motions show a distinct westward propagation with phase speeds of up to 30 km/day as predicted by recent eddy-resolving numerical circulation models. A correlation coefficient of about 0.3 was measured between deep eddy currents and temperature fluctuations, which gives rise to a deep eddy heat flux. If similar correlations hold in the surface Gulf Stream where current and temperature changes are much greater, we will know that the resulting eddy heat fluxes are large enough to figure in the mean global heat balance.

A second moored array experiment, the 50°W Array, was conducted between May 1977 and September 1979 along with supporting CTD work. This array was placed to the south of the Gulf Stream at 50°W. Preliminary results indicate that the eddy energy at 4000 m decreased by a factor of two between 55°W and 50°W, but that the deep zonal flow pattern that has been studied extensively at 55°W is continuous between the two longitudes.





TOP:
The water budget for the North Atlantic Ocean relative to the 2,000 m surface - After Worthington, L.V. 1962. Evidence for a two-gyre circulation system in the North Atlantic. Deep-Sea *Research 9:* 51-67.

BOTTOM:
The current system southeast of the Grand Banks - After Mann, C.R. 1967. The termination of the Gulf Stream and the beginning of the North Atlantic Current. *Deep-Sea Research 14:* 337-359.

CLIMATE AND THE MARINE SEDIMENTARY RECORD

The Atlantic Geoscience Centre in co-operation with the Atlantic Oceanographic Laboratory at BIO has been investigating the variations in climate from the geological record.

Climate variations are characterized by, among other things, annual variations in the amount and type of precipitation, and in the timing and speed of snow and ice melting in the spring. The speed and other rate-related attributes of precipitation and melting can be expected to vary locally in comparison to the total Canadian land mass. However, in all instances, these processes are either directly or indirectly associated with variations in mean annual temperature that appear to be synchronous over large areas of North America.

In some parts of Canada, long-term variations of mean annual and mean monthly temperature have been documented for about 100 years. Variations of these parameters over this time interval have been shown to be relevant to several subjects of practical concern such as for example the prediction of annual yields of commercial fish, Perhaps of equal importance is the significance of these trends to weather patterns that can, in turn, dictate annual national energy requirements. One statistic published in 1981 suggests that annual fuel costs in the United States would increase by several billion dollars for every one degree drop in mean winter temperature. Many scientific reports have demonstrated that these departures from mean winter temperature are more pronounced north of latitude 50°N; thus, a national climate prediction capability for a time scale of 3-10 years that also considers regional variations throughout the country could have profound economic implications in the course of formulating long-term national-energy strategies.

Reliable climate models with predictive value for these time scales require records that are several hundred years longer than the written records available for most parts of Canada; this means that proxy or substitute data that can be derived from natural recording mechanisms must be used. One of the many natural recorders of proxy data on climatic variation is the sediment in certain parts of fjords and estuaries. These environments represent an interface between continental and marine regimes, each of which has the potential to modulate the sedimentary and biological processes that operate in nearshore ocean systems.

Spring temperature variation and cumulative winter precipitation are two variations in a model that describe the intensity of the spring discharge of rivers situated within the north temperate climatic belt of Canada. The relationship between the spring discharge characteristics of the Saguenay River in Quebec and the rate and type of sediment deposition at the head of the Saguenay fjord has been under investigation by BIO scientists since 1976. The deposition rate at the head of the fjord is relatively high (3 to 7 $cmyr^{-1}$) so that many bottom dwelling organisms found in other parts of the fjord, which are capable of mixing the sediments, are reduced in number or totally absent under these conditions. This situation has resulted in the development of a virtually “unbioturbated” sedimentary record that can be resolved on a time scale of months to years. The pollution history of the fjord can be easily discerned from cores along with major events such as the St. Jean Vianney, P.Q., landslide of May 1971. This slide introduced about 7.6×10^6 m^3 of older postglacial marine sediment into a tributary of the Saguenay River and much of this material was ultimately deposited at the head of the fjord in a discrete layer. In a somewhat analogous manner, the spring discharge, or freshet, of the Saguenay River deposits a distinctive annual layer of sediment over the bottom of the fjord. The geological characteristics and fossil content of these annual sediment layers provide information on the relative intensity of spring river discharge over the period represented by the core samples. The samples can be dated using the lead-210 isotopic dating technique, a method that is especially applicable to material less than 200 years old.

The investigation of the link between river discharge and climate focuses on the calibration of the known discharge intensity to recorded climatic variables such as the long-term variation of mean monthly temperature during the spring seasaon and the cumulative precipitation during the preceding autumn and winter. The time interval for which the modern discharge record is known can then be calibrated to the dated profiles of geological and paleontological variables deduced from sediment cores. This calibration permits an empircal model to be constructed to interpret the time interval of the core that is older than the period of written records and thereby to estimate the river discharge conditions over a longer period of time. This information can help to estimate indirectly the character of older annual autumn-winter-spring sequences. The proxy time series can also be examined for repetitive or cyclic variations, and for information on the local manifestations of well known 19th and 20th century climatic trends that are evident throughout much of the northern hemisphere.

DEEP OCEAN MARINE CHEMISTRY

Chemical oceanographers of the Atlantic Oceanographic Laboratory of BIO are studying the transport and transformation of chemical substances in the deep ocean as one way of better understanding the deep ocean processes that are important for climate prediction. Some of this work has been concentrated in Baffin Bay and the western basin of the Atlantic Ocean where strong atmospheric exchanges are important. One study of particular interest examined the carbon dioxide (CO_2) content of the deep and intermediate waters of Baffin Bay.

The increasing level of CO_2 in the atmosphere caused by the burning of fossil fuels on a growing scale and the capability of the oceans to absorb it from the atmosphere are very significant in their relation to future climate. Atmospheric CO_2 has little effect on the sun’s incident radiation and consequently on the level of the solar energy absorbed by the atmosphere. It is the blanketing of the earth’s long wave (infrared) radiation by CO_2 that effectively raises the temperature. It has been estimated that, at the present rate of growth, the CO_2 concentration will double in the next century and probably cause the global temperature to rise by 1.5 to 4°C. Although controversy remains over certain aspects of the global carbon cycle, the importance of the oceans in modifying the climate response to the increasing CO_2 concentrations is strongly indicated. To what degree, however, is yet to be determined.

Until quite recently any increase in inorganic carbon in the sea has been difficult to measure because of the complicated ocean chemistry of carbon. New methods were developed in 1978 and measurements of CO_2 were successfully made in the Atlantic and Pacific oceans. Using recently developed methods, chemical oceanographers at BIO studied the seawater of Baffin Bay to determine if a correlation could be made with the earlier findings.

The work involved estimating the relative age and determining the concentrations in a number of samples after assessing the probable origins of the water at various depths. As explained below, it would then be possible to correlate the differing carbon concentrations with the degree of past exposure to the atmosphere, and hence to estimate the build-up since the onset of the industrial revolution. There were two conditions that had to be met before a valid estimate could be made: first, the "old water" had to have remained isolated from the atmosphere during industrial development and second, the "new water" had to have had the same history and origin as the old except for its exposure to the atmosphere.

Baffin Bay was an ideal site for such an experiment because of its depth of 2300 m and the pronounced sills in the straits and sounds that provide access to it. Water flows into the Bay from the Arctic Archipelago via Jones and Lancaster Sounds (150 m), from the high Arctic via Nares Strait (250 m), and from the Labrador Sea/North Atlantic via Davis Strait (800 m). The deep water in the Bay is thereby entrained. Its long isolation from the atmosphere and its separation from the shallower water were significant to the experiment.

The water column in the Bay in fact has three distinct layers, all of which appear to be of North Atlantic origin. The upper layer (150-300 m), however, is considerably modified by the addition of Bering Sea water and therefore could not be used in the experiment because of the second condition noted above. The 'age' of the water masses was determined by measuring the content of tritium derived from the atmosphere and its daughter-product $helium^{-3}$, as well as by considering oxygen utilization. The age of intermediate and deep water varied from two years at 500 m to a few hundred years at the bottom, and these waters showed no signs of mixing with other water. Since the age measurement in Davis Strait was also about two years at 500 m, it is highly probable that both the intermediate and deep water in the Bay was last in contact with the atmosphere in the North Atlantic. All these age measurements were determined by helium-tritimm tests backed up by oxygen utlization measurements.

During the experiment itself, samples were collected from seven stations at depths of about 200 to 2000 m. The total increase in dissolved inorganic carbon in the ocean since the onset of the industrial revolution was estimated at 1.0% (1979), which is in excellent agreement with the previous estimate of 1.3% in the Atlantic and Pacific Ocean studies.

Although not all questions are resolved, the good correlation between observations made in very different parts of the oceans shows support for the method and the abundance of data must give considerable credibility to the evidence of fossil fuel carbon build-up in the sea.

Roger Belanger 4564-10

Eric Levy, Peter Jones, and Frank Zemlyak aboard CSS *Hudson* in Jones Sound, eastern Arctic.

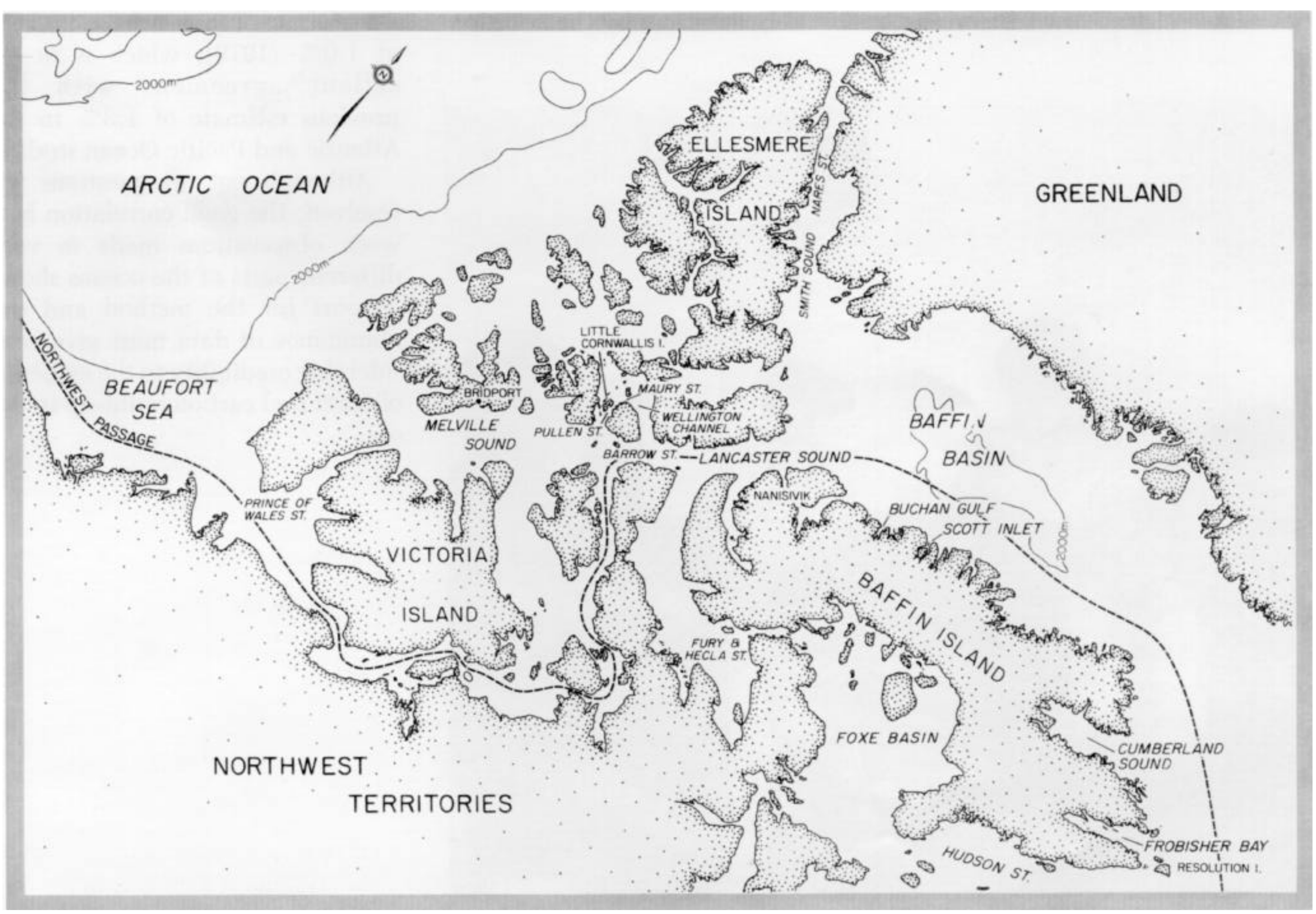
chapter 2

Northern Development

The pace of action is quickening to identify and to develop the assets of the Canadian north. Shipping traffic in the Arctic is increasing and icebreaking tankers could be regularly traversing the Northwest Passage as early as 1986. Oil companies have already discovered large quantities of oil and gas in the Beaufort Sea and in the Arctic Archipelago. Problems that now must be faced involve the engineering required to produce and transport these resources to market economically and safely. Both the oil industry and the Canadian government have to consider the scientific, socio-economic, regulatory, and legal aspects of developing the north and many research projects are being conducted to improve knowledge of this vast area.

Everyone concerned with Arctic development agrees that the development of reliable marine transportation is a most pressing need. The Canadian Hydrographic Services (CHS), whose Atlantic Region office is at BIO, assumes a major responsibility for this task by systematically surveying and charting all navigable waters within the eastern Canadian Arctic and the Atlantic region of Canada.

BIO is also contributing to Arctic development by adding to knowledge of the north - particularly its physical oceanography, marine geology and geophysics, biological and chemical oceanography,, and weather. In addition, the determination of the total tidal regime through the Arctic Archipelago is under study as an element in developing ice forecasting models. This basic information will be essential to effective Canadian development of the north. The results of BIO studies are published in scientific reports and BIO indexes and archives pertinent data so that they will be available to industry, government, and the public for future investigations.



The Arctic locations discussed are shown. Note that shipping traffic may he able to navigate through Prince of Wales Strait into Melville Sound and Barrow Strait instead of following the more traditional Northwest Passage shown.

Roger Belanger 5390-5

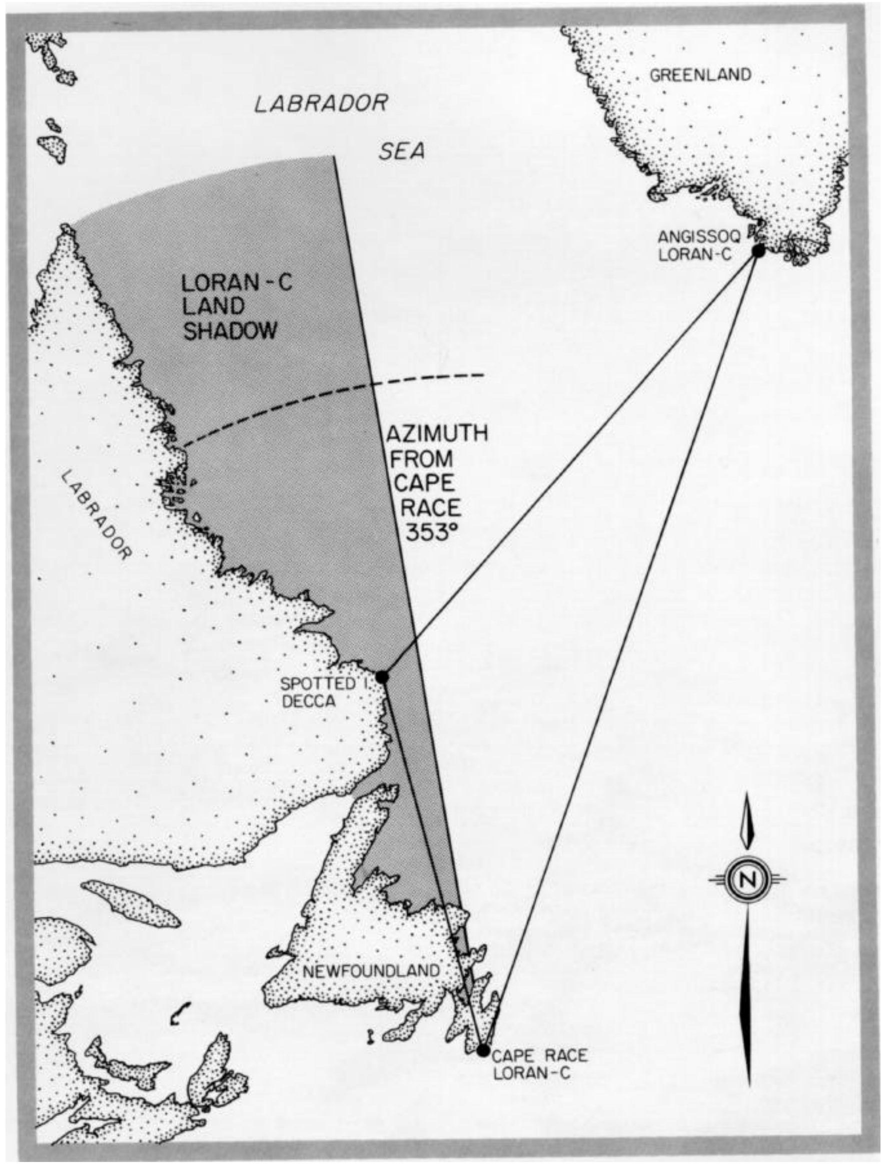
CSS *Baffin* en route to Ungava Bay.

In the sections that follow, a brief and selective review is provided of current BIO involvement in Canada's northern regions.

MARINE TRANSPORTATION

As mentioned, an essential step in the development of Arctic resources is the opening of the area to large scale, year-round navigation by deep-draft shipping. One of the major elements of this task is to develop an understanding of the dynamics and properties of sea ice. A second and equally pressing task is the production of adequate navigational charts. Once this information is available, it will be necessary to develop and provide reliable aids to navigation and shore-based control systems for year-round safe passage under Arctic conditions.

Much of the Arctic is either uncharted or insufficiently charted for the type of marine traffic anticipated. The severity of the environment renders the survey season short and uncertain and limits the rate at which such charts can be produced. At the present time surveys made by measuring through the ice must be followed up by full-scale conventional ship and launch methods that are expensive and time consuming. Although developments in airborne survey techniques are encouraging, they are neither ready nor do they have the potential for sounding in the relatively deep channels to be used by supertankers. Nonetheless, the 1981-85 Canadian Hydrographic Service survey plan to be conducted by the three CHS regions with responsibility for the Arctic- Atlantic, Central and Pacific - meets the requirements for the adequate charting of development sites, passages, ports, and harbours for the first phase of resource development. This includes a bathymetric survey of the Beaufort Sea where detailed soundings are required to locate the many 'pingo-like' ice hillocks that pose a navigational hazard to deep-draft traffic, and surveys of Bridport Inlet and the passages to Lancaster Sound. The tanker route from the Beaufort Sea is expected to proceed via Prince of Wales Strait, Viscount Melville Sound, and Barrow Strait through into Baffin Bay, with possibly an alternative route through Fury, Hecla, and Hudson Straits. The proposed year-round Arctic Pilot Project route for LNG (liquified natural gas) tankers from Bridport Inlet on Melville Island will probably, follow the same route. The terminal at Bridport, which had earlier been surveyed by through-the-ice techniques, was surveyed successfully by launch and ship last year. Ore carrier routes from Little Cornwallis Island are via Pullen Strait, Maury and Wellington Channels, and Barrow Strait, and from the Nanisivik mine on northern Baffin Island directly into Lancaster Sound.



Loran-C operations in the Labrador Sea are complicated by the large amount of land path to the Cape Race transmitter.

The CHS has in addition developed special expertise in offshore navigation, and this knowledge is required when it comes to deciding on the most effective system for positioning ships in the ice-infested waters and often featureless land masses in the Arctic. The present Transit satellite navigation system provides spot fixes at intervals, between which ships must rely on dead reckoning or supplementary fixes using Loran

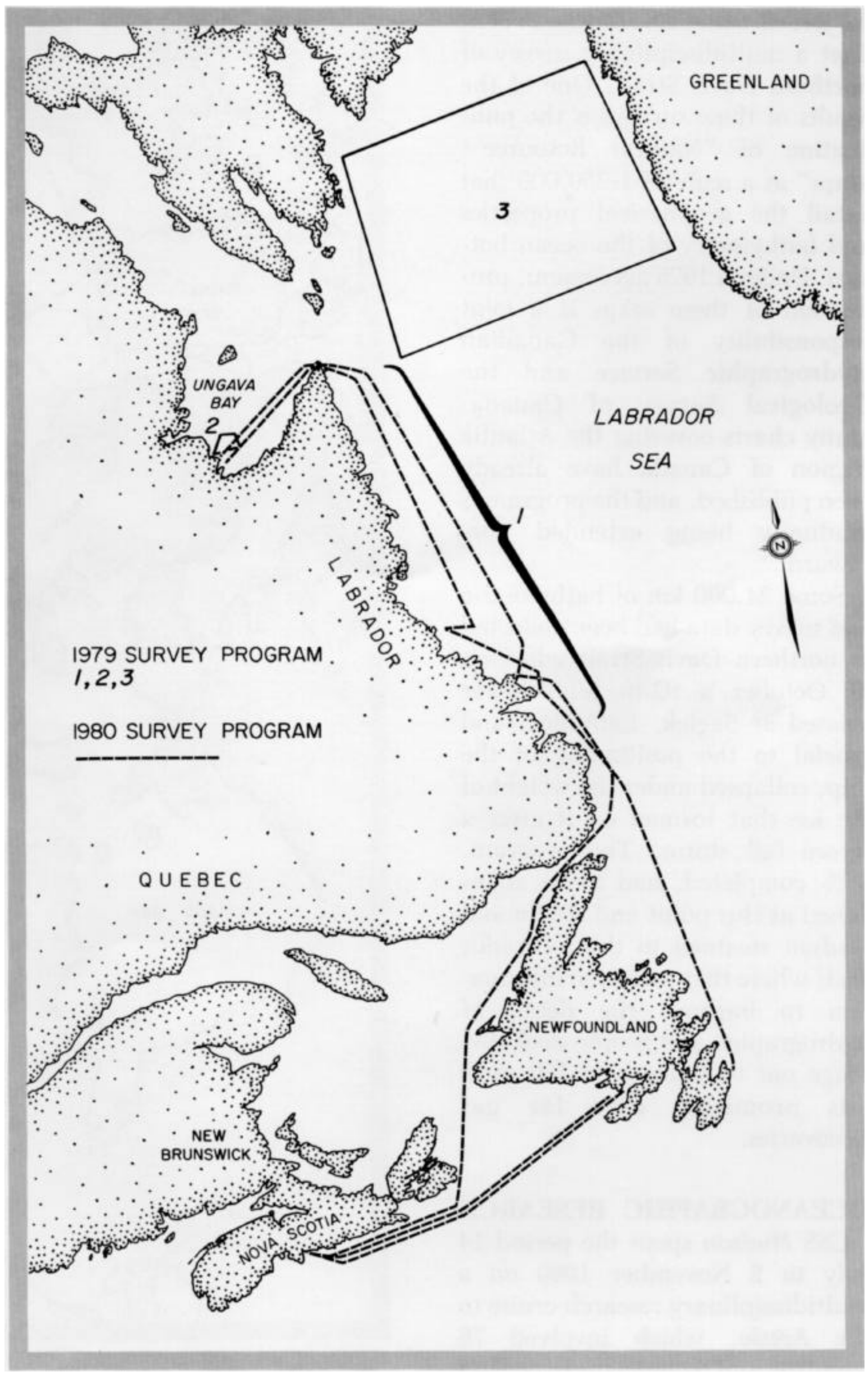
C sky waves. The future Global Positioning System NAVSTAR will provide continuous fixing when fully operational in about 1987 but until then it gives full positioning for only 11 hours a day and partial fixes for another two hours. During this latter period a Loran C sky wave reading could be added to provide a satisfactory fix. It is probable, however, that for safe navigation through the Northwest Passage, the Satellite System will have to be supplemented with a close range radio aid, particularly for harbour entry and departure. There are a number of systems available and under development, but none have yet been used in the Arctic. The behaviour of electromagnetic waves in the arctic permafrost and sea ice is of prime concern since it affects the range and accuracy of any radio positioning system. At the present time the Atlantic Region of the Canadian Hydrographic Service at BIO is carrying out a field test of Loran C groundwave propagation in the Beaufort Sea using small portable transmitters in order to determine to what extent arctic conditions may alter the performance seen in temperate regions, which we know well from previous experience. This test, which is being made in collaboration with the Pacific Region of CHS and the Canadian coast guard, will permit us to predict the number of Loran-C transmitters required to cover a given area with the accuracy of navigation to be expected.

1980 ARCTIC CRUISES

CSS *Hudson* and CSS *Baffin* were engaged in hydrographic and oceanographic work in the Canadian Arctic for a combined total of nearly eight months during 1980. These cruises typify BIO's commitment to Arctic studies and so a review of the major experiments and surveys conducted is appropriate.

HYDROGRAPHIC SURVEYING -CSS *Baffin* was engaged in hydrographic survey work in Ungava Bay and along the Labrador Coast from 7 July to 29 September 1980. During that period, hydrographers working from the ship, its five survey launches, and a helicopter collected nearly 12,000 km of bathymetric sounding data, examined 2,111 shoals, and established 108 elevations: to relate this information to the new charts proposed for these areas, it was necessary to establish 36 horizontal control stations, two tide gauges for vertical control, and one current meter station.

The *Baffin's* cruise track for her 1979 and 1980 northern work is shown on the accompanying figure. The first leg of the cruise along the Labrador coast was the conclusion of work begun earlier to survey a route for ships along the coast near the Ragged Islands. That survey had been requested by the Newfoundland Shipowners' Association. The next major leg involved work in Ungava Bay and George's River in order to provide more



The cruise tracks of CSS *Baffin* on her 1979 and 1980 northern hydrographic survey program.

detailed bathymetric information where to date tankers supplying aid to settlements have been forced to sail through uncharted, rock-infested waters. This survey had been requested by the Dominion Marine Association and Shell Canada Limited. The national plan for hydrography calls for a continuation of surveys of the Labrador coast and Davis Strait during 1981 and *Baffin* will have a major responsibility in meeting this target.

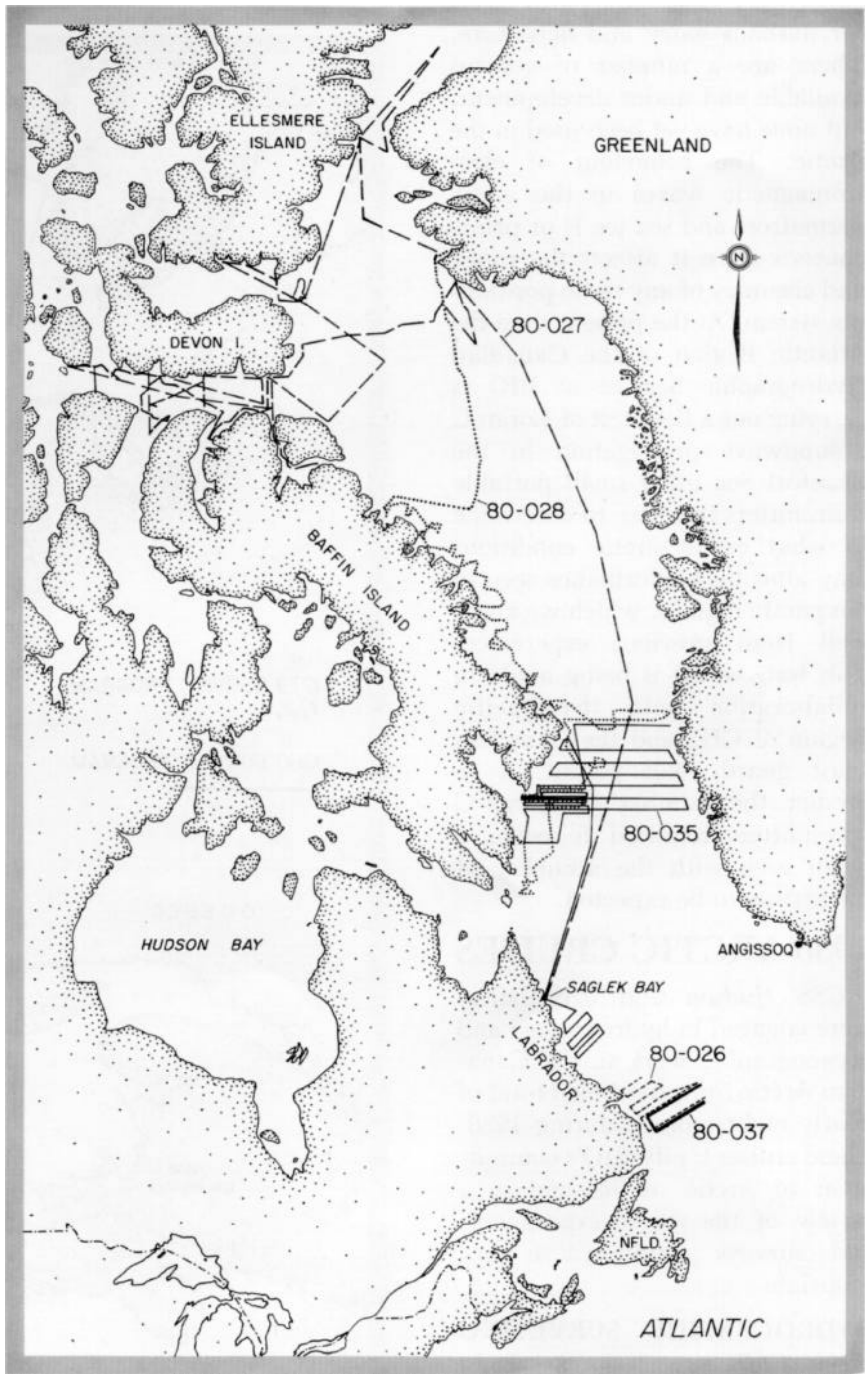
From 10 to 27 October, CSS *Baffin* joined with CSS *Hudson* to conduct a multidisciplinary survey of northern Davis Strait. One of the results of these surveys is the publication of "Natural Resource Maps" at a scale of 1:250,000 that detail the geophysical properties and bathymetry of the ocean bottom. Under a 1975 agreement, production of these maps is a joint responsibility of the Canadian Hydrographic Service and the Geological Survey of Canada. Many charts covering the Atlantic Region of Canada have already been published, and the program is gradually being extended northward.

Some 24,000 km of bathymetric and survey data had been collected in northern Davis Strait when on 21 October a 92-m high tower located at Saglek, Labrador, and crucial to the positioning of the ship, collapsed under the weight of the ice that formed on it after a severe fall storm. The program, 65% completed, had to be abandoned at this point and *Baffin* and *Hudson* steamed to the Labrador Shelf where they collected information to improve the detail of hydrographic and geophysical coverage out to a depth of 100 m in this promising area for gas discoveries.

OCEANOGRAPHIC RESEARCH

CSS *Hudson* spent the period 14 July to 2 November 1980 on a multidisciplinary research cruise to the Arctic, which involved 76 scientists and technicians from BIO and from Canadian and foreign universities. During the cruise, *Hudson* worked one biological station at almost 80°N in the southern end of Nares Strait, probably further north than any previous oceanographic station occupied in the Canadian Arctic by a ship. A total of 305 stations were worked and over 300 km of underway observations were made using towed equipment.

The first major section of the cruise (24 July - 29 August) was organized by the Marine Ecology Laboratory and devoted to the biological oceanography of three areas: Lancaster Sound, northern Baffin Bay, and Melville Bay. This cruise represented BIO's first major biological expedition in that area and was largely developed from previous work on other BIO expeditions (chemical and physical oceanography) and research conducted aboard Canadian Coast



The cruise tracks of CSS *Hudson* on her 1980 multidisciplinary research cruise to the Arctic. The most northerly point reached by *Hudson* on these cruises (79°46.9.N) is not shown.

Guard icebreakers.

The research program was based on the fact that the distribution and abundance of marine organisms throughout the Arctic is reasonably well described by previous studies, and that what is chiefly lacking is an understanding of how the physiological processes of Arctic organisms differ from what is known for similar kinds of marine organisms in lower latitudes. Thus, the objective was to investigate some fundamental ecological processes essential to the understanding of the dynamics of marine ecosystems under the environmental stress imposed by the Arctic's highly variable light regime and constant cold temperatures. Research was concentrated on the biochemistry of the photosynthetic process in Arctic phytoplankton and on feeding and metabolic processes in Arctic zooplankton.

Early indications are that arctic phytoplankton are not uniquely adapted to their light and temperature environment but respond to changes in these physical properties much as would organisms from temperate latitudes. Dissolved nutrients required for phytoplankton growth are typically in short supply in these waters but populations examined to date have shown no signs of severe nutrient deprivation.

Distributional studies focused on micro- and macroplanktonic organisms (phytoplankton and zooplankton) and particularly on the fine details of their vertical distribution in the water column. For most areas studied, plankton were extremely abundant with the greatest densities occurring below the sea surface and typically associated with the physical/chemical structure of the water column.

The relations between concentrations of plankton and the distribution of seabirds were also studied and. in one location, the physical mechanism (oceanic front) causing near-surface plankton aggregation, which in turn caused sea bird aggregation, was clearly demonstrated. Physical oceanographers concentrated on measuring the transport of Arctic Ocean water eastwards through Lancaster Sound and other passages, and on the role played by glaciers in the supply of phytoplankton nutrients to the coastal areas as well as mineral solid particulate material (rock-flour) to the particulate matter budget of the sounds. The biochemistry of littoral fish including their anti-freeze protein systems and pesticide contamination levels was also investigated. Analyses of the data collected on the approximately 17 separate ecological investigations is proceeding smoothly and results will begin to be published in 1981.

The next leg of the cruise (August 29 - September 14) was devoted to chemical oceanography in the deepest parts of Baffin Bay and chemical/geological studies of the hydrocarbon seepage discovered by BIO in 1976 in the Scott Inlet - Buchan Gulf area off Baffin Island. It was organized by the Atlantic Geoscience Centre and the Atlantic Oceanographic Laboratory.

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Biologist Ed Gillfillon of Bowdoin College, Maine, joined BIO scientists aboard CSS *Hudson* in the high Arctic during the summer of 1980.

Chemical oceanographers collected water and bottom sediment samples from mid-Baffin Bay and analyzed them for nutrients, radionuclides, hydrocarbons, oxygen and salinity. The aim of these ongoing studies is to partition the sources of Arctic Ocean water in Baffin Bay between the overflows through Lancaster and Smith sounds.

The chemical and geological oceanographers then returned to the site of the oil seep at Scott Inlet and reconfirmed its location. Oil droplets were observed erupting at the surface of the sea and forming iridescent patches that almost instantaneously spread into slicks. The seep is associated with a structural high near the seaward end of the submarine trough that extends across the Baffin Island continental shelf at Scott Inlet. Upturned strata that flank this high beneath the outer south wall of Scott Trough are the likely source of the persistent seepage observed at that locality. Seepage also appears to be occurring at other localities in this region on a more spasmodic basis both in the Scott Inlet area and at Buchan Gulf to the north, where truncation of underlying strata by erosion permits formation fluids or gases to escape into the water column.

The third section of the cruise (September 15 - October 10) was devoted to geological and geophysical investigations by the Atlantic Geoscience Centre of the Baffin Island shelf, southward from Scott Inlet to Resolution Island, and in mid-Davis Strait. Bedrock and surficial sediment investigations involved collection of data with a wide range of equipment. The major objectives of this section were reached and included several highlights.

A petroliferous core of considerable interest was collected from a diapir-like (piercing-fold) structure east of Cumberland Sound on the Baffin Island continental shelf. The 65-cm long mudstone core gave off a strong petroliferous odour and bubbles upon recovery. It provided the first tangible evidence of the age and composition of the strata present at this structure, and is encouraging news for northern oil exploration. Another highlight of the cruise was the successful recovery of basaltic rock cores from the structural high under mid-Davis Strait and also from a locality seaward of Cumberland Sound. The cores are now being analyzed in detail and are expected to provide important clues that will help resolve scientific controversy that now exists on the nature of the earth's crust underlying Davis Strait. The argument centres on whether the region is underlain by oceanic crust that was formed by seafloor spreading when Greenland separated from Baffin Island or by continental crust that was subsequently modified by the intrusion or extrusion of basaltic rocks during the Tertiary Period.

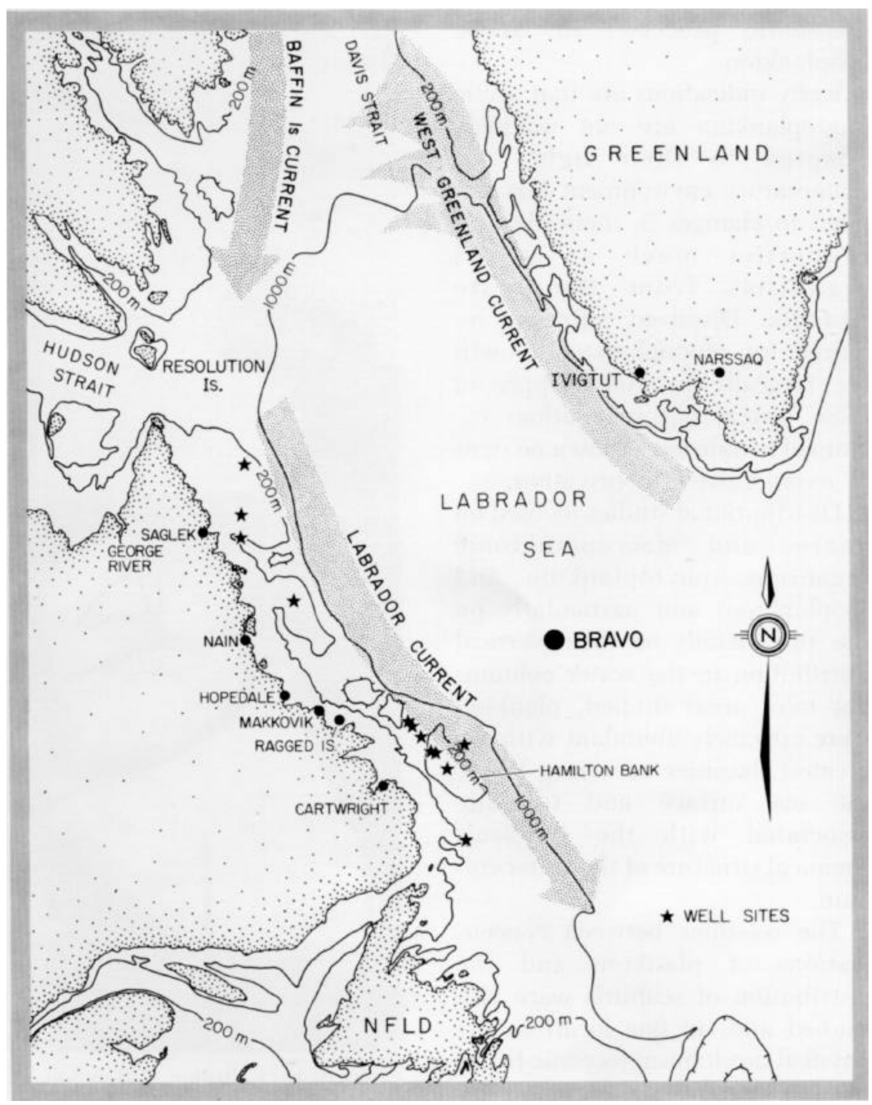
The fourth leg (October 10-26) of the cruise was a continuation of the joint AGC - Canadian Hydrographic Service (Atlantic Region) program of multiparameter surveys described earlier.

The last leg (October 26 -November 2) was used by physical oceanographers to recover three long-term current meter moorings and to replace them, to investigate via CTD profiling the oceanography of Hamilton Bank, and to investigate the bedforms present in the Strait of Belle Isle where plans are now being made to run a power cable. This research is discussed in more detail below.

FOCUS ON THE LABRADOR SEA

The Labrador Sea connects the Atlantic Ocean to the waters of Hudson Bay and the Arctic Archipelago. It is bounded to the west by Newfoundland, Labrador, and southern Baffin Island, to the east by Greenland: shallow Davis Strait separates it from Baffin Bay to the north. The sea has been a focus of interest for both government and industry for a number of years. To date, about 20 exploration wells have been drilled on the Labrador Shelf and data from more than one-third of these have been released from confidential status and made available for analysis. Hydrographers, geologists and geophysicists, and physical oceanographers from the Institute, from universities, industry, and other nations such as Denmark and Germany have carried out numerous research and survey projects in the Labrador Sea and surrounding areas.

The first information concerning the geology of the Labrador continental shelf came in the early sixties from geophysical surveys and early hydrographic charting efforts. Today, a large body of information on its geology, geophysics, hydrography, and physical oceanography exists. Ongoing studies in the area by scientists at BIO fall into five areas: (1) analysis of the geological information provided by exploratory wells drilled on the shelf; (2) regional geophysical-hydrographic surveys that are conducted as part of a multiparameter survey operation by the Atlantic Geoscience Centre and the CHS Atlantic Region office; (3) Determinations of the effect and extent



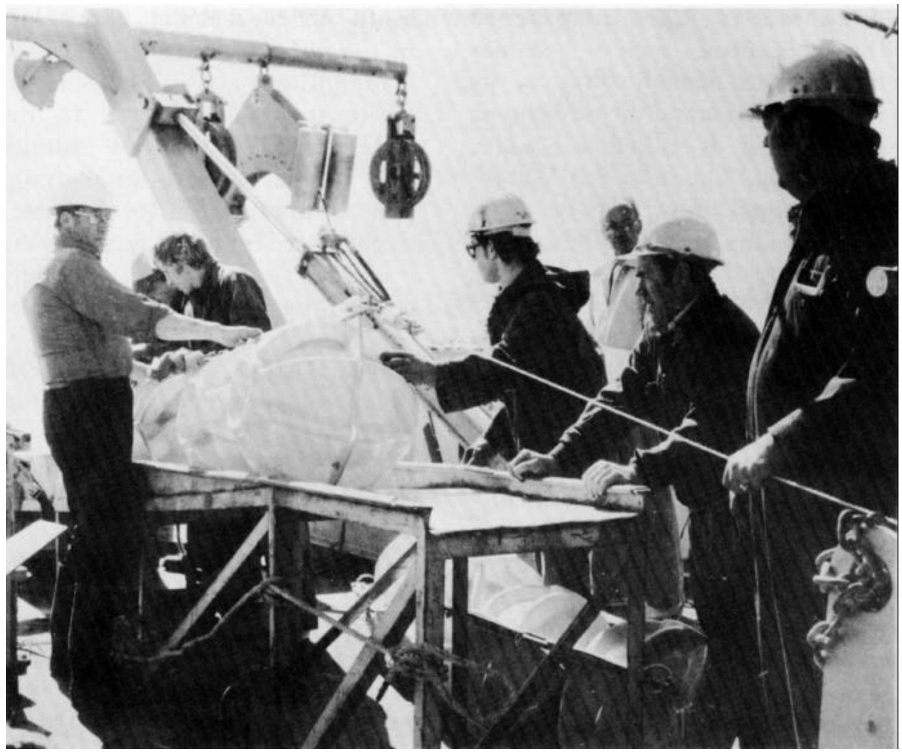
The Labrador Sea showing the major features discussed in the text. Blackened circles on Labrador and Greenland are meteorological stations.

of iceberg scouring in the Labrador Sea; (4) Analyses of its paleo-oceanographic conditions during the last ice age; and (5) Description and modelling of its physical oceanography. A few recent developments in these areas are discussed below.

PHYSICAL OCEANOGRAPHY - Over the past 15 years scientists at BIO have been analyzing data from the Labrador Sea in an effort to increase understanding of the important processes in the area and the possible local and "downstream" effects that variations in these processes may have. Some of these data have come from the major oceanographic cruises conducted by the Institute and some have come from foreign scientific expeditions to the region. Other useful oceanographic information was collected during the last ten years of the ocean weather ship *Bravo*. This ship was stationed halfway between southern Labrador and Cape Farewell between 1945 and 1974.

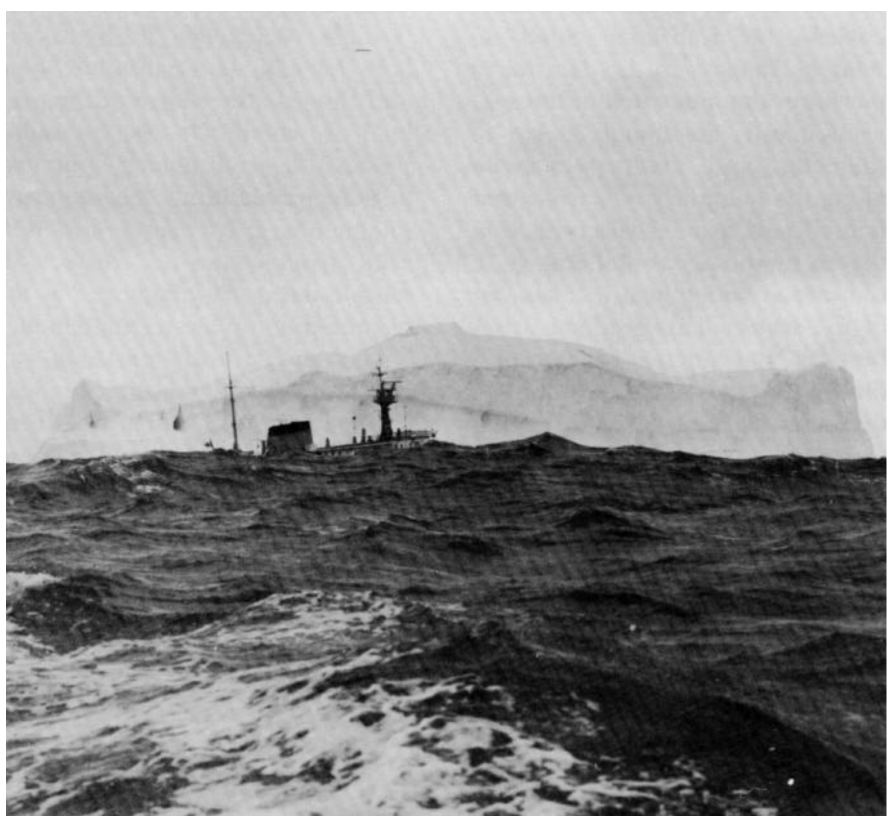
The Labrador Sea forms a big mixing bowl where the last vestiges of the northward flowing, warm, salty, subtropical water meet and mix with colder, fresher, Arctic water. Changes in these two primary flows or in the atmosphere can produce important changes in the local and distant marine and terrestrial climates. If, for example, the northward warm water flow decreases, the temperature over the cod-spawning areas off West Greenland and Labrador decreases and fewer fish larvae presumably survive. On the other hand, if the flow of polar water increases the fish stocks may again be affected. Also, a larger supply of polar water may be partially responsible for cooler and drier climates in eastern North America.

In the centre of the Labrador Sea, the mixing of the north and south waters proceeds slowly, but in winter violent storms often bring cold Arctic air out of the area. The surface water is cooled and becomes denser, then sinks and begins to transfer heat by convection to



John Lazier

Bosun Joe Avery (at left) directs operations aboard CSS *Hudson* during deployment of moorings in the Labrador Sea.



Roger Belanger 4555-7

CSS *Hudson's* superstructure silhouetted by an iceberg.

deeper waters. When the water in the convective region becomes homogenous enough (that is, its temperature and salinity are almost constant) it is called a “water type”. The “Labrador Sea Water” thus formed flows slowly away from the area, and is found at depths of 1200-1800 m throughout the northern North Atlantic Ocean.

The Atlantic Oceanographic Laboratory’s principal research program in the Labrador Sea has been to investigate the details of the convection processes operating in late winter when the depth of convection is at its maximum. The first cruise, in 1966, turned out to be during an exceptionally mild winter and no production of Labrador Sea water by convection was found. Scientists thought they had misjudged the size of the area over which the convection would take place but more probably convection cells were too small to detect from their widely spaced stations. Another cruise in 1976, an exceptionally cold and windy winter, used CTD’s, moored current meters, Batfish, and vertical current meters to find zones of deep convection to 2000 m not far to the east of the ice edge that usually covers the Labrador Shelf in winter. Analyses of the data taken on this cruise indicate that the convection cells are about 30 km in diameter and rotate clockwise along the boundary of a front that is itself part of a larger circulation driven by the horizontal change in the rate at which heat is taken out of the water. This gradient arises because the air-sea temperature difference across the Labrador Sea decreases as the eastward flowing air warms up.

Changes in the depth of the deep convection have also been examined in the 10 years of oceanographic data from weather ship *Bravo*. During the period 1967-1971, an exceptionally large volume of low salinity Arctic water flooded the Labrador sea. These conditions have been traced to an anomalously high atmospheric pressure cell over Greenland that drove an unusual amount of cold water south. A radical change at this time in the climate of Iceland and the United Kingdom has also been linked to this phenomenon. In the Labrador Sea, the low salinity water coincided with usually mild winters and deep convection effectively ceased for four years until the cycle was broken by the unusually cold winter of 1972.

GEOLOGICAL DEVELOPMENT - The geology and geophysics of the Labrador Sea are now well described and scientists at the Atlantic Geoscience Centre feel that the Labrador Shelf could well prove to be an important hydrocarbon province.

All drilling activity and hydrocarbon discoveries to date have been on the Labrador Shelf and the shelf off southern Baffin Island, both areas believed to be underlain by continental crust. As in the case of Davis Strait discussed earlier, unequivocal evidence is lacking on whether the Labrador Sea was formed by seafloor spreading, by the subsidence and foundering of continental crust, or by some other process. However, resolving this question has important implications regarding the possible occurrence of hydrocarbons beneath the Labrador Slope and Rise. At the centre of the problem is whether in the Labrador Sea area the traditional geophysical criteria for defining oceanic crust (magnetics, gravity, and refraction and single-channel reflection seismic data) are diagnostic as interpreted in a plate-tectonic mode. The traditional criteria as evaluated for the Labrador Sea, Davis Strait, and Baffin Bay form the basis for suggesting that these areas developed by the process of seafloor spreading. Multichannel reflection seismic surveys coupled with stratigraphic data from exploratory wells on the Labrador continental shelf (and excluding Baffin Bay and Davis Strait) have been used to argue that seafloor spreading need not be invoked to explain the origin of the Labrador Sea. These latter results indicate that vertical crustal movements can account for the origin. Another mode of origin proposed is based on the undation theory (or blister hypothesis), which holds that some structural and tectonic features of the Earth’s crust are caused by vertical movements that result from disturbances within deep-seated mobile rock material. Information derived from industry-drilled deep wells indicates that the sediments overlying the oceanic crust in the middle of the Labrador Sea are of early Tertiary or younger age. As many of the world’s oil deposits are found in older rock formations, this reduces the likelihood that the central part of the Labrador Sea contains significant accumulations of oil and gas. Nevertheless, because younger Tertiary sequences in other areas contain oil and gas, there remains the possibility that petroleum accumulations may be found closer to the margin of the Labrador Sea where these sequences are thickest.

ICEBERG SCOURING AND GLACIATION STUDIES - Icebergs pose a hazard to shipping and to undersea structures such as wellheads and pipelines. About 15,000 icebergs are calved each year mainly from the western Greenland Ice Cap with small contributions from East Greenland and Canadian glaciers. Many drift southward with ocean currents past the coasts of Baffin Island, Labrador, and Newfoundland. Side-scan sonar records of the ocean bottom show that the keels of the larger bergs, which weigh several million tonnes, often scour the Labrador continental shelf and indeed some of the larger bergs may ground in water depths of more than 200 m. The Atlantic Geoscience Centre has been studying iceberg scours formed by bottom-dragging icebergs to assess the hazards they pose. Three types of study have been undertaken cooperatively with the Centre for Cold Ocean Resources Engineering of Memorial University, Newfoundland, and the oil industry.

(1) Information about the limits and variability of ice scours is

being derived from about 7000 km of side scan sonar (1.5 km swath) and high resolution seismic reflection lines across the shelves of Baffin Bay and the Labrador Sea and on the Grand Banks off Newfoundland. Morphological characteristics of the scours in sample sections are compiled into a computer data bank for analysis and reference. Scour morphology together with information such as water depth, sediment type, seabed slope, and oceanographic and geological settings are being analyzed to identify ice-scour populations, their spatial distribution, and their environmental control.

(2) The scour population is being studied in detail at sites on the southern Saglek Bank, the central Makkovik Bank, and the Hibernia oil discovery area off Newfoundland by using closely-spaced side scan sonar lines, seisinic reflection profiles and geological analysis of grab and core sediment samples. By repeating the surveys annually and comparing seafloor mosaics, new scouring events are detected to help define the modern scouring regime as a basis for evaluating the probability of future impacts on the seafloor and for differentiating the regime (present or relict) in which particular ice scours occurred.

The observed concentration of ice scours that are believed to have formed over the past 10,000 years varies substantially from region to region. On the Labrador Banks, extensive areas have been completely reworked by ice keels: the maximum penetration is 17 m locally in soft mud and about 8 m in the more widespread firm sediments. In contrast less than 10% of the seabed on the northeast Grand Banks has been disturbed and the maximum scour depths observed are 5.4 and 6.5 km.

(3) Actual grounding events provide valuable data for modelling the dynamics of the ice scouring process and for linking the observed scour form to iceberg movement related to seasonal, storm, tide, or other conditions. To date we have observed the ice keel contact and scours resulting from the observed summer grounding of two icebergs - one on Saglek Bank in 120 m, the other on Nain Bank in 140 m depths.

In general, the offshore banks have been well scoured in the past and scouring still occurs today. The geological record contains much information on the scouring process that can be exploited by further detailed study of surficial sediments, co-ordinated with investigations of modern iceberg flux and grounding dynamics,

The Atlantic Geoscience Centre has also been studying the stratigraphy of surficial sediments on the northern Labrador Shelf and the eastern Labrador Sea in order to correlate the sedimentary chronology of these areas to a worldwide chronology and to North Atlantic paleo-oceanographic history. Huntec company deep-tow seismic records, and echo sounder records, airgun reflection records, coring, and carbon-14 dating have been used to delineate ten acoustic-morphologic areas between 57 and 61°N. The data suggest a sequence of glaciation and deposition starting with the maximum extent of the glaciation about 10,000 years ago. As glaciers receded, fine-grained muds began to be deposited in the basins.

Analysis of cores obtained along the West Greenland continental rise has enabled us to develop a stratigraphic framework that relies heavily on oxygen isotope information from two cores together with analyses of volcanic ash and microfossils to extrapolate this chronology to other cores. From these data, the glacial and nonglacial periods over the past 90,000 years have been deteminded.

By combining the results from these two studies, a model of the glaciation and deglaciation periods for the Labrador Sea and its oceanic setting has been reconstructed. This research has contributed to worldwide knowledge of glacial periods and brought scientists closer to the ultimate goal of understanding the fundamental cause of the ice ages.

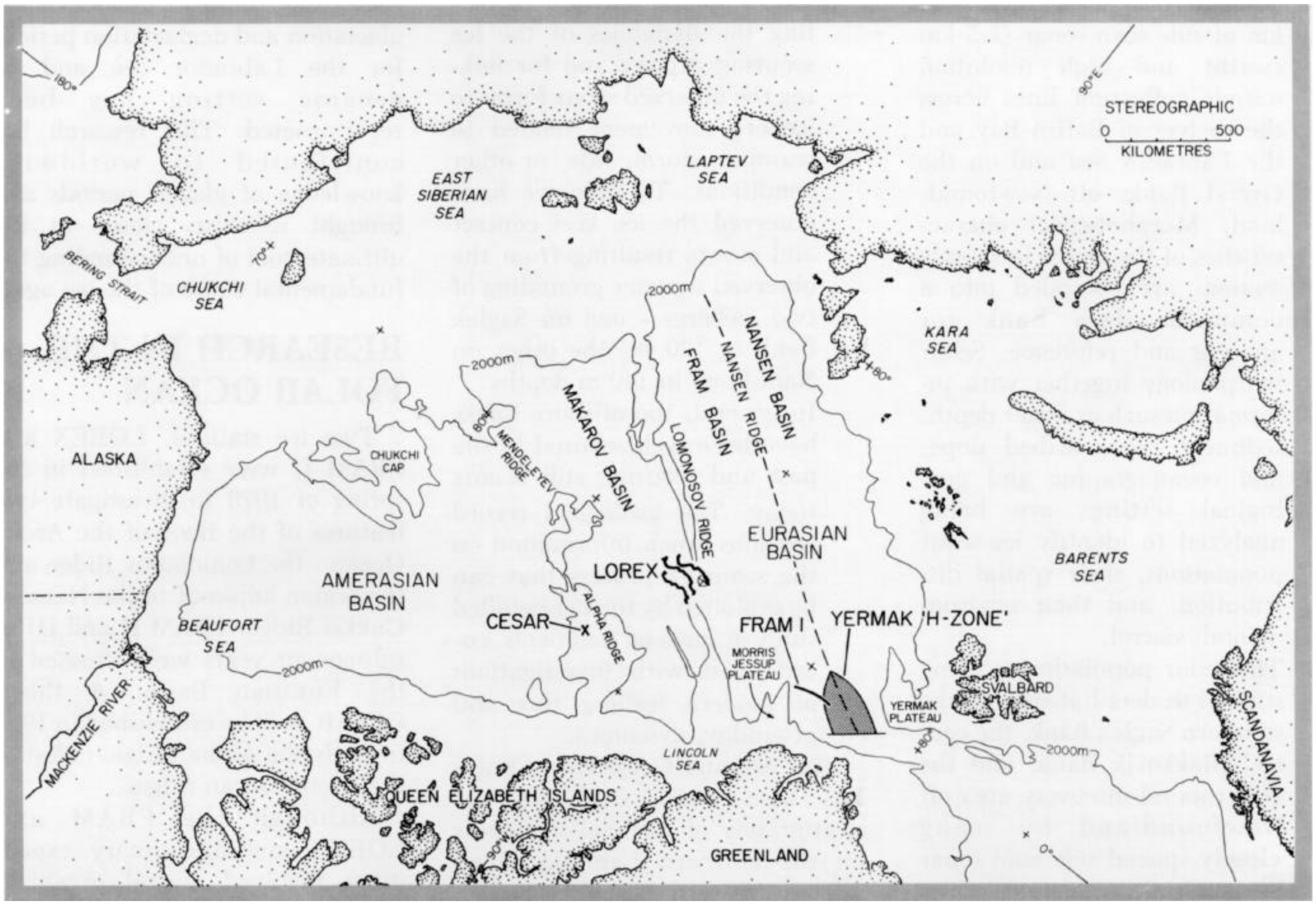
RESEARCH IN THE POLAR OCEAN

Two ice stations, LOREX and FRAM I, were established in the spring of 1979 to investigate two features of the floor of the Arctic Ocean - the Lomonosov Ridge and the region adjacent to the Nansen-Gakkel Ridge. FRAM II and III in subsequent years were situated in the Eurasian Basin. A third, CESAR, will be established in 1983 to study the Alpha Ridge, oldest of the Arctic Ocean ridges.

Although the FRAM and LOREX multidisciplinary expeditions involved several organizations, participants kept in constant touch from the planning stages through to execution and this resulted in excellent co-operation that culminated in a one-day special session devoted to the results of the expeditions at a joint meeting of the Canadian and American Geophysical unions in Toronto in May 1980.

FRAM - Four FRAM expeditions were actually planned: three have taken place and the fourth is planned for spring 1982. The expeditions were named in honour of the ship of Norwegian explorer Fridtjof Nansen. His ship, the *Fram*, was frozen into the Arctic ice pack north of Siberia in 1893: nearly three years later it freed itself from the ice northeast of northern Greenland after having drifted to within 576 km of the North Pole.

Participants on FRAM I, II, and III did not use a drifting vessel as a research station, but rather flew in and set their camp and equipment up on the drifting sea ice for two months. The overall objectives of the expedition were to learn more about the behaviour of acoustic



The major features of the Arctic Ocean floor showing the FRAM I, LOREX, and CESAR main camps.

transmissions in Arctic waters, to map the little known topography of the Arctic Ocean floor, to study the geology and geophysics of the area, and to study the oceanographic characteristics of the water mass.

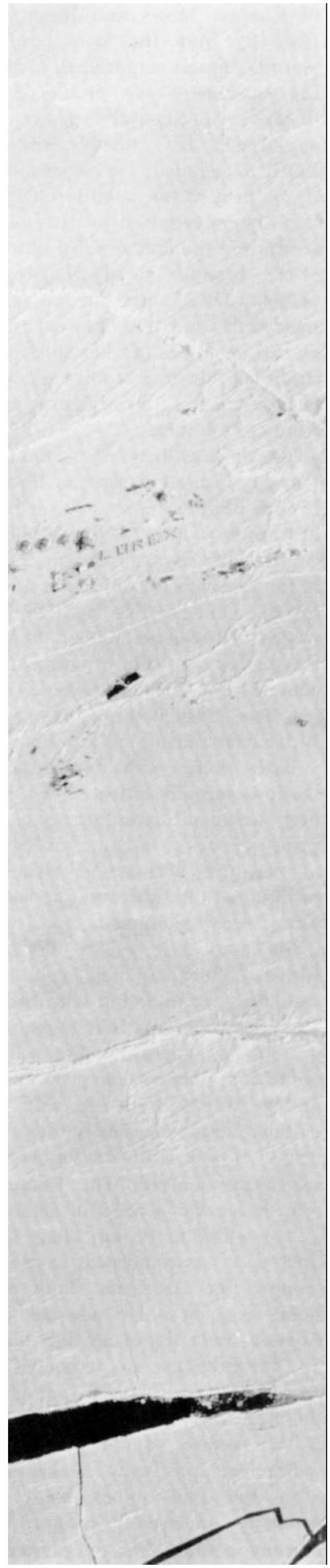
The Canadian contribution to FRAM I was to use seismic methods to study the earth's crust on the southern part of the Nansen-Gakkel Ridge, which extends from near Greenland to eastern Siberia and forms a part of the globe-encircling system of mid-ocean ridges. The Nansen Ridge is the slowest forming ridge in the world - it spreads at the rate of only 0.6 to 1.0 $cmyr^{-1}$. It has the uniform parallel magnetic stripes typical of spreading ridges but near the "Yermak hot spot" - an area of enhanced magnetic activity - the amplitude of these anomalies is unusually great. More information was needed to try to explain these phenomena.

Scientists from the Atlantic Geoscience Centre at BIO and Dalhousie University measured sediment thickness using an airgun reflection system and the deeper structure using seismic refraction tools. Despite the fact that the ice initially drifted in a direction opposite to what was expected, which meant that it crossed neither the Nansen Ridge axis nor the Greenland margin during the expedition, most scientific objectives were met. From eight refraction lines on the ridge flank, scientists determined that the crust in this area is as thin as anywhere worldwide but that its thickness increased near the "Yermak Hot Spot". This thicker crust may account for the strong magnetic anomalies detected in this area. Further FRAM experiments were concerned with variations in crustal thickness away from the spreading centre in progressively older rocks.

LOREX - Whereas FRAM was essentially a U.S. sponsored multination expedition, the Lomonosov Ridge Experiment (LOREX) was a wholly Canadian affair. Its objective was to define more clearly the geologic nature and origin of the Lomonosov Ridge and to develop Canadian expertise in conducting research from floating ice platforms. This feature, which was discovered in the winter of 1948/49 by the USSR and named after an 18th century Russian scientist, is linear and aseismic and extends across the floor of the Arctic Ocean some 1800 km from the continental shelf near the New Siberian Islands and then to the shelf north of Ellesmere Island and Greenland. It separates the Amerasia and Eurasia basins and rises some 3000 m from the abyssal plains to a depth of only 1000 m below sea level. Close to the continental shelves it attains its maximum width of 200 km while its minimum width of 25 km occurs near the North Pole.

The LOREX project was conceived and organized by the Earth Physics Branch of the Department

Clockwise from above: Supplies being air dropped to FRAM I participants; the LOREX main camp showing an ice fissure such as split the camp midway through the expedition; Brian Bornhold and Steve Blascoe examining a core from the Lomonosov Ridge far below them; and a closer view of LOREX accommodations.



of Energy, Mines and Resources (DEMR) and the considerable logistic support required to mount the experiment was provided by the Polar Continental Shelf Project of DEMR. BIO involvement in LOREX included: (1) responsibility for part of the satellite navigation system required to determine accurately the horizontal positions of the three ice stations that comprised LOREX and to measure their drift, and (2) comprehensive seabed geological and geophysical studies of this ridge feature and adjacent areas of the Makarov and Amundsen basins.

Transit satellite receivers and the Omega navigation system, linked by the BIONAV system described in Chapter 7, provided positioning control with an accuracy of ± 100 m for the satellite fixes and ± 1 km for the Omega. The LOREX ice station drifted a net 160 km during the 62-day scientific program and came within 35 km of the pole: the ice floe crossed the Lomonosov Ridge once during the experiment.

Bathymetric sub-bottom and shallow seismic reflection profiling, sediment sampling, seabed photography, water column temperature and sound velocity profiling, and surface plankton tows were conducted from the main camp as it drifted over the Ridge. These seabed geologic studies, in conjunction with other scientific programs that measured gravity, magnetism, plumb-line deflection, deep seismic properties, and heat flow were successful in delineating the physical nature and origin of this little-known Arctic submarine feature. The Lomonosov Ridge has a relief of 2800 m and a width of 88 km along the drift path. Asymmetrical in cross-section, the Amerasia flank has slopes as steep as 10° whereas the Eurasia flank slopes are less than 7°. The ridge appears to consist of *en echelon* fault blocks that give the crest an irregular morphology. A thin veneer of unconsolidated sediments, primarily associated with the fault block tops, is presently undergoing erosion by current action. These sediments may have been deposited prior to the assumed separation of the ridge from the Barents Continental Shelf. The biostratigraphy of surface material recovered from the ridge crest suggests that this separation was initiated no earlier than the mid-Cretaceous period.

CESAR - The Canadian Expedition to Study the Alpha Ridge will take place in 1983. This expedition is being organized along the lines of LOREX and by the same people. It is expected that this expedition will involve participants from the Atlantic Geoscience Centre, Atlantic Oceanographic Laboratory, and Marine Ecology Laboratory of BIO as well as scientists from Dalhousie University in Halifax.

The Alpha Ridge is a broad and prominent feature south of Ellesmere Island that is presently aseismic. Its crest is 1200 to 2000 in below sea level. The main objective of the BIO geological work on CESAR will be to rnore clearly define its structure and lithology, and the ages of its rocks and sediments. This information combined with other geophysical measurements of the Ridge will help us determine the nature and timing of the development of the Arctic Ocean Basin.

SEABIRD VULNERABILITY TO NORTHERN DEVELOPMENT

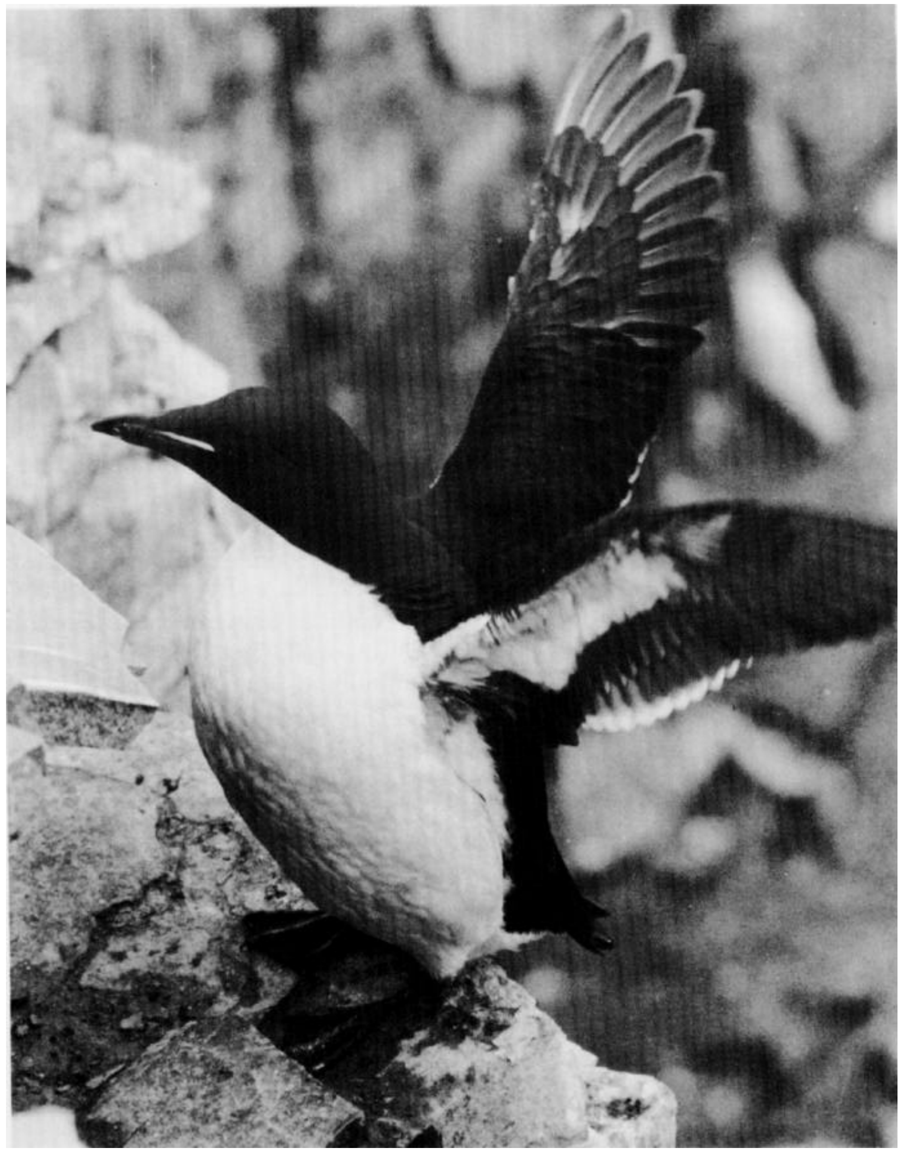
The industrial development of the Canadian Arctic has been a stated objective of the Canadian government for more than a decade. Although it has always been understood by both the government and private sector that special envirormental considerations must be satisfied before large-scale development is permitted to proceed, the imminence of oil and gas development is now apparent. As a part of the general envirormental question, an assessment of the impact on the Arctic seabird population of oil and gas exploitation and the routing of the associated marine transportation to take the resource to market is required immediately to safeguard and maintain the ecosystem.

The vulnerability of the seabird to man's interference with the envirormental balance is accentuated because of its breeding habits. The selection of breeding sites on land is a critical facet of survival. The selected site must be suitable for nesting, must provide an abundance of food close at hand, and at the same time must be relatively free from predators. The scarcity of such sites has caused the seabirds to aggregate into colonies for the breeding season during which they are extremely vulnerable as they assemble in immense numbers at the relatively few suitable locations.

Even during the nonbreeding periods, the patchiness of marine productivity influences the seabirds' pelagic behaviour by restricting them to specific nutrient-rich waters such as those of the Scotian Shelf Break, the Grand Banks, and the shoreward boundary of the Labrador Current. They are therefore constantly vulnerable to localized ecological unbalances - natural or man-made. A third characteristic that makes them vulnerable is the limit nature puts on their ability to recover rapidly from a reproductive failure. They are long lived, reach sexual maturity slowly, and have low and erratic reproductive rates. The very wide year-to-year variation in their breeding performance, in fact, makes it extremely difficult to distinguish natural fluctuations from the effects of human environmental interference and makes protective measures difficult to establish.

In response to the growing hazard to seabirds and the increased public concern, especially over the effects of oil pollution and pesticide persistence, the Canadian Wildlife Service of Environment Canada has been directing extensive investigations into the breeding and pelagic ecology of seabirds in eastern Canada. The overall aims of the Seabird

Seabird research field station on the Gannet Cluster, Labrador.



Thick-billed Murre *Uria lomvia* at Prince Leopold Island, Lancaster Sound, Northwest Territories.

Research Unit at BIO are to establish and maintain a catalogue of breeding sites, to determine the environmental requirements for successful reproduction and the maintenance of populations, and to determine the water habitat usage of seabirds throughout the annual cycle. The group's area of responsibility is the northwest Atlantic and eastern Arctic north of 40°N and west of 40°W. Quantitative observations of all colonies are made by the Unit.

As an example of the type of observation made, a study system was designed and set in place in Lancaster and Jones sounds between 1975 and 1979 to provide baseline information on the Thick-billed Murre, a species selected as a study subject because of its dominance in the area, its breeding requirements in the eastern Arctic, its colonial breeding behavior, and its high vulnerability to surface water pollution both during the breeding season and throughout its life cycle. From the data compiled, it was possible initially to measure its population size and trend; that is, to determine whether the species was in equilibrium or not by counting the populations and assessing the breeding performance at major colonies. It should be noted that it is essential to know precisely when populations are changing. Rapid detection permits an early assessment and makes it possible to identify problems and take remedial action while there is time. From the compiled baseline information of measured population variables, estimates were and are being made of the population density fluxes, biomass changes, and bioenergetic demands related to the breeding season to determine the ecological requirements for successful reproduction and for the better understanding of the structure and function of northern ecosystems.

Only by the careful monitoring of population levels and other important population parameters of seabird species inhabiting our coastal and offshore waters will biologists and wildlife managers be able to ensure the future well being of this valuable group of marine animals.

chapter 3

Offshore Oil and Gas

The alarming worldwide increases in oil and gas prices over the last decade have focussed attention on the plight of many countries whose domestic supplies are decreasing. This is true in part of Canada, which is blessed with an abundance of natural gas but cannot hope to be self-sufficient in oil unless synthetic crude plants proliferate and exploration proves successful. One of the last great frontiers available for exploration in our country is the east coast offshore, where about 140 wells have been drilled since 1966, and where several major oil companies are now actively looking for oil and gas

The Grand Banks of Newfoundland is one of the most explored regions in offshore eastern Canada. Oil companies drilled their first wells on the Banks in 1966 and by the end of 1978 had completed 39, two of which produced small quantities of hydrocarbons. In 1979, a major deposit currently estimated to exceed one billion barrels of recoverable crude oil was discovered at the Chevron *et al.* Hibernia P-15 well in the East Newfoundland Basin.

The seafloor in the area of the Hibernia P-15 oil well on the northeast Grand Ranks of Newfoundland.

The intense activity that has resulted from this and over other discoveries in offshore eastern Canada has underscored the need for accurate and detailed knowledge of these frontier areas. A number of groups at BIO have been involved since long before the discoveries in collecting some of the information required. Their recent activities are the subject of this review.

PETROLEUM GEOLOGICAL STUDIES

Biostratigraphers, lithostratigraphers, geophysicists, and petroleum geologists with the Atlantic Geoscience Centre pool their efforts to study the structure and history of the sedimentary basins of eastern Canada. These studies make direct contributions to the assessment of oil, gas, and coal reserves in eastern Canada. One area of research that has received close attention is the relationship of organic matter to the generation of hydrocarbons.

The occurrence of oil and gas in offshore eastern Canada is to some extent predictable. Oil in commercial quantities has been found only in the East Newfoundland Basin, where the Hibernia well has been acclaimed as the most significant in Canadian history. Natural gas is present in potentially commercial amounts on both the Scotian Shelf and the Labrador Shelf. This geographic separation of the oil- and gas-prone areas reflects the nature of the organic material in the sediments offshore.

All hydrocarbons including oil, gas, and coal are derived from organic material produced by living organisms. The nature of this organic material and the extent to which it is heated during burial determine the type of hydrocarbons produced. The oldest records of organic life are from rocks in South Africa, which are about 3.2 billion years old. Large-scale production of organic material, however, only became possible two billion years ago when organisms that could carry on photysynthesis first occurred in large numbers. Initially all such organisms were single-celled marine dwellers and not until the Late Silurian, about 420 million years ago, did the land plants evolve and begin to cover the continents. Today land (terrestrial) plants are an important source of organic matter in sediments, although their contribution is still far less than that of marine plants.

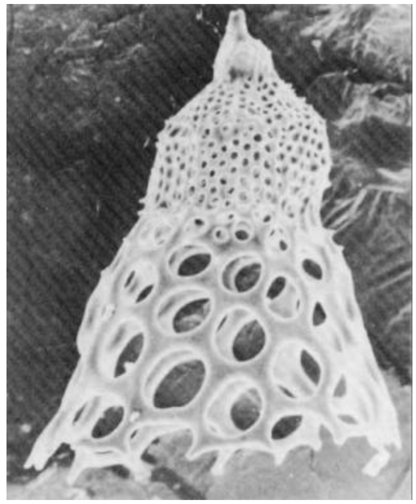
There are thus two major types of organic material, marine and terrestrial. The marine material is generally concentrated on continental margins, because the highest productivity in the marine realm tends to be in such regions. The recognition and separation of the types in sediments is important because of their tendency to source different types of hydrocarbons. Marine organic material if heated over sufficient time will tend to give oil, while terrestrial material will predominantly source gas. The degree of heating can be related to a maturation scale that indicates the ability of the organic material to source hydrocarbons.

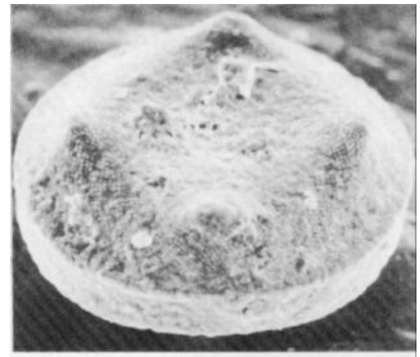
If marine and terrestrial organic matter can be separately identified in sediments and if it is possible to deter&mine the degree of maturation by using a thermal indicator, then it is usually possible to predict if hydrocarbons are present in the surrounding rocks or nearby reservoir rocks. This is the basis of source rock studies carried out by the Atlantic Geoscience Centre, one of which is termed visual kerogen analysis. Kerogen as used here means "all finely disseminated organic material freed from a sedimetary rock after acid treatment"*. The organic matter, or kerogen, in a rock sample can be concentrated by dissolving the inorganic fractions through successive acid treatments, and mounting the residue on a glass slide for microscopic analysis.

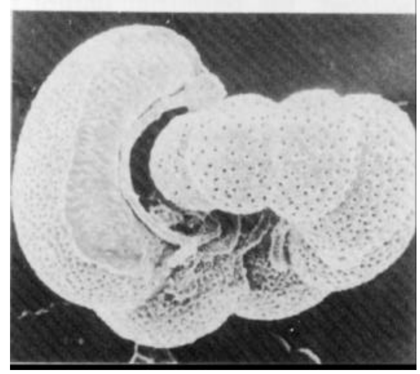
Scientists at the Atlantic Geoscience Centre have recognized four types of kerogen in transmitted light microscopy: amorphogen, phyrogen, hylogen, and melanogen. Amorphogen is structureless organic material that may be finely disseminated or coagulated into fluffy masses; it is thought to represent predominantly marine-sourced kerogen. Phyrogen comprises all non-opaque, recognizable, plant matter that is not of a woody origin and includes plant cuticles, spores, and dinoflagellate cysts. Hylogen includes non-opaque fibrous plant material of woody origin. Melanogen is all opaque organic matter. Phyrogen, hylogen, and melanogen are primarily terrestrially-sourced kerogen.

The thermal history of the sediments is also important for the generation of hydrocarbons. The time-temperature history of the sediments can be estimated by examining the colour of the dispersed organic matter. The colour of the kerogen changes predictably with increased heat and time from almost colourless or yellow through brown to black. These colour changes are observed under the microscope and have been used to construct a thermal alteration index (TAI) that can be related to oil and gas generation. This has been graphically demonstrated by Bayliss** in a predictive model colloquially known as the oil window model. The figure (top, p.26) shows the relationship of the four types of kerogen to the types of hydrocarbon sources with increasing heat. At a TAI of 2, amorphogen forms liquid hydrocarbons whereas phyrogen produces only minor amounts of thermally derived gas and little or no liquid hydrocarbons, and hylogen and melanogen are inert.

A raise in temperature equivalent to a TAI of 2 + results in all four kerogen types giving rise to hydrocarbons although the nature of the generated hydrocarbons varies with kerogen type. The upper time-temperature boundary defining the oil window (TAI approximately 3) varies according to kerogen type, with amorphogen being the last to stop sourcing oil. Above 3 + all kerogen types have







The study of microfossils, organisms 1/1000th mm to several millimetres long, is an important part of oil exploration. Illustrated here are: (above and middle right) fossil radiolaria about 55 million years (m.y.) old; (top right) a fossil diatom perhaps 15 m.y. old; and (bottom right) a very old (105 m.y.) fossil planktonic foraminifera.

*Burgess, J.D. 1974. Microscopic examination of kerogen (dispersed organic matter) in petroleum exploration. Geological Society of America, Special Paper 153: 19-30.

**Bayliss, G.S. 1975. Chemical changes attendant with thermal alteration of organic materials following deposition. Abstracts, Eighth Annual Meeting, American Association of Stratigraphic Palynologists, Houston, Texas.

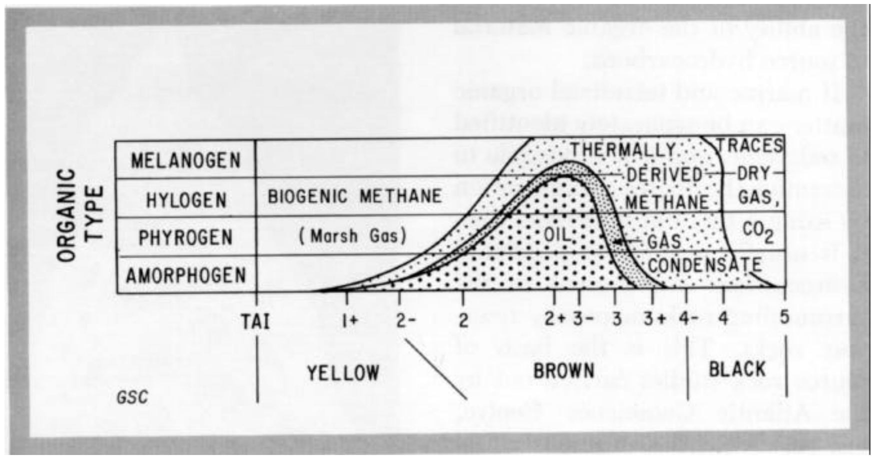
only the potential for sourcing thermally-derived dry gas or methane. The oil window model highlights the need for kerogen typing and TAI determination before making predictions on source rock potential.

AGC scientists have carried out visual kerogen studies of about 100 offshore wells, variously located on the Labrador Shelf, East Newfoundland Shelf, Grand Banks, and Scotian Shelf; they have determined for each the relative abundances of the kerogen types and the TAI. The Scotian Shelf wells (figure at bottom right) shows a dominance of terrestrial kerogen (phyrogen, hylogen, or melanogen) throughout most of the Jurassic and Early Cretaceous with some influxes of amorphogen in the Late Jurassic. Therefore, although the TAI is high enough for oil to be sourced, the terrestrial nature of the organic matter means that gas is the major hydrocarbon unit. In the Upper Cretaceous-Tertiary, amorphogen predominates but has not been heated sufficiently to source hydrocarbons. Thus, part of the section is said to be immature.

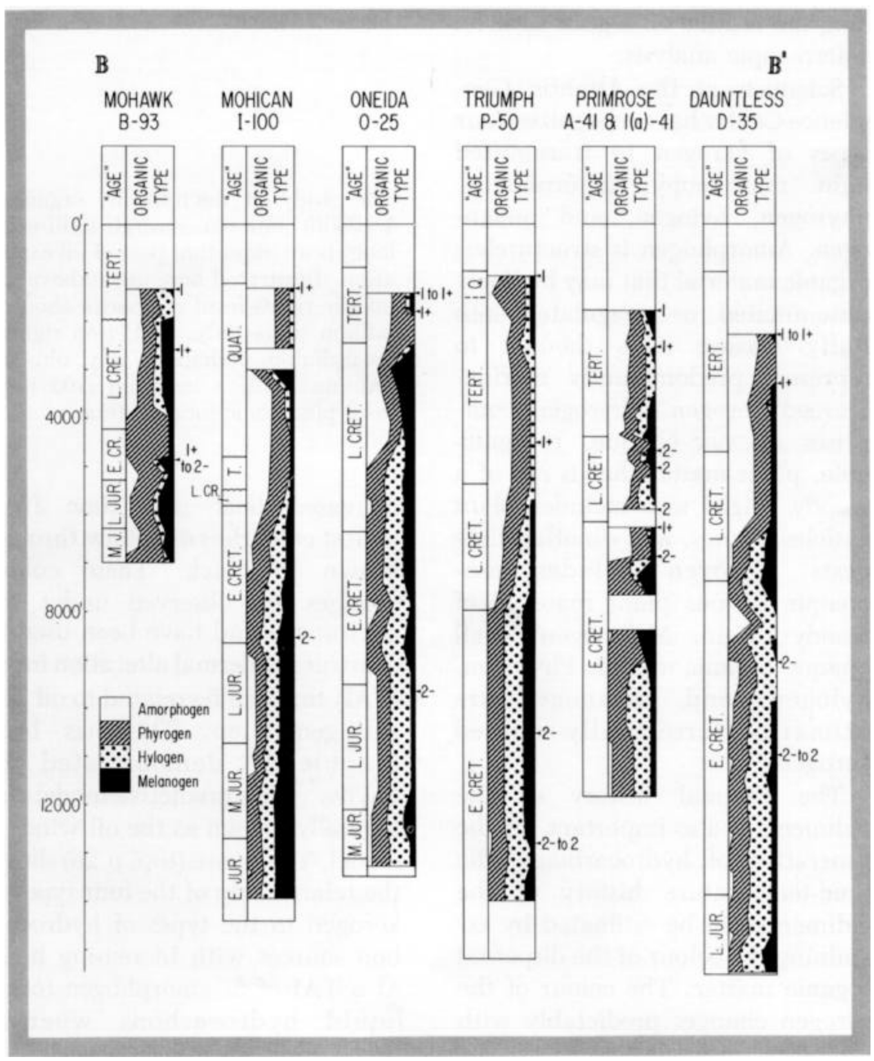
In the East Newfoundland Basin, including the Jeanne D’Arc Subbasin where the Hibernia well is situated, the Jurassic-Lower Cretaceous sediments usually contain more almorphogen than on the Scotian Shelf. Since the TAI values are high enough to source oil from amorphogen, the Basin may be an oil-prone area. The Upper Cretaceous-Tertiary sections are generally very amorphogen-rich but the TAI values are generally too low for sourcing oil.

The Labrador Shelf is an anomalous situation since the oldest dated sediments are Early Cretaceous and nonmarine. There are amorphogen-rich intervals in the very thin Upper Cretaceous and Tertiary sections, but the TAI is usually too low to source liquid hydrocarbons. Consequently, the area seems to be a gas-prone province, which accords with discoveries to date.

The studies have shown that amorphogen is deposited in marine



The oil window model (after G.S. Bayliss) depicting the nature of the hydrocarbons generated from the four organic types with heat increasing from left to right (1 + to 5). *(TAI* Thermal Alteration Index).



Histogram plot of the relative percentages of the amorphogen, phyrogen, hylogen, and melanogen in six Scotian Shelf wells. Values for the Thermal Alteration Index are given to the right of each column. *(E* Early; *CR* or *CRET* Cretaceous; *J* or *JUR* Jurassic; *L* Late; *M* Middle; *Q* or *QUAT* Quaternary; *T* or *TERT* Tertiary.)

environments and probably represents in large part the remains of phytoplankton and zooplankton. Phyrogen occurs in sediments deposited in all environments, hylogen predominates in nearshore marine and nonmarine sediments, and melanogen is found in shallow-water deposits. Since amorphogen equates with marine organic material, it is presumably the major oil source and mature sediments in which it predominates will have sourced oil. This suggests that there may be some potential for oil in the more marine, deeper parts of the Scotian and Labrador Shelves. Other parts of these two areas must be considered as predominantly gas prone, which however does not lessen their economic potential. Other basins along the eastern continental margin of North America are also probably gas prone with the notable exception of the East Newfoundland Basin.

REGULATION OF OFFSHORE OIL OPERATIONS

As the regulatory agency responsible for implementing the provisions of the Oil and Gas Production and Conservation Act, the Operations Division of the Resource Management Branch of the Department of Energy, Mines and Resources based at BIO administers a monitoring and inspection service designed to minimize the environmental threat and ensure the conservation of the resource. Regulations require the operator to submit a comprehensive drilling program to include an explanation of the engineering concepts, a satisfactory contingency plan covering protection of the environment, and the safety of the rig and working personnel, as well as security of the well against blowout, fire, and explosion. A complete abandonment plan is required prior to termination of each well. Standards are set for the general performance of the rig, for all drilling and handling equipment, for the preventive systems to be put in place by the operator, and for the necessary support and supply facilities. The operator is also required to forward biological and physical oceanographic observations while drilling operations are being conducted and to generate routine weather and ice surveillance reports. Routine visits to operating rigs are made by branch inspectors. These standards apply to all oil and gas operations in Canada's shelf seas. The division also acts as the government curator for information and geophysical sampling from all activities. Samples are catalogued and stored at the division after analysis by the Atlantic Geoscience Centre at BIO or the Institute of Sedimentary and Petroleum Geology in Alberta, both of the Canada Department of Energy, Mines and Resources.

CHARTING AND MAPPING OF THE EAST COAST

Recent discoveries on the Grand Banks and the Scotian Shelf have brought about a shift in the offshore activities from an exploration phase to one of development, and this has made further demands on both the hydrographer and the marine geologist. Hydrographic surveys and charts done to modern standards are required of the Newfoundland inshore in order to select and develop major sites for the construction and repair of production platforms and facilities. Further information is also required on the subsurface geology at the drilling sites to verify the stability of the seabed before planning and designing the subsea structures for both the Grand Banks and Scotian shelf developments. Recent efforts by BIO in meeting these requirements are discussed below.

CANADIAN HYDROGRAPHIC SERVICE - ATLANTIC REGION PROGRAM - With the advent of these offshore operations, three inadequacies in CHS's existing charts have become critical. First, many older charts - surveyed in the last century - either have an incorrect geodetic datum or no geographic grid whatever. Although this may or may not pose serious problems for the coastal pilot, significant errors in the datum create difficulties when patching in new information or making data comparisons. Second, surveys of harbours and approaches do not provide sufficient detail beyond the ten fathom line and while adequate for the shallower draft conventional shipping of an earlier time, are totally

Roger Belanger 5794-11

Phil Karg and Tony Clark storing supplies of cores from oil well drill sites.

inadequate for the deep draft traffic now needed by the oil and gas industry. Third, most of the soundings on these charts were conducted by hand lead and line and thus provide spot soundings only. Slight rises in the seafloor between soundings are not critical because of the large safety factor in the charted depth for the moderate draft of the existing traffic. With the advent of the very deep draft carriers and production facilities, however, clearance in many cases has been reduced to a few metres or less and it is vital that minimum depths in any channel or berth be specified. Continuous soundings are therefore required and can only be provided using acoustic sweeps. Finally, very little charted information is available for some of the bays and inlets in Newfoundland and Labrador and, although they appear to provide excellent deep water harbours, they have only been used up to this point by seamen with local knowledge using small craft. Because of their proximity to the offshore sites and the requirement for inshore support facilities, the provision of new charts based on modern surveys for deep draft traffic has become a necessity. Quite apart from the requirements of oil and gas exploitation, the extension of the fisheries and the consequent future requirement for larger vessels has also made it necessary to update the charts of many of the smaller outports.

Last year a major program was launched in the Newfoundland inshore in support of offshore oil and gas. A modern survey was completed in Halls Bay at the Head of Notre Dame Bay, a survey of Fortune Bay was started, and a variety of smaller projects directly connected with inshore development were undertaken. During the 1981/82 period it is intended to complete Fortune Bay, begin a survey of Trinity Bay, and complete a survey of the coast of Labrador from Hamilton Inlet north to Nain, Labrador. The Strait of Belle Isle is also to be calmpleted during this period to check its suitability as a route for tankers carrying liquified natural gas from the Arctic. The chart production program is designed to keep pace with the surveying. It should be noted that the production time for a new chart is about 15 months after all of the survey field data have been made available in prepared form.

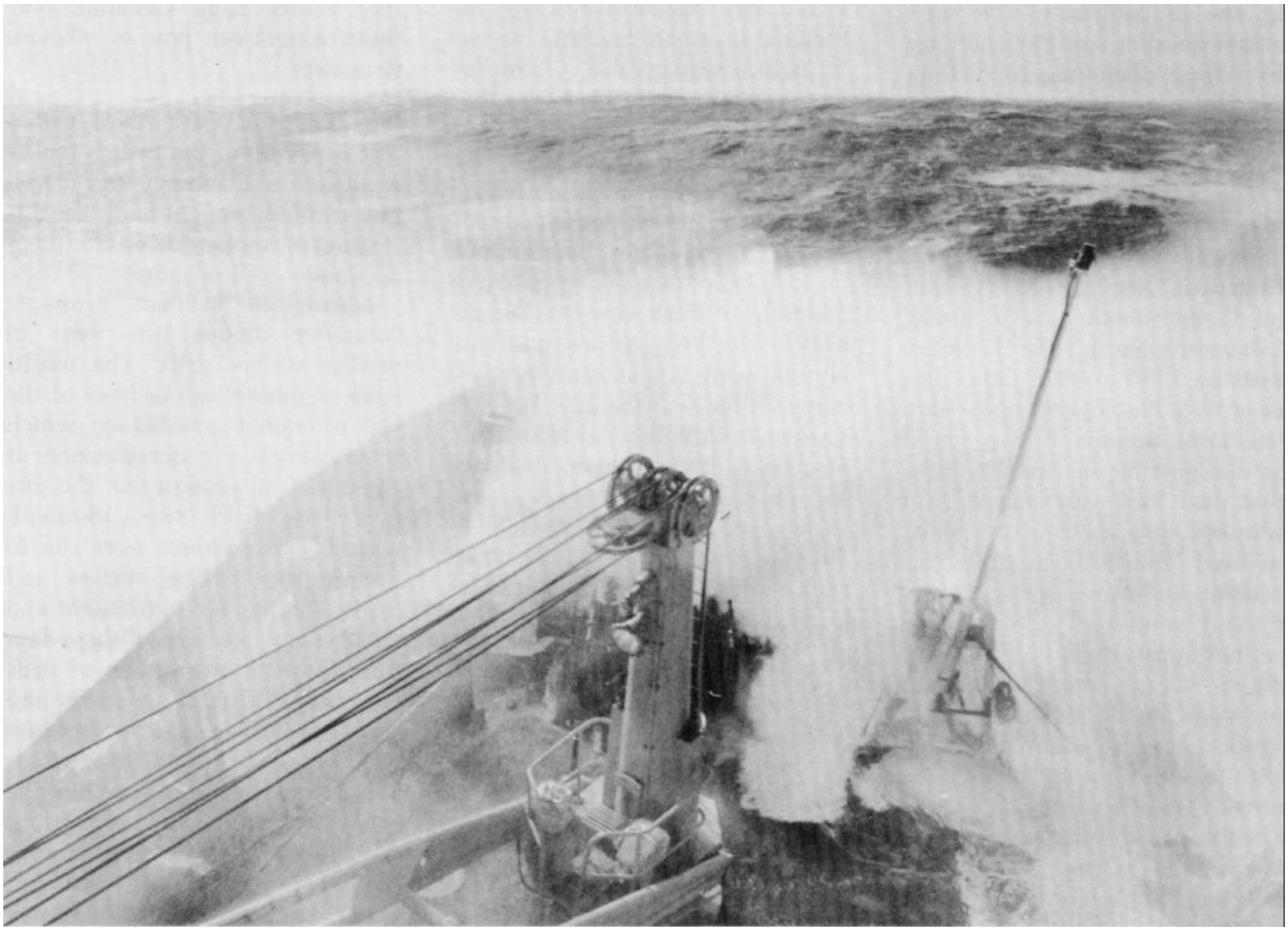
Other functions of CHS have a direct bearing on meeting the requirements of oil and gas development. The ocean mapping program, through which the Natural Resource Series of maps is produced, is a joint responsibility of the Canadian Hydrographic Service and the Atlantic Geoscience Centre. The multiparameter surveys mentioned earlier provide the detailed bathymetry, gravity, magnetics, and other geological parameters of importance to mineral and hydrocarbon exploration. A large part of the Scotian Shelf, Grand Banks, and Labrador Sea including Davis Strait has been completed. It is planned during the next two years to densify the survey lines, where required, and subsequently to extend the surveys north into Baffin Bay. The surveys should be completed from the Grand Banks through to northern Baffin Bay by the end of 1985.

The compilation of data and preparation of material for the seventh edition of the Newfoundland Sailing Directions, reflecting the modern surveys described above, should be ready for printing soon and the calibrations of Loran C lattices for the new Labrador Sea and extended East Coast chains should be completed by 1985.

SURFICIAL GEOLOGICAL MAPPING - Geologists with the Atlantic Geoscience Centre at BIO have for 15 years been mapping the regional surficial geology of the eastern Canadian continental shelf. Such maps summarize the geology of the unconsolidated sediments and near-surface bedrock of the seabed. Also, they include information on the nature, extent, and age of features such as sand waves, iceberg furrows, pockmarks, and gas-charged sediments. The maps are of special interest to engineers who wish to determine the feasibility of placing undersea structures such as wellheads and pipelines in particular areas. The engineers are mainly concerned with the geotechnical properties and stability of the sediments in their site evaluations, and much of this information can be gleaned from the surficial geological maps.

In April-May 1980, CSS *Hudson* was used to conduct a reconnaissance study of the stratigraphy, lithology, and morphology of the Grand Banks surficial sediments, including those in and around the Hibernia site. A multiparameter integrated geophysical and geological approach was used to collect data. High resolution seismic reflection information on the sediments and bedrock was obtained with the Huntec Deep Tow High Resolution Seismic Reflection System described in Chapter 7 (see SEABED). A BIO-designed side-scan sonar profiler with a range of 750 m on each side of the ship provided sonograms of the seabed. Magnetic data were collected with a proton precision magnetometer, surficial sediment samples were collected with a van Veen grab, and the bottom of the seabed was photographed at various sites.

A discovery made during this survey underscores the importance of the surficial mapping program to engineering proposals. Although the decision on how oil will be carried from the Hibernia production platform to Newfoundland has not yet been made, a pipeline was initially the preferred choice. The survey revealed, however, that the proposed underwater pipeline route was interrupted by an area of exposed, well indurated bedrock that was well scoured by grounded icebergs. The threat from icebergs requires that any pipeline be buried for protection but this is not possible because the bedrock cannot be trenched by conventional means.



CSS *Hudson* in a North Atlantic storm.

RELATED ECOLOGICAL STUDIES

Regulation of offshore oil operations is based on the premise that environmental impacts must be kept to a minimum. The Marine Ecology Laboratory has undertaken a program to study the continental shelf ecology in close co-operation with the Marine Fish Division's (chapter 5) Scotian Shelf Ichtioplankton Program (SSIP). Its aim is to better understand the details of the fish production system on the Scotian Shelf.

For several years, a complex network of stations on the Scotian Shelf has been sampled every one to two months. Data have been collected on the occurrences and distribution of nutrients, phytoplankton, zooplankton, and larval and juvenile fish. It is expected that the results will permit the main breeding grounds and feeding grounds of cod, haddock, silver hake, herring, and other stocks on the continental shelf to be identified. Since it is known that eggs and larval fish are particularly sensitive to oil contamination, the information from this program will guide decision makers in the resolution of potential conflicts between the interests of the oil and gas industry and those of the fishery.

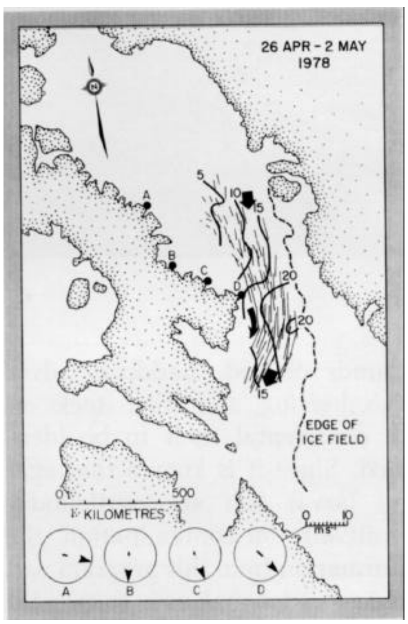
RELATED OCEANOGRAPHIC STUDIES

Physical oceanographers with the Atlantic Oceanographic Laboratory are conducting research that plays an indirect role in the successful exploitation and management of Canadian offshore resources. Three of their initiatives in this area are discussed below.

WAVE CLIMATE STUDIES - One group has been working since 1968 to produce a reliable and comprehensive description of the sea state. When they began, the only available information one could use to develop a wave climate came from the data collected four times daily by the Meteorological and Oceanographic Centre (METOC) of the Maritimes Weather Centre in Halifax, Nova Scotia. These data were compilations of the visual observations made by individuals aboard the up-to-100 ships that could be in transit across the North Atlantic at any one time. Data recorded by instruments were a rarity then but even today their total cost is prohibitive when considering the density of the network that would be needed to cover such a large area. With the wide and continuous data base that METOC provided, the group has developed techniques to produce statistics related directly to observable quantities such as wave height and period, wave-height distribution, and the probability of the wave height exceeding a given height in a given time (including predictions for 100-year maximum wave heights). To date this group has analyzed: (1) the annual wave climate for 1970 of the Canadian Atlantic Coast; (2) the annual wave climate for the years 1970 to 1972 of the entire North Atlantic Ocean; and (3) the monthly wave climate of the entire North Atlantic Ocean based on 1970 to 1972 data. The last of these has not yet appeared in atlas form because it was found that the monthly sea state varied a great deal from year to year. An unbroken data bank of ten years has been established to study this variation and is now being digitized and analyzed. Preliminary results indicate that in the North Atlantic Ocean there are large, long-term fluctuations in average, significant wave height similar in magnitude to those in the regular, annual cycle between winter and summer. An analysis of the entire North Atlantic Ocean showed that these large variations occur in the northern part of the Ocean and then, alternatively, two years later in the southern part. Thus, these long-term fluctuations are a significant feature of the North Atlantic wave climate. They must be fully investigated to ensure more accurate predictions of extreme values for the safe design of oil production installations and navigational facilities.

Wave climate information such as that collected by this group is critically needed when considering the handling and safety of oil tankers, evaluating the navigational hazards of shipping liquified natural gas from the Arctic, and designing deep-draft harbours. The information is also valuable when considering the sea states of local areas, as was the case in dealing with the oil spill from the break-up of the tanker *Kurdistan* (see Chapter 8).

TRACKING ICE FLOES - To obtain a clearer idea of the ice floe movement in Baffin Bay and Davis Strait, the Atlantic Oceanographic Laboratory recently tracked individual floes and developed weekly surface water velocity patterns by analyzing satellite pictures. Pictures in the visual and infra-red range were collected daily by NOAA 5 satellite, one of each during the day and one infra-red picture during the night. Transparent positives were made of the pictures and pairs of these were overlaid on a light table and precisely positioned relative to one another by matching visible land features. Ice floe movement in Baffin Bay and Davis Strait was determined by comparing selected sets of photos for each week over the period March 1, 1978 to February 2, 1979. The results of this study were plotted on maps showing the extent of the ice



Sea surface currents derived from ice movement (the shorter tracks) in Davis Strait. A, B. C. and D are meteorological stations.

cover during each month, the velocity components of the ice floes, and the mean vector winds, which were developed from data supplied by four weather stations operated by the Atmospheric Environment Service along the coast of Baffin Island. The data collected during this study provide a clearer understanding of the surface circulation of Baffin Bay and the Labrador Sea, and of the potential hazards that the ever-present drifting sea-ice from Canada's northern waters can pose to offshore structures.

OIL TRAJECTORY ANALYSIS - The break-up of the British tanker *Kurdistan* and subsequent oil spill in icy waters brought home the difficulties of tracking oil on continental shelves well offshore.

During the incident, a simple computer model was used to predict surface drift. The results were of limited use because of the lack of regular surveillance, which is necessary to permit refinement of the initial oil pattern and the surface current field. Over a 15-month period, many cruises were run to sample the surface waters and water column for particulate and dissolved oil. An atlas of these data together with the results of drift card and drifting buoy tracks and the Gulf Stream axis trajectories was compiled. A hindcast model is being run for the first month of the spill, the period before serious shoreline fouling occurred. A joint government-industry working group on oil-spill trajectory modelling has been established. It has completed a review of a representative group of scenario-type trajectory models that are in use today, and recommended the best algorithms. A similar review of real-time models was completed; attempts are now being made to ensure that, for Canadian waters. both government and industry will use a common model to minimize confusion in times of crisis.

During the *Kurdistan* spill and in co-operation with the Canadian Coast Guard. several expensive FGGE type drifting buoys were deployed. These were undrogued and so responded to currents in the top metre of water and to direct wind pressure. The buoys were positioned automatically by satellite several times a day to an accuracy of about 1 km anywhere in the oceans. Their trajectories showed the full spectrum of motions (tidal, wind driven, and forcing from Gulf Stream eddies). Following the addition of a small UHF beacon to these buoys, several successful recoveries and redeploy-

Kurdistan trajectory modelling for 15-20 March 1979. The surface oil slick prediction is based on the vector addition of 3% of the winds measured six times per hour at Sydney, N.S., and a residual current. Ice predictions are based on velocities from the Ice Information Branch, Atmospheric Environment Service, DOE, using a wind-based model.

ments were made before the buoys escaped eastward across the Atlantic.

A very inexpensive tarball tracker buoy has been developed at BIO. It is intended to deploy large numbers of them over a fishing ground, and fishermen are being instructed to merely report their positions whenever they sight them. This will help us to build up a picture of residual surface currents in a given region. A more basic type of study has begun to develop a buoy configuration whose performance is fully known. (Most buoys in use today are merely reported to 'drift at about 3% of the wind speed' or to 'follow surface oil drift', and verification of these claims is sketchy or non-existent.) Following tests with clusters of simple prototype buoys in the sheltered waters of Bedford Basin, N.S., some oil industry funding has been secured to permit offshore trials to be mounted.

chapter 4

Coastal Engineering

A sound knowledge of local oceanographic conditions is essential to properly develop engineering works such as power-generating stations, liquified natural gas terminals, causeways, and dams to be sited in or near coastal waters. The formulation of the environmental impact statements often required for large-scale projects is a complex and time-consuming procedure that requires a sound understanding of the proposed development's effect on the ecology of the area, its physical oceanography, sediment distribution and accumulation, climate, agriculture, groundwater, and so on. When such projects are under consideration in eastern Canada, the Institute is often asked for advice and information.

Accurate predictions of the environmental impacts of coastal engineering works depend upon two types of scientific studies. The first, which fall under the general mandate of BIO, are long-term studies of fundamental environmental processes. These studies identify the most important processes that control the characteristics of a particular geographic region and provide insight into their rates and variability. The second type, which is totally dependent on the first, is short-term studies that concentrate upon the interaction of the *important* environmental processes and a specific, proposed engineering development. These studies are of an applied nature and are traditionally conducted by environmental consultants funded by the project proponent. The BIO input to the second type of study is generally limited to providing advice and information.

BIO has recently devoted considerable effort to studies of the fundamental ecology of the Bay of Fundy where tidal power may be developed; to the establishment of a program to monitor the pre-operational and operational phases of the Point Lepreau, N.B., nuclear power generating station; and to the impact of the Canso Causeway on the lobster fishery. In these investigations, the Institute's primary goal is not to conduct short-term studies but rather to determine the fundamental ecological and oceanographic properties of the areas in question. Only when this kind of information is available can confident estimates of the impacts of any engineering project be made, and assessments of the correctness of a proponent's environmental impact statement be made.

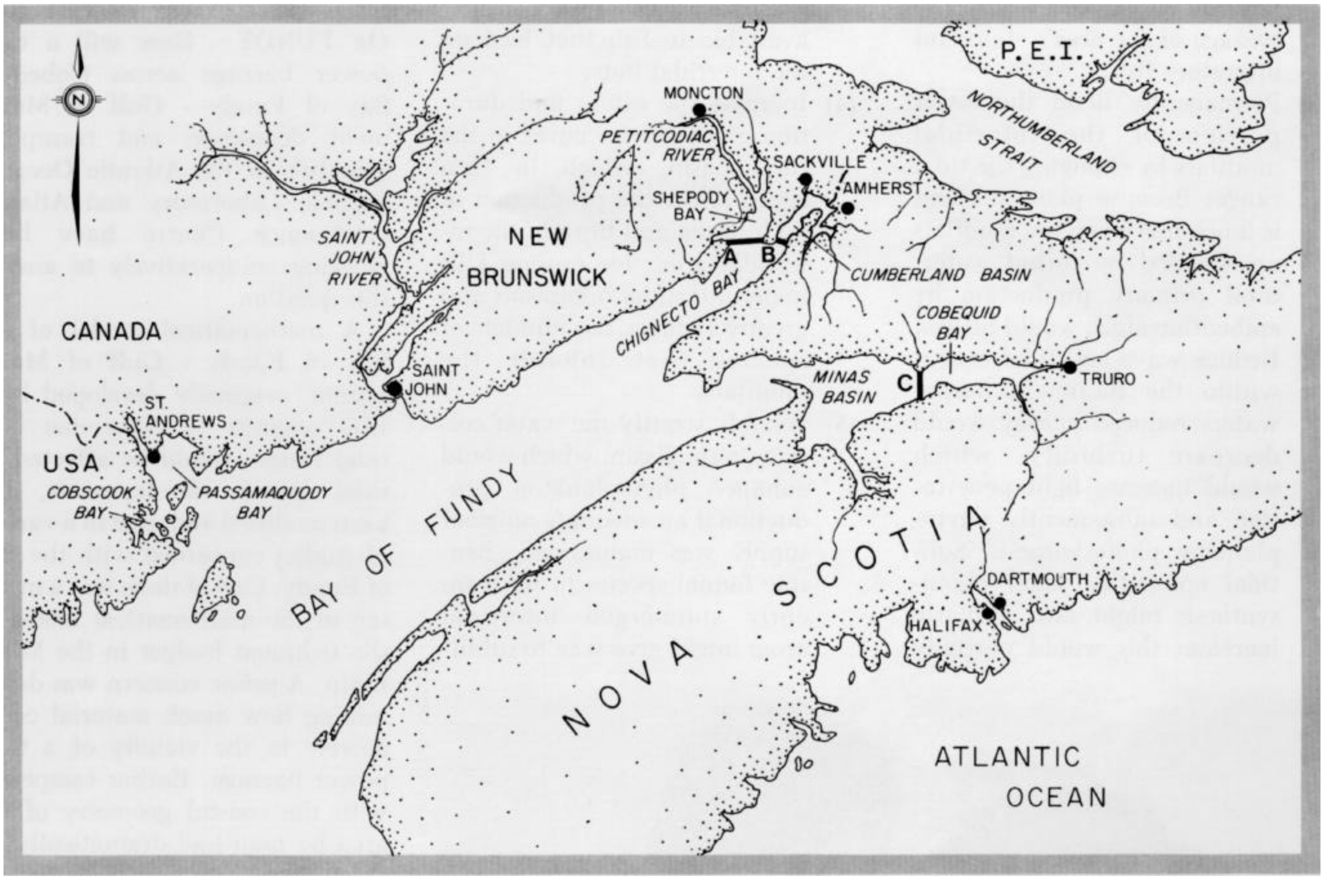
FUNDY TIDAL POWER

The construction of a tidal power project in the upper reaches of the Bay of Fundy is presently under very serious consideration. In late 1977, the final report of the Bay of Fundy Tidal Power Review Board concluded that a major project was now economically as well as technically feasible and recommended two sites for development - the mouth of the Cumberland Basin in Chignecto Bay and of Cobequid Bay in Minas Basin. The first would have a net capacity of about 1100 megawatts, the second of about 4000 megawatts. The recommendations are still being considered and Nova Scotia is currently most interested in the Minas Basin proposal. The next step in any development would be the funding of a three to four year pre-investment design program to complete the necessary economic, engineering, and envirommental studies.

The governments involved in this evaluation have recognized that serious gaps exist in our knowledge of the ecology and oceanography of the Bay of Fundy and that sound basic data must be available to prepare an environmental impact statement prior to the project's approval. Consequently, research in the Bay of Fundy was extended and the Fundy Environmental Studies Committee was established under the Atlantic Provinces Council on the Sciences to co-ordinate the work of the numerous regional government and university groups involved. This brief report focusses on BIO's contributions to these studies.

ECOLOGICAL STUDIES - In 1977, scientists at the Marine Ecology Laboratory began a concerted program to determine the properties and interactions of the marine ecosystems in the Bay of Fundy, especially those in the upper reaches. Their aim was to understand how these systems are influenced by the physical, geological, and chemical characteristics of the region. The role of the high tidal range - over 16 m in places - and the large

Nova Scotia is building a trial single-effect tidal power generating station in the lower reaches of the Annapolis River Basin.



The possible sites for tidal power barrages in the Bay of Fundy are shown.

amount of suspended sediment in the water column were a major concern. Since it is well known that predicting the behaviour of ecosystems is a complex process where all environmental factors must be considered, this program was carried out in close collaboration with other groups such as the Atlantic Geoscience Centre, Atlantic Oceanographic Laboratory, Canadian Wildlife Service, St. Andrews (N.B.) Biological Station (DFO), and Dalhousie and Acadia Universities.

Conducting scientific surveys along the entire axis of the Bay to complete the description of the region was the program's first priority. For example, the major and trace metal content of the sediments and the nutrient and organic chemistry of the water column were determined from over 100 grab samples and several thousand water samples. The composition, biomass, and productivity of the Bay's macrobenthic community as well as its phytoplankton productivity were measured, Numerous anchor station experiments aboard CSS *Dawson* were conducted with currents being measured and water samples collected at hourly intervals for complete tidal cycles. These latter data were used to estimate the flux of suspended sediment, nutrients, organic matter, and plankton along the length of Chignecto Bay up to and including the mouth of the Cumberland Basin, the major focus of the next part of the program.

A detailed study was begun of the ecology of the Cumberland Basin, which included a very close look at the ecology of the representative Pecks Cove, N.B., mudflat within the Basin. The Basin was surveyed regularly by helicopter and data were collected to quantify the strong chemical and biological gradients of the water column along the axis of the Basin and to compare the biological productivity of the major mudflats. The Pecks Cove mudflat, apparently the most productive one in the Basin, was visited bi-weekly until the end of 1980 and monthly thereafter.

Investigators are now engaged in the interpretation of a data base that covers all seasons in the Bay of Fundy proper as well as Chignecto Bay, the Cumberland Basin, and the Pecks Cove mudflat. Attempts at whole ecosystem modelling may be tried in 1982 after all the results are integrated. At this stage the tidal power impacts can be evaluated from a project with known engineering requirements. From their experience to date, the investigators speculate that a large scale tidal power plant at the entrance to the Cumberland Basin would:

(1) Severely reduce the exchange of water between the tidal basin and the sea and, in turn, affect the flux of nutrients, organic matter, and planktonic organisms into and out of the Cumberland Basin; the tidal basin could become more productive at the possible expense of waters immediately outside it; and the barrage (equipped with sluice gates and turbines)

would interfere with the passage of the area's abundant migratory fish.

(2) Permanently flood the lower portion of the intertidal mudflats by changing the tidal range. Because photosynthesis is much less when the mudflats are flooded by turbid water, total primary production by epibenthic algae would be less.

(3) Reduce wave and tidal energy within the Basin: in deeper waters reduced energy would decrease turbidity, which would increase light penetration and subsequently phytoplankton photosynthesis. Subtidal epibenthic algal photosynthesis might also similarly increase: this would partially offset any lost productivity from water level increases. Reduced wave energy at the water's edge would reduce the resuspension that occurs as the tide moves across the mudflats: this change might reduce, for example, the food supply available to fish that feed on the intertidal flats.

(4) Increase the extent and duration of winter ice cover in the tidal basin, which in turn could affect the production of both fauna and flora in the intertidal area. Ice erosion kills many intertidal organisms and greatly reduces the number of species that inhabit the mudflats.

(5) Possibly stratify the water column in the Basin, which would enhance phytoplankton production if an adequate nutrient supply was maintained. Benthic faunal species in permanently submerged intertidal areas might give way to sublittoral communities such as those now found in deeper water, and the enhanced phytoplankton production would provide additional organic matter for their survival.

Heinz Wiele 5721

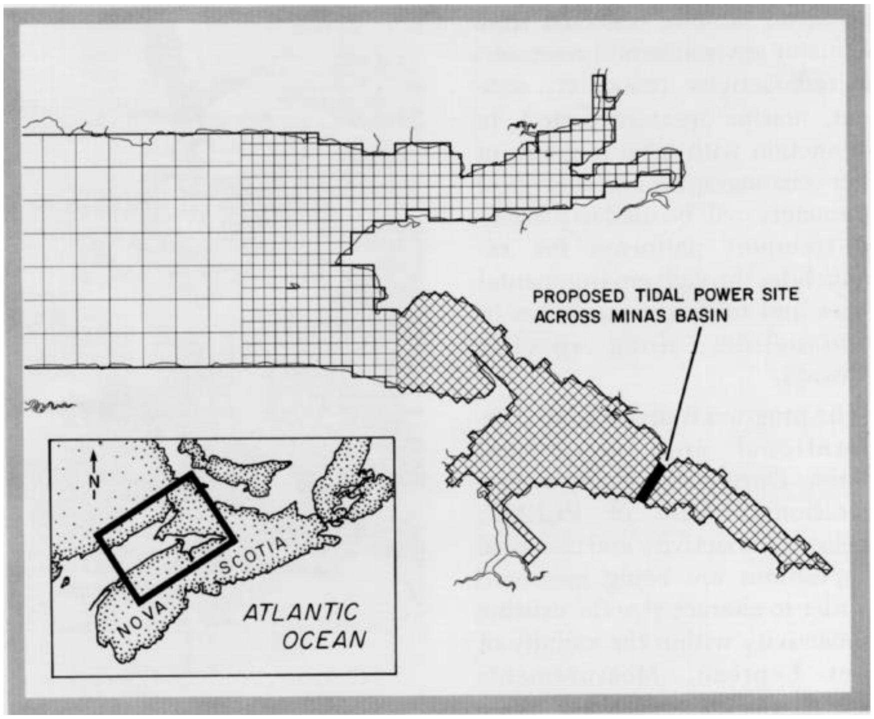
Ed MacDormand collecting samples for ecological analysis from the Pecks Cove Mudflat, Nova Scotia.

SEDIMENTATION IN THE BAY OF FUNDY - How will a tidal power barrage across Cobequid Bay of Fundy - Gulf of Maine ment deposition and transport? Scientists at the Atlantic Oceanographic Laboratory and Atlantic Geoscience Centre have been working co-operatively to answer this question.

A mathematical model of the Bay of Fundy - Gulf of Maine system, originally developed by a BIO scientist to determine how tidal ranges would be affected by tidal power developments, has been modified and used in a variety of studies concerned with the Bay of Fundy. One of these was a merging of the mathematical model to the sediment budget in the Minas Basin. A prime concern was determining how much material could accrete in the vicinity of a tidal power barrage. Earlier tampering with the coastal geometry of the area by man had dramatically increased silt accumulation; for example, shortly after the Windsor Causeway was completed an extensive mudflat was deposited, and continues to be deposited, on its seaward side.

The Minas Basin has the highest recorded tides in the world (16.4 m), The tides are also very regular with two tides of nearly the same magnitude and pattern occurring every 24 hours and 50 minutes; variations in range within each lunar month are very small. Tidal currents travelling at 3 to 4 ms^{-1} are brought about by the flooding and draining of 15.3 km^3 of seawater semidiurnally. At low tide, 306 km^2 of intertidal flats are exposed to reveal a wide wave-cut platform covered by a thin and mobile sediment layer; suspended material is also very abundant and imparts a characteristic red colour to the tidal water.

A regional evaluation of the Minas Basin system was conducted in five steps: (1) the sedimentary character was determined and the manner in which existing hydrodynamic conditions control sedimentation was evaluated; (2) the budget of the various types of

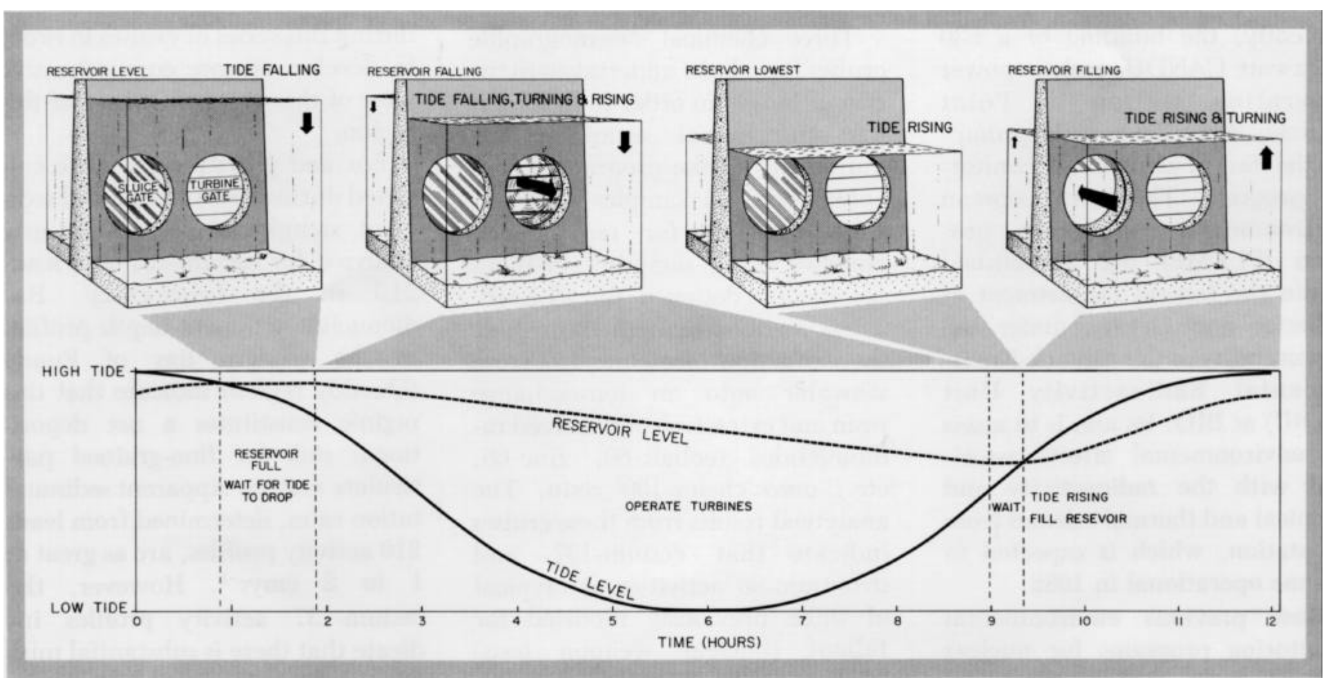


To simulate the tides with a computer model, the area is divided into grid cells before the scientific equations that describe water movement are solved.

sediment and their sources was determined; (3) the transport of sediment from source to ultimate site of deposition was determined; (4) the postglacial historical development of these variables was traced; and (5) predictions were made based on the above data using the mathematical and geological models mentioned earlier.

Below are only a few of the contributions derived from these studies:

- Scientists are confident that a tidal power plant in Minas Basin would not contribute to the extensive build-up of silt in front of the barrier that occurred in the Windsor Causeway and other areas. This conclusion was based on model predictions and the success of these models is such that they will likely be applied to the data now being analyzed from Chignecto Bay and to the development of a bedload model for coarse material.
- By calibrating Landsat imagery, scientists were able to determine the spatial distribution of suspended sediments in



The different phases of Bay of Fundy tidal power generation are shown. The reservoir is filled when sea level is higher than the reservoir level; power is generated when the reservoir level is sufficiently higher than the sea level outside. The electricity is generated intermittently but it can all be used without the need to store the tidal energy if fed into a large electrical network.

the Basin. Heretofore, this task was considered extremely difficult to achieve because in macrotidal environments the processes controlling sediment distribution and transport are complicated by many factors such as the dynamic intermixing of tidal waters and the reversing, accelerating, and decelerating tidal currents in ever-changing water depths.

The tidal amplitude in the Basin is increasing at the rate of 15 cm per century and there has been a steady increase in the amount of material entering it since about 6300 years before present. However, tidal power will not be inhibited by material deposited from suspension.

POINT LEPREAU ENVIRONMENTAL MONITORING PROGRAM

It is not possible to generate electricity from nuclear power (or for that matter from the burning of coal) without releasing some radioactivity into the environment. Consequently, the building of a 630 megawatt CANDU nuclear power generating station at Point Lepreau, New Brunswick, prompted the start of an ongoing monitoring program. The Point Lepreau environmental monitoring program (PLEMP) was established within the federal Department of Fisheries and Oceans under the responsibility of the Atlantic Environmental Radioactivity Unit (AERU) at BIO. Its aim is to assess the environmental effects associated with the radioactivity and chemical and thermal releases from the station, which is expected to become operational in 1982.

Most previous environmental monitoring programs for nuclear reactors were mainly concerned with the impact of radioactivity on human health but this program has been designed to provide a broader understanding of the distribution of radioactivity throughout the environment. Measurements conducted on samples collected from the major environmental reservoirs for radioactivity (seawater, sediment, marine organisms, etc.), in conjunction with measurements of other oceanographic and ecological parameters, will be used to identify the transport pathways for radionuclides through environmental phases and to determine fluxes of radionuclides along specific pathways.

The program is divided into pre-operational and operational phases. During the current pre-operational phase of PLEMP, baseline radioactivity and chemical compositions are being measured in order to characterize the existing radioactivity within the vicinity of Point Lepreau. Measurements made during the operational phase of the reactor lifetime will be compared to the pre-operational conditions in order to establish the environmental effects of the reactor as a function of time. The ultimate goal of the program is to provide government with a sound scientific basis upon which to assess the environmental implications of the operation of nuclear reactors in coastal environments.

Three chemical oceanographic cruises have been undertaken in the Bay of Fundy in order to fulfill the pre-operational sampling requirements of the program. Large volume (60 L) samples of water were collected for radionuclide analyses using sampling methods specifically designed for PLEMP. These shipboard methods include the extraction of cesium-137 from seawater onto an ion-exchange resin and extraction of dissolved radionuclides (cobalt-60, zinc-65, etc.) onto chelex-100 resin. The analytical results from these cruises indicate that cesium-137 and strontium-90 activities are typical of those previously reported for fallout (nuclear weapon tests) levels in nearshore and open ocean environments. The average ratio of cesium-137 to strontium-90 for the Bay of Fundy water samples is 1.4, compared to the 1.5 in fallout debris. Tritium levels in the Bay of Fundy are very close to the analytical detection limit as they are in other coastal environments. The activities of other gamma-emitting radionuclides are below the analytical detection limit. Hydrographic data and water samples for nutrient and trace metal analysis were also collected during this series of cruises in order to develop a more comprehensive view of the water chemistry of this region.

Recovery of LeHigh corer aboard CSS *Dawson.*

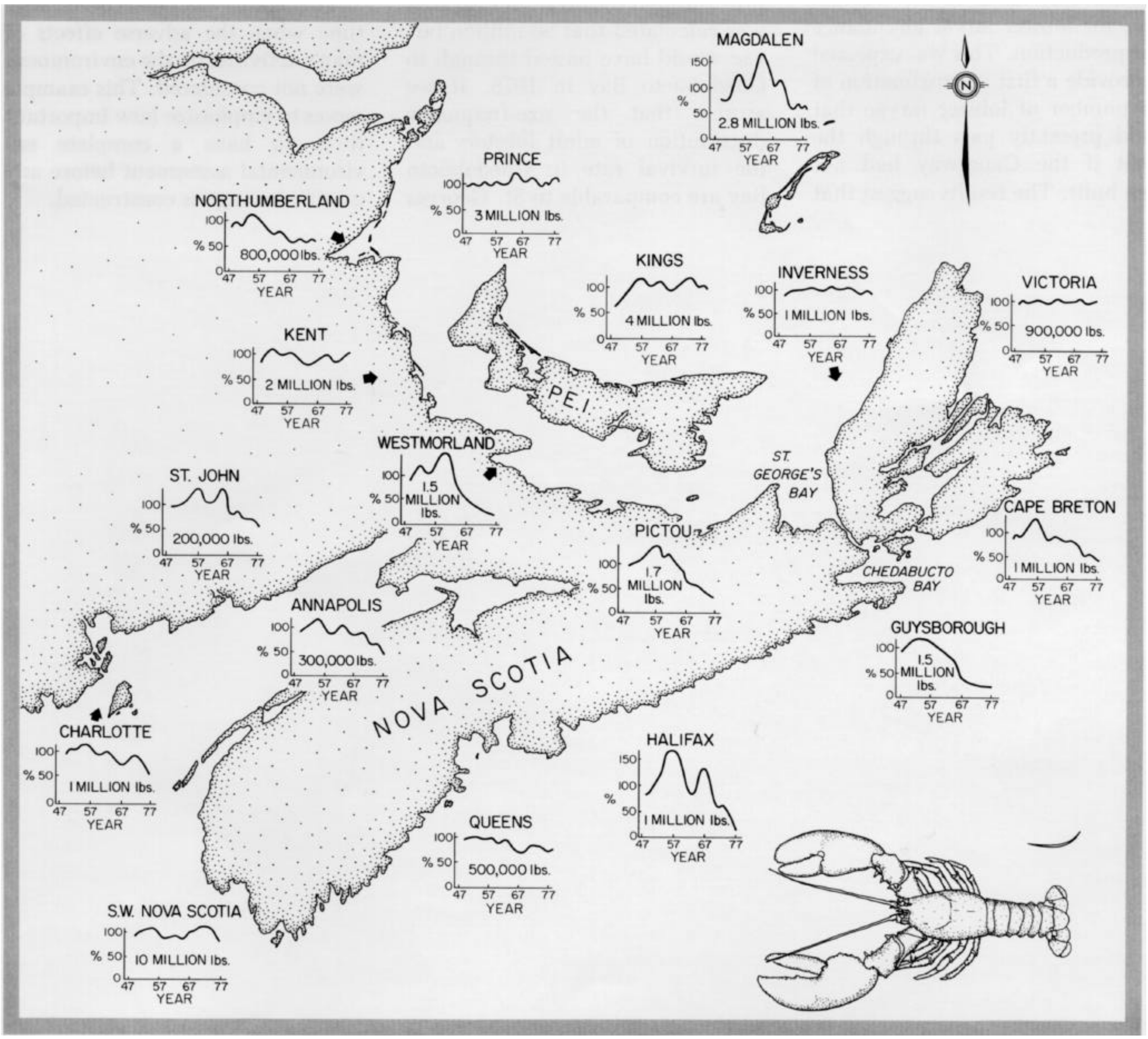
Box and gravity cores were collected during these cruises and sediment samples were subsequently analysed for cesium-137 and lead-210 in the laboratory. Radionuclide sediment-depth profiles in the western Bay of Fundy (Quoddy region) indicate that this regime constitutes a net depositional sink for fine-grained particulate matter. Apparent sedimentation rates, determined from lead-210 activity profiles, are as great as 1 to 2 $cm yr^{-1}$. However, the cesium-137 activity profiles indicate that there is substantial mixing of sediments caused by burrowing benthic organisms and that the overall distribution of both radionuclides and trace metals in these sediments is governed by a mix of sediment bioturbation and particle resuspension.

Other studies carried out as a part of this program include: (1) an ecological baseline survey of the nearshore benthic community near Point Lepreau, (2) a re-examination of the benthic community near the Colson Cove, N.B., generating station to determine the environmental impact of thermal discharges from this plant, and (3) a bird sampling program that included an analysis of the radionuclide content of the critical organs of the various species. A drifter survey has been completed to identify the circulation patterns in the Bay of Fundy that are likely to be important for the transport of both dissolved and particulate forms of radioactivity. Atmospheric sampling stations have been constructed and deployed in the field near Point Lepreau in order to collect atmospheric water vapour, particulates, and iodine-131 from large-volume air samples.

Two additional cruises will be conducted in 1981 to provide complete seasonal coverage and fulfill the pre-operational sampling requirements of this program. Measurements during the first year of reactor operation should provide an early indication of radionuclide release rates, but continuous monitoring over several years will be required to properly assess the environmental impact of the nuclear generating station.

CANSO CAUSEWAY - EFFECTS ON LOBSTER CATCH

The lobster landings along much of the Atlantic coast of Nova Scotia have been declining at an alarming rate over the past 25 years. For example, the landings in Chedabucto Bay have declined continuously from 803,000 kg in 1954 to 54,000 kg in 1979. Lobster fishermen believe that the closure of the Strait of Canso is responsible for this decline in the Chedabucto Bay fishery. The Canso Causeway, connecting mainland Nova Scotia to Cape Breton Island, was completed in 1954 and effectively blocks all water exchange between St.



Lobster landings from 1947 to 1977 in selected counties of Nova Scotia, Prince Edward Island, and New Brunswick are expressed as a percentage (%) of the mean landings during the stable period in the fishery.

Georges Bay and the Atlantic coast.

In the fall of 1977 the Canadian Atlantic Fisheries Scientific Advisory Committee met at BIO to examine all the effects that the Canso Causeway has had on local fisheries. In relation to lobsters, the hypothesis was raised that prior to the Causeway, St. Georges Bay larvae could have been carried through the Strait by tidal currents in sufficient numbers to affect recruitment to lobster populations on the Atlantic coast. Scientists in the Marine Ecology Laboratory have been studying St. Georges Bay for many years as a spawning area for pelagic fishes such as mackerel and herring and the Laboratory agreed to re-analyze these larval fish surveys, taken in St. Georges Bay, for lobster larval abundance and production. This was expected to provide a first approximation of the number of lobster larvae that could presently pass through the Strait if the Causeway had not been built. The results suggest that the Causeway had a minimal effect on lobster recruitment in Chedabucto Bay. However, these surveys were designed to estimate larval fish abundance and are known to underestimate the lobster production because the lobster larvae inhabit greater depths.

In 1978 a special surface net was designed to sample the upper metre of sea surface where most larval lobsters occur. A fresh survey of St. Georges Bay with this gear revealed production of 367 million larvae, which is four times higher than had previously been estimated. Survival of these larvae to first entry into the fishery was estimated to be about 0.3 %. Using pre-causeway estimates of volume flow through the Strait of Canso, it was calculated that 86 million larvae would have passed through to Chedabucto Bay in 1978. If we assume that the size-frequency distribution of adult lobsters and the survival rate in Chedabucto Bay are comparable to St. Georges Bay, then the contribution of the 1978 larvae to the fisheries yield in Chedabucto Bay would be 64 % of the peak landings averaged over the ten years before Causeway construction. Because 1978 was a population high for St. Georges Bay, this estimate was scaled to range between 38 to 64 %. The results indicate that St. Georges Bay was an important source of larvae for lobster recruitment in Chedabucto Bay. Unfortunately we know nothing about lobster recruitment along the Atlantic coast. It is therefore currently not possible to evaluate the importance of larval recruitment from St. Georges Bay with that occurring within Chedabucto Bay.

The Causeway was built at a time when the adverse effects of man's activities on the environment were not considered. This example serves to emphasize how important it is to have a complete environmental assessment before any marine barrage is constructed.

chapter 5

Management of the Fisheries

On 1 January 1977 Canada extended its offshore jurisdiction of the fisheries to 200 nautical miles. This move was made to take more direct control of the inshore and offshore fisheries, which had become depleted in part because they were not effectively managed under international agreements. With a yearly catch of about 2.5 billion pounds, two-thirds of which are sold in foreign markets, Canada's fishing industry is one of the world's largest. In unilaterally extending jurisdiction, the Canadian Government undertook to increase its fisheries surveillance, enforcement, and stock assessment efforts and to conduct research that would enable it to manage the resource in the best interests of conservation.

At BIO, a number of groups are partly or wholly concerned with practical and theoretical studies of benefit to effective fisheries management.

(1) The Marine Fish Division assesses the stocks of finfish and grey and harbour seals in the Atlantic area. Their assessments, prepared annually and sometimes more frequently, are used to determine the status of fish stocks and to provide a basis for regulation of the catches. The Division also maintains an associated research program that includes resource inventory cruises to analyze the population dynamics of the fish stocks, to describe the effects of fishing on the stocks, and to predict the response of stocks to regulatory measures. The manner in which they conduct their work and examples of their recent efforts are discussed in this chapter (see "Management Advice and Related Research").

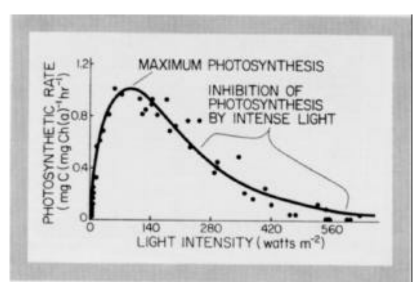
(2) Complementing the practical approach of the Marine Fish Division is the work carried out by the Marine Ecology Laboratory on the analysis of ecosystem structure in relation to fisheries. The Laboratory's aim is to predict how those systems will behave and in particular how much fish they are capable of producing and how they will respond to intense exploitation. Examples of their recent studies are presented under the first five headings below.

(3) Lastly, because of the close relationship of ocean circulation to the variability in the fisheries, the Atlantic Oceanographic Laboratory at BIO carries out physical and chemical oceanographic studies that pertain to fisheries management. Two such studies conducted during this review periods are described in the next-to-last section of this chapter.

PHYTOPLANKTON PHYSIOLOGY AND BIOENERGETICS

Primary production studies by the Marine Ecology Laboratory are chiefly concerned with the physiology and productivity of marine phytoplankton. The objectives are to understand the mechanisms by which phytoplankton production is regulated in the marine environment and to improve our ability to predict primary production from easily measured environmental and physiological parameters. Prumary areas of research are: (1) mathematical description of the photosynthesis-light relation in natural phytoplankton assemblages, (2) nutrient utlization by natural phytoplankton, (3) biochemistry of phytoplankton; photosynthetic enzymes, and nucleic acid synthesis, (4) phytoplankton-bacterioplankton interactions, and (5) the interaction of phytoplankton with their physical environment.

Studies have been both process- and site-oriented. For example, much of the group's work has been directed toward a comparative study of the growth of phytoplankton populations to light variations (phytosynthesis-light curve). Data have been compiled from diverse marine habitats ranging from tropical seas to Arctic waters in winter. Most recent studies have been on the growth and physiology of Arctic phytoplankton



Photosynthesis is measured in the laboratory by following the uptake of radioactive carbon (^{14}C) dioxide in samples of natural phytoplankton. A light saturation curve is drawn from the data. In the graph above, each point represents one incubated phytoplankton sample bottle.

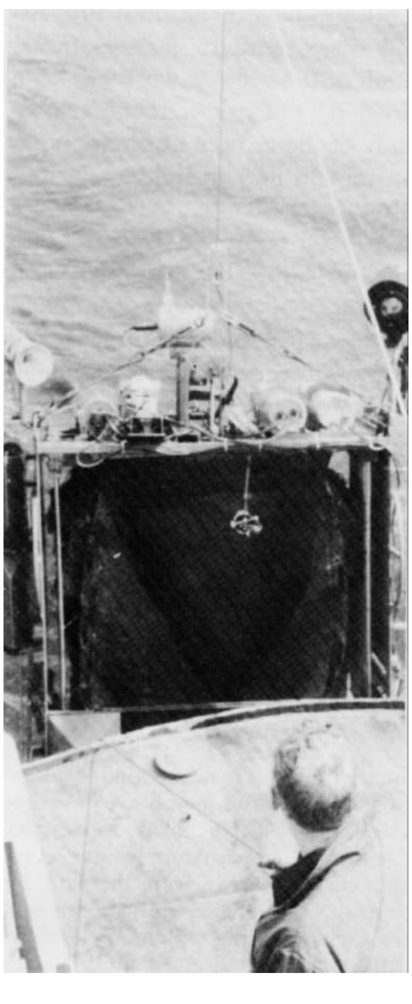
Central to most of the group's physiological work has been research on the mathematical representation and parameterization of the phytosynthesis-light relationship of natural marine phytoplankton populations. This fundamental relationship has served as a basis for study of the means by which the environment regulates primary production. Earlier descriptive work on the natural variations in phytosynthesis-light parameters addressed time-scales of seasonal variation down to hourly changes in response to natural light fluctuations. This work has evolved into a more detailed consideration of the environmental factors that can account for photysynthesis-light changes. Most recently, research has emphasized the mechanisms by which phytoplankton adapt to environmental changes by adjusting their photosynthetic response to light and temperature.

ZOOPLANKTON AND MICRONEKTON IN MARINE FOOD CHAINS

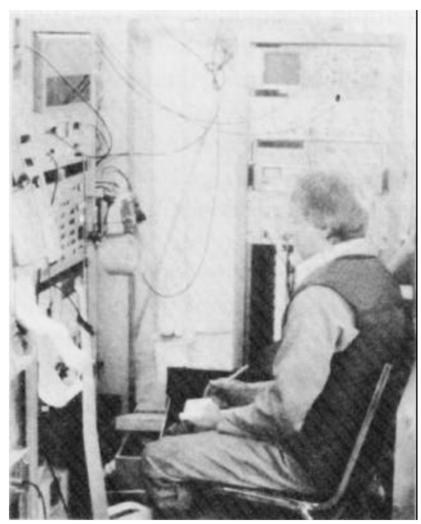
Very few fish graze directly upon phytoplankton. Instead, phytoplankton are grazed by zooplankton, which in turn are eaten by fish, especially juvenile fish. Over the past decade, Marine Ecology Laboratory scientists have been studying zooplankton grazing in a variety of conditions ranging from close inshore to the open ocean in both Arctic and tropical latitudes. Zooplankton filter the water with their mouth parts and have a remarkable ability to select different size ranges of particles, and to discriminate them on the basis of nutritive value. Their digestive processes are little understood, but a new program to study the role of enzymes in the gut has recently been initiated.

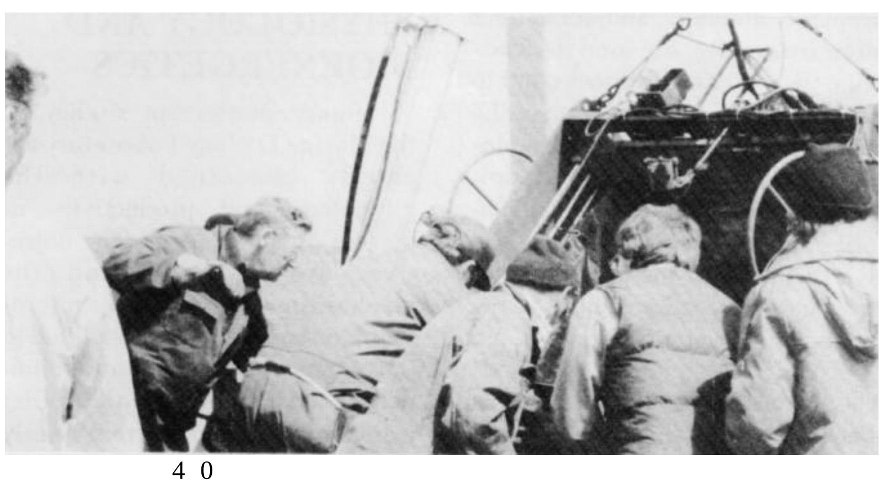
Large zooplankton organisms and juvenile fish are able to escape from the nets used to catch the medium-sized zooplankton. A special apparatus (BIONESS) was developed to sample the macroplankton and used extensively to plot vertical and horizontal distributions in a variety of habitats. In some situations, it was used in parallel with the Longhurst-Hardy Plankton Recorder (LHPR), an automated sampling device for general zooplankton.

Attention has recently been focussed on very small zooplankton, which may have a relatively small biomass but have an important role in the food chain because of their high metabolic rate. Methods are being developed for routine sampling and analysis of the microplankton. It is thought that in some situations more energy is processed by the very small forms than by all the other size fractions combined.



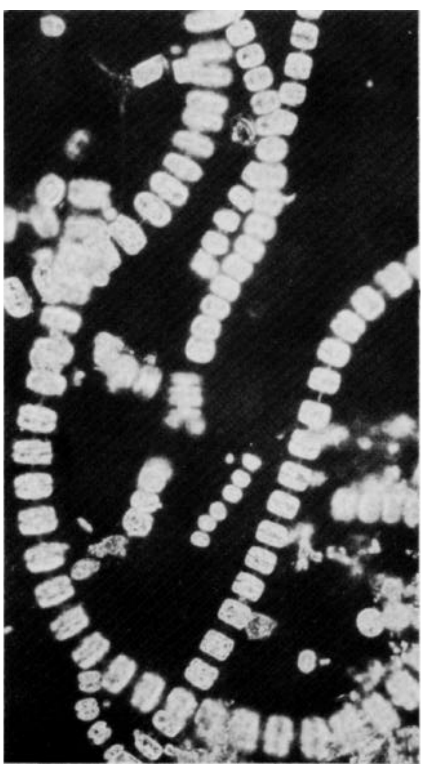
BIONESS, with Doug Sameoto at the controls, obtains zooplankton samples from ten depth intervals, and simultaneous profiles of temperature, salinity, chlorophyll, and illumination; photographic records of plankton are taken when required and the attitude (yaw, pitch, roll) of the net is monitored.





Zooplankton studies have been related to fish production studies in two main areas: across the frontal zone at the edge of the continental shelf and on the shelf itself. Three cruises were undertaken to analyze the situation off the edge of the shelf. The majority of the samples were taken at night when the zooplankton community is concentrated in the upper 150 m of water. Net sampling was supplemented by acoustic observations, in which the back-scattering permits the identification of major concentrations of zooplankton. Analysis of the results indicated that two major planktonic and nektonic predators of herbivorous zooplankton consumed over half of the herbivorous zooplankton production. An energy flow budget showed that the zooplankton and its predators appeared to be capable of sustaining the observed biomass of pelagic fish. This was contrary to some earlier conclusions.

Studies of zooplankton, phytoplankton, and nutrients have also been made in conjunction with the Scotian Shelf Ichthyoplankton Program (SSIP). An extensive grid of stations on the Scotian Shelf has been sampled at intervals of l-2 months for several years and measurements have been made of the mass and distribution of larval fish, zooplankton, chlorophyll, and nutrients. When these data are plotted and interpreted, it should be possible to identify the important areas for fish breeding, and the feeding grounds of larval and juvenile fish. In conjunction with other studies of physical and biological oceanography, it will then be possible to understand and manage the Scotian Shelf as a fish-producing ecosystem.



Phytoplankton are neutrally buoyant unicellular aquatic plants that are usually immotile but are transported passively by water.

ECOLOGICAL THEORY AND STRUCTURE OF ECOSYSTEMS

At present, the only practical way of making management decisions about fish stocks is to collect information about each species individually and to estimate what proportion of the stock can be removed without overfishing. The difficulties with this approach result from the interactions between different species of fish, and from the effects of environmental changes on the ecosystems containing the fish. At the Marine Ecology Laboratory, a group of fisheries oceanographers studies marine ecosystems to develop ecosystem theory to the point where changes can be predicted. One project considers energy flow in marine ecosystems, and the ways in which it influences the metabolism and growth of fishes. Metabolism of fish populations is extremely difficult to measure, but a way has been found of calculating complete energy budgets from growth data, which can be measured routinely. As fish grow larger, they are able to shift to larger and larger food organisms, and as they do so their energy budgets show marked changes. This has been shown to be true for Atlantic and Labrador cod stocks.

Once the energy budget of a fish stock is known, it is possible to estimate the degree of competition for food between different species in the same area, an important aspect of the interactions between species. It is also possible to calculate how important the interaction may be should the adults of one species prey on the young stages of another species.

Environmental changes that have important effects on fish stocks include changes in average water temperature resulting from differing amounts of run-off from major rivers, or changes in the direction of major ocean currents. Temperature affects fish metabolism, and indirectly influences competition for food and predator-prey relationships. Hence, the study of fish energetics contributes to our understanding of unexpected shifts in the balance between species.

Fisheries laboratories elsewhere have attempted to model ecosystems on computers, using a reductionist (simplified) approach. The properties of each individual species are fed into the computer and made to interact with all others in the hope that the computer model will behave like the natural ecosystem. An important innovation at BIO is the concept of 'top-down modelling', which begins with a consideration of how the whole ecosystem behaves, and introduces only the level of detail needed for the particular application. This approach has more reliably represented ecosystem functions. It is expected to lead to better models of marine ecosystems that will improve fishery management.

ECOLOGICAL STUDIES OF COASTAL FISHERIES

St. George's Bay, Nova Scotia, provides an excellent site for ecological studies of a nearshore fish population. The Bay opens into the Gulf of St. Lawrence and shows a set of ecosystem properties that contrast to those of the bays opening to the Atlantic Ocean; for example, the waters are warmer in summer and cooler in winter. There is a clockwise gyre in the Bay with a mean, depth-averaged velocity of 10 cms^{-1}. The Bay is strongly stratified in summer, and the effects of stratification on circulation have been investigated both in the field and by means of a 2-layer, quasi-geostrophic vorticity, numerical model.

Within George's Bay an extensive series of field observations has been taken on the food and growth of larval mackerel, on primary production, zooplankton production, and on nutrient dynamics in the water column. An important finding is that there is no critical stage in the development of mackerel. Mortality is distributed fairly evenly throughout the early life history. This is in marked contrast to the views of other ecologists working with larval anchovy and with English plaice.

Zooplankton data are being used to calculate secondary production in the water column by means of cohort analysis. Observations on nutrient dynamics are being related to information on physical oceanography, phytoplankton production, zooplankton grazing, and rates of sedimentation to yield a dynamic picture of the ecosystem in which mackerel spend the first few months of their lives, Particular attention is being paid to vertical fluxes both in the water column and across the sediment-water interface. When published, this will probably be the most complete ecological study to date of the early life history of a commercially important fish species. If similar studies are made in other areas, such as the Scotian Shelf and the Grand Banks, we shall have a much better grasp of the important events leading to success or failure of recruitment to the commercial fish stocks.

CLIMATE CONTROL OF FISH POPULATION ABUNDANCE

The assumption underlying much of the current management practice is that fishing effort is the most important determinant of change in the fish stocks, so that control of fishing effort is the most useful management device. Evidence is now accumulating to suggest that the influence of environmental factors is much greater than had been previously supposed. A dramatic demonstration of this effect was obtained some years ago, when it was found that most of the variation in catches of certain species of fish, lobsters, and scallops in the Gulf of St. Lawrence could be attributed to variation in the spring run-off of fresh water in the St. Lawrence River in the year when a particular stock was hatched. For example, the catch of lobsters in a particular year was strongly correlated with the spring run-off of the St. Lawrence nine years earlier, when those lobsters were in the larval stage. It was subsequently shown that the same effect could be detected along the Atlantic coast of Nova Scotia as far south as George's Bank, although at this distance the effect of the St. Lawrence was less strong, and tended to be confounded by other environmental changes.

It has recently been shown that similar effects can be detected in Hudson Strait, where a volume of river water many times greater than that of the St. Lawrence comes out and joins the Labrador Current. Correlations between environmental signals and productivity of cod on the Labrador Shelf have been detected, and it is believed that the effect may extend south to the Grand Banks.

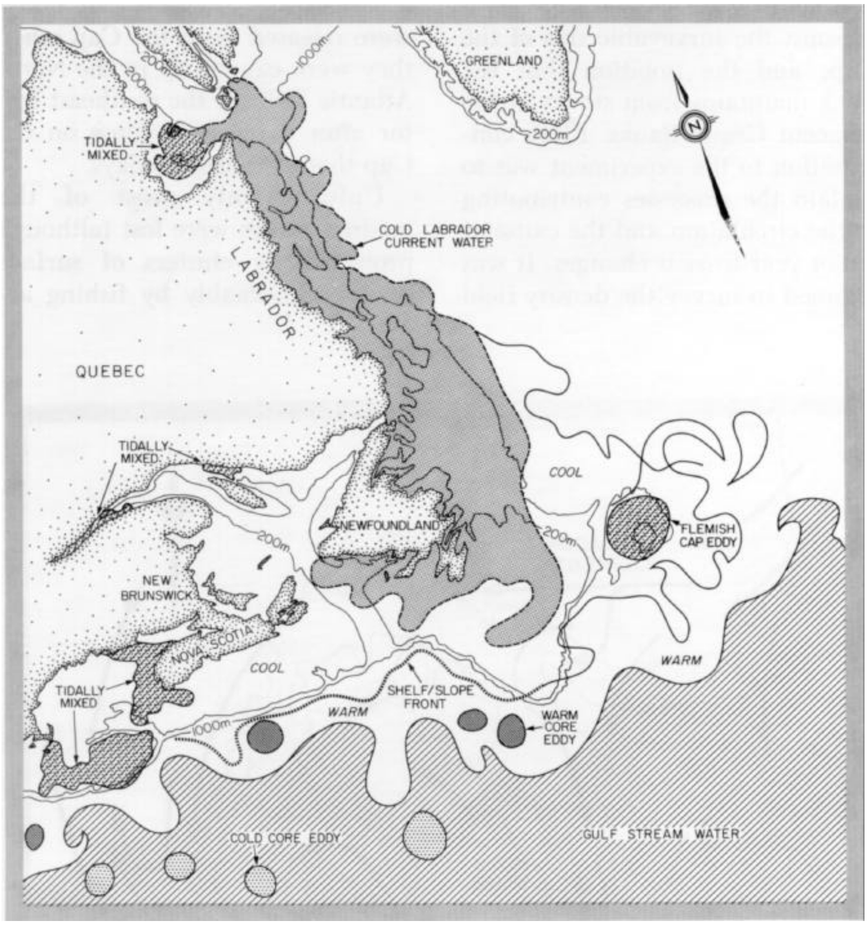
A working group has been formed to review the whole question of how run-off from the land influences productivity in coastal waters to determine whether existing information is good enough to provide guidance to those concerned with modification of that run-off (i.e., in the construction of power dams), and to make recommendations for further work. Its report is expected shortly.

Another project is concerned with the way in which dense patches of larval herring move in response to physical oceanographic factors. In a joint experiment with the Marine Fish Division and with the U.S. National Marine Fisheries Services, a patch of herring larvae off the Nantucket Shoals was sampled intensively for several weeks, and concurrent physical oceanographic measurements were made. The patch remained intact for the whole period of study and moved passively with the water masses. When all data are analyzed it will be possible to provide an account of the early larval history of the herring in terms of vertical migrations, growth, mortality, and feeding.

OCEAN CIRCULATION AND THE FISHERY

The tendency of water masses to capture and retain patches of fish larvae mentioned in the previous paragraph demonstrates the influence of circulation patterns on biological activity and the subsequent patchiness of fish abundances. Ocean and tidal currents, in fact, are probably as great an influence on the fishery as is the freshwater run-off from rivers and the melting ice of the low Arctic. In order to better understand the effect of the circulation of water masses on the fishery, the Atlantic Oceanographic Laboratory has undertaken two ongoing studies in areas of high fish abundance; the inshore area around Cape Sable in southwestern Nova Scotia, and the offshore area of the Flemish Cap at the extremity of the continental shelf off the Grand Banks.

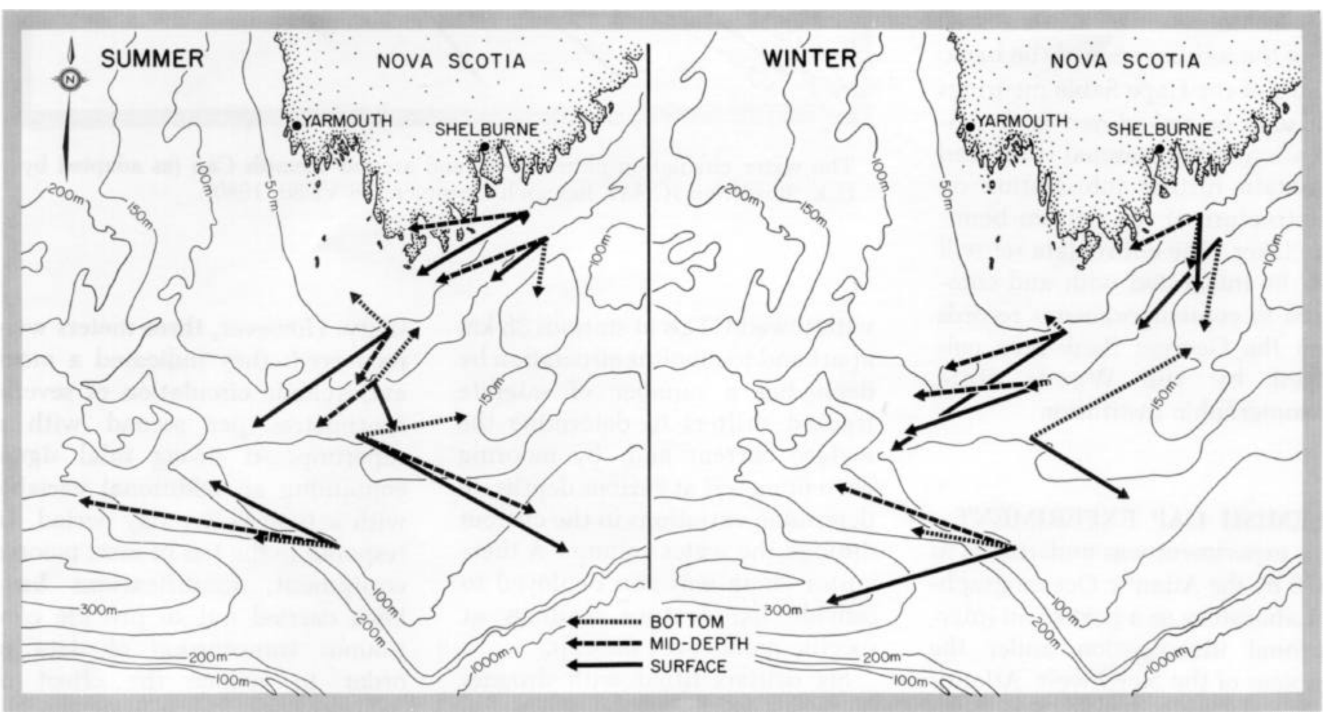
CAPE SABLE EXPERIMENT - This experiment was designed to investigate various fisheries-related aspects of the circulation off southwestern Nova Scotia. In particular, hypotheses associated with: (1) seasonal mean inflow into the Gulf of Maine related to fresh water run-off from the Gulf of St. Lawrence, (2) tidally-driven centrifugal upwelling, and (3) stratification versus tidal mixing were to be tested. The pulse of



This composite map was drawn from several non-simultaneous infra-red photographs. The major ocean circulation patterns as they might be at one instant in time are shown. The variability of ocean circulation in the Northwest Atlantic has a major impact on the primary production of our waters.

fresh water that emanates annually from the Gulf of St. Lawrence and travels westward along the continental shelf is thought to provide an 'oceanic pathway' for river run-off from the Gulf, which thereby exerts a strong influence on the shelf fisheries. The centrifugal upwelling hypothesis states that a seasonally-independent upwelling circulation that pumps nutrient-rich deep water up into shallow surface layers is produced by tidal flow around southwest Nova Scotia. In addition, the strong tidal mixing in this shallow zone results in a well-defined front in summer between homogeneous and stratified waters and appears to induce high levels of primary and secondary production.

The primary data sources for the experiment consisted of: (1) an array of current meters and bottom pressure gauges moored at four sites across the shelf at Cape Sable and two sites up the shelf off Shelburne, (2) a series of surface drift tracks derived from satellite-tracked drogues, and (3) monthly sea-surface temperature maps of the region. * In general, the current meters were set to monitor conditions near the surface (15 m), at



Seasonal circulation patterns off Cape Sable, N.S. The nearshore current arrows suggest that upwelling and inflow into the Gulf of Maine are taking place, the offshore arrows that there is a clockwise gyre over Brown's Bank.

*Courtesy of the Hydrometeorology Division of the Atmospheric Environment Service, Downsview, Ontario.

mid-depth, and at 10 m above the bottom, but a dense array of instruments was concentrated in the bottom boundary layer for certain periods. In addition to their relationship to this experiment, the near-bottom temperature records form part of the data set for the Long-Term Temperature Monitoring Program for fisheries climatology.

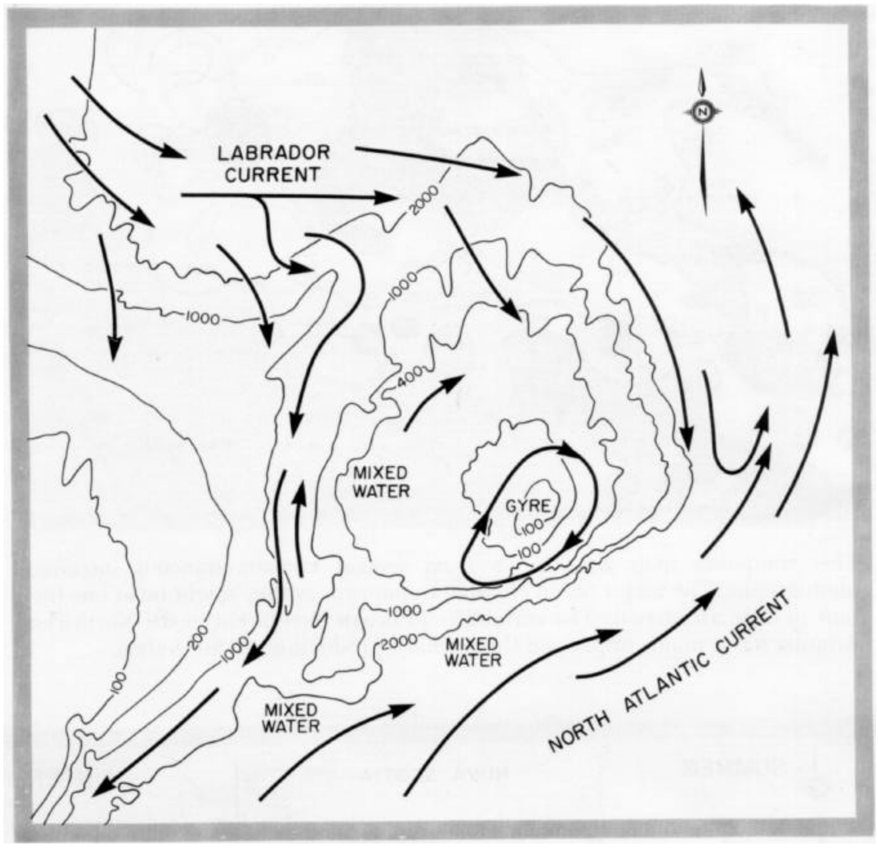
To date, the results of the Cape Sable Experiment have been encouraging. A strong inflow of cold and fresh water into the Gulf of Maine has been measured in two seasons. The arrival of this anomalous water at Cape Sable is marked by a very sharp drop in properties (particularly salinity) that is sometimes followed by a succession of weaker pulses. Direct evidence of onshore bottom and offshore surface velocities confirms the upwelling circulation off Cape Sable and contrasts sharply with the circulation off Shelburne, Nova Scotia. Moreover, the bottom temperature field associated with the upwelling and strong inshore mixing is much more uniform than that off Shelburne. Another unexpected finding is the evidence for a strong anticyclonic gyre around Browns Bank, which results in transport from the Gulf of Maine to the Scotian Shelf along the inshore edge of the bank.

Two of the Cape Sable moorings will soon be redeployed as a continuation of the seasonal study and to obtain further information on the structure of the bottom boundary layer. The entire data set will then be integrated with and compared to contemporaneous records from the Georges Bank area collected by the Woods Hole Oceanographic Institution.

FLEMISH CAP EXPERIMENT - This experiment was undertaken in 1979 by the Atlantic Oceanographic Laboratory as a part of an international investigation under the auspices of the Northwest Atlantic Fisheries Organization (NAFO) to investigate the possible reasons for the year-to-year variation of the cod stock. The location of the experiment was chosen for two reasons: the surveyable size of the Cap, and the isolation that the stock maintains from stocks in the adjacent Grand Banks. BIO's contribution to the experiment was to explain the processes contributing to the circulation and the cause of major year-to-year changes. It was planned to survey the density field with towed CTDs at stations 38 km apart and to monitor circulation by deploying a number of satellite tracked drifters to determine the surface current and, by mooring current meters at various depths, to determine variations in the current through the water column. A thermistor chain was also deployed to provide temperature readings at specific points over the cap.

Six drifters fitted with drogues that reduce the effect of surface wind on movement were deployed. The general circulation pattern was confirmed as clockwise (anticyclonic) and sluggish. All buoys were released from the Cap when thcy were caught up in the North Atlantic Drift at the southeast sector after a residence time on the Cap that averaged 50 days.

Unfortunately most of the moored arrays were lost (although protected by clusters of surface buoys) presumably by fishing activity. However, three meters were recovered; they indicated a mean anticyclonic circulation of several centimetres per second with a superimposed strong tidal signal containing an additional variable with a four to five day period. In response to the loss of most moored equipment, modifications have been carried out to provide continuous transmission of data in order to reduce the effect of damage caused by fishing activity. It is planned to use this modified equipment for the experiments that will be conducted this year.



The water circulation pattern over and around Flemish Cap (as adapted by C.K. Ross from ICNAF Research Document 78/VI/80, 1980).

MANAGEMENT ADVICE AND RELATED RESEARCH

The Marine Fish Division has components at both the Biological Station at St. Andrews, New Brunswick, and at BIO. It is impossible to separate completely the functions of each component, but emphasis here will be placed on programs initiated largely from the BIO contingent.

The Division carries out research on marine finfish in the Maritimes Region itself and has responsibility for tuna, swordfish, and grey and harbour seals for the whole Atlantic coast. Research is organized to provide the factual and scientific basis for the ongoing analysis of the major stocks. The wide geographical coverage and the continuing nature of the assessment responsibilities, which date back to the late 1940s in the Maritimes, has ensured the development of a broadly based ecological program. This is now paying dividends in the form of more emphasis on the fundamental biological questions raised by man's intervention as a chief predator of the ecosystem's major components.

The Division's annual, or more frequent, analyses of the status of the major commercially exploitable fish stocks in the Maritimes Region is the basis for advice on management of the fisheries for the coming year. Advice channeled through scientific bodies such as the Northwest Atlantic Fisheries Organization (NAFO), the Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC). and the International Commission for the Conservation of Atlantic Tuna (ICCAT) goes to the federal Minister of Fisheries and Oceans, but is also available to all fishermen and the fishing industry.

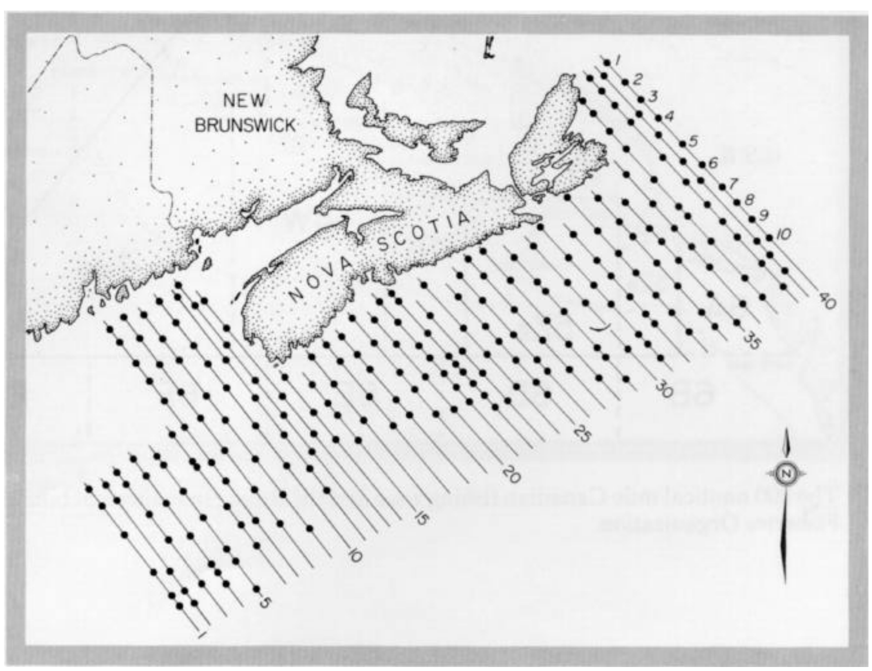
The basic assessment function can be reviewed best in relation to the various types of data-collecting programs involved.

PORT SAMPLING - Five field offices at major fishing ports are maintained to sample commercial fish landings representatively. A reliable description of the size and age structure of the catch that can be translated into a documentation of the vital parameters for each individual stock being exploited is what is required. This involves making measurements when sampling and collecting otoliths (ear bones) and other structures, which are used to determine the ages of fish. The ability to sample efficiently. is fundamental to any ecological study and field offices are also called on to provide samples for basic research programs such as life-history, feeding, and growth studies relevant to species interactions.

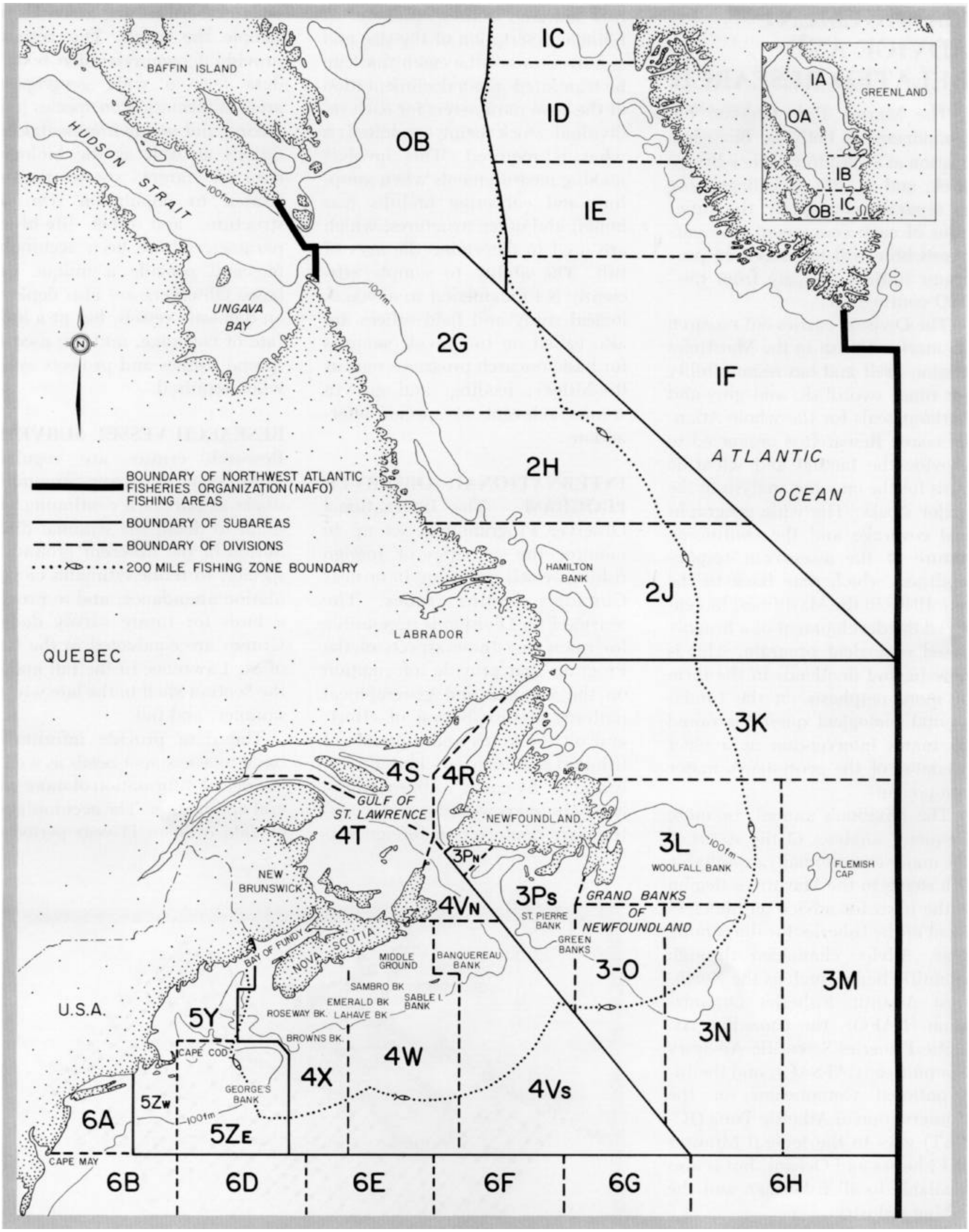
INTERNATIONAL OBSERVER PROGRAM - The International Observer Program was set up to monitor the activities of foreign fishing vessels operating in or near Canada's fishing zones. The Marine Fish Division is responsible for managing those aspects of the Program that provide information on the seasonal and geographical patterns of distribution of effort, and on the kinds and amounts of fish that are removed - both directly and as "by-catch". Approximately 50 observers working under contract are deployed on foreign vessels to record fishing activities and sample the catch. The activities provide a comprehensive body of data over a wide geographical area. Information on species intermixing and on environmental conditions as well as the biological data on "target" species that are related to population size, age structure. and other life-history parameters have been accumulating and provide a unique data base. Observers are also deployed on domestic vessels, but at a lower rate of coverage, and are used for special studies and projects as and when required.

RESEARCH VESSEL SURVEYS - Research cruises are regularly undertaken to survey groundfish stocks as part of a continuing program to detail the seasonal distribution of the different groundfish species. to refine estimates of population abundance and to provide a basis for future survey design. Cruises are conducted in the Gulf of St. Lawrence in the fall and on the Scotian Shelf in the late wintcr, summer, and fall.

The data provide information basic to assessment needs as well as biological information of more genera1 application. The accumulation of data over an 11-year period on



Sampling stations for the Scotian Shelf Ichthyoplankton Program (SSIP).



The 200 nautical mile Canadian fishing zone and the fishing management boundaries established by the Northwest Atlantic Fisheries Organization.

both commercially exploited and other stocks represents an ecological coverage of the greatest value. Its full scientific impact will depend on the calibration of the fishing performance of each individual vessel that has been used, a process that is now being undertaken by comparative fishing trials.

SCOTIAN SHELF ICHTHYOPLANKTON PROGRAM - A long-term program was begun in 1979 to investigate the factors that control year-class strength in fish stocks. The first phase of the Scotian Shelf Ichthyoplankton Program is nearing completion and attention is now being focused on detailed studies of the egg and larval stages of sevreral major fish species.

About 200 stations are occupied each month so that the seasonal distribution of fish eggs and larvae can be determined in sufficient detail to outline the characteristic life-history, events at this crucially important stage of development. Together with the environmental data and information on other planktonic forms, this represents the most comprehensive ecological coverage yet possible for the Scotian Shelf.

Information on the basic biology of both common and rare species of fish is continually being updated, and additions to the fauna of the area recorded; in this way, the structure of the fisheries ecosystem in our region is becoming clearer, and the place of commercial fish within it better understood.

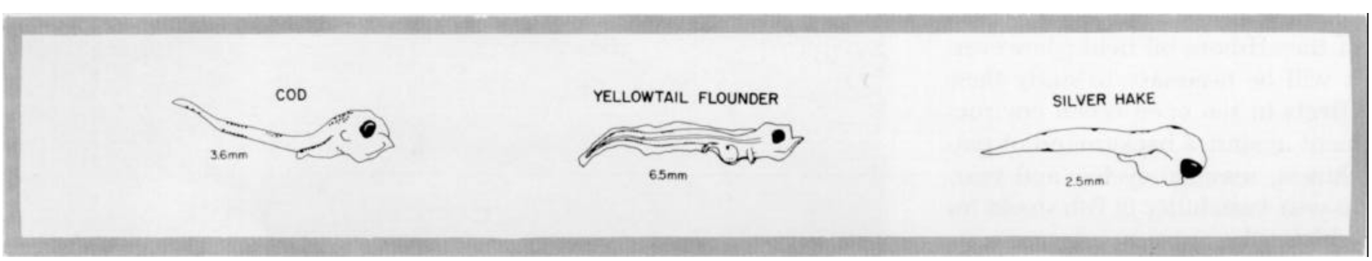
Data from this program are of great interest in relation to environmental impact studies of offshore oil and gas developments and they provide essential input to ongoing fisheries ecology studies.

FISH TAGGING - Fish tagging experiments are conducted to provide critically important information on stock structure and inter-relationships and on migration patterns. During 1980, for example, cod were tagged on four cruises and numerous shore parties continued a juvenile-pollock tagging program along the coast of Nova Scotia and in the Bay of Fundy. Data from such experiments complement the results of the Scotian Shelf Ichthyoplankton Program and help elucidate stock structure units for management purposes.

ASSESSMENT - Assessment can be defined as the analytical evaluation of population size and of factors causing its changes, and this represents the end result of a series of complex interacting processes and operations. Essentially, it involves the merging of two sets of data: those obtained from the commercial fishery and those by the sampling survey and research activities of the Department. The end product is documented in papers of the kind listed under the Marine Fish Division in Chapter 9 that are considered as CAFSAC, ICNAF and NAFO Research Documents. The accompanying chart indicates the NAFO fishing areas for which assessments are provided.

As an example of the interaction between management and assessment that this represents, we can take the case of cod in the areas 4Vs and 4W. Only one biological unit - or stock - is thought to be involved and this is referred to as the 4VsW cod stock.

Since 1977, the 4VsW cod fishery has been nearly 100% Canadian. When the stock first came under quota management in 1973 and for the following year, the combined stock was apparently in decline: from 1975 to 1978, however, the stock increased. The 1980 analysis showed that the cod also increased in abundance in 1979 and 1980 but that the rate of increase was less than for 1975 to 1978. Assuming a catch of 45,000 metric tonnes for 1980, the 1981 TAC (total allowable catch) was set at 49,000 metric tonnes. This modest increase in a successful fishery is consistent with Canada's goal to rebuild its fish stocks by stringent conservation measures within its 200-mile fisheries zone. It is not solely the result of assessment but it could have been neither achieved nor documented without competent assessment, and the co-ordinated effort that it implies.



Fish larvae.

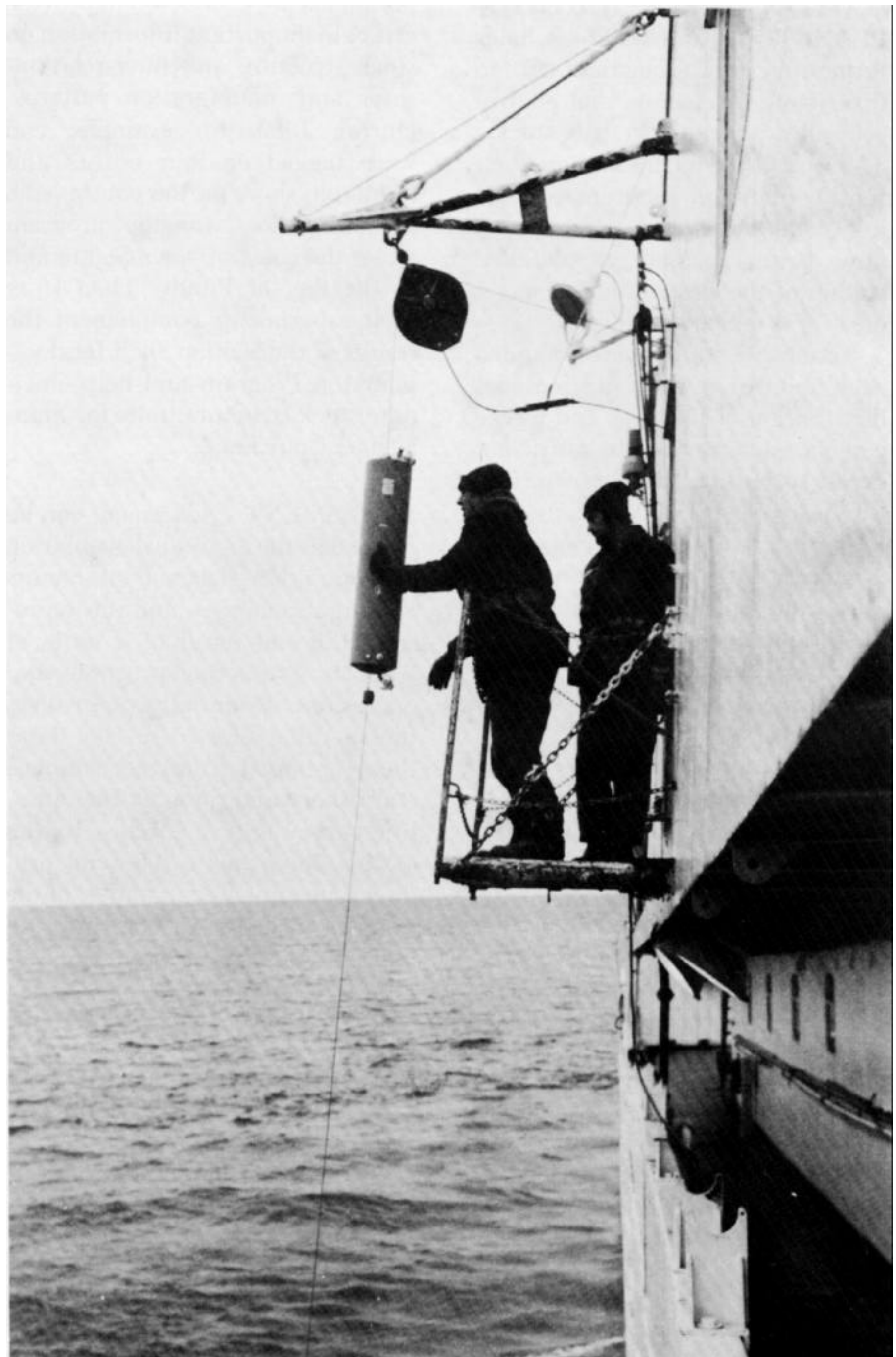
chapter 6

Marine Contamination

The preservation of the quality of the marine environment is of vital importance to the management of the living resources of the sea discussed elsewhere in this report. Today the threat of further pollution associated with offshore oil and gas on the continental shelf is a matter of concern. Offshore development adds a new dimension to pollution from land-based industry and marine transportation. The continuing build-up on a large scale of crude oil and its refined fractions in the oceans is estimated to be greater than six million tons annually and in quantity far exceeds all other forms of pollution combined. Today there is hardly an ocean region, regardless of its remoteness, where petroleum degradation, combustion products, or other evidence of man's consumption of oil cannot be found.

Although other persistent pollutants entering the coastal waters may be dispersed widely in the oceans by natural mixing, and may be transported over great distances in the atmosphere, they have reached significant levels only in some inshore areas, where most of BIO's work on the effects of ecosystem contamination has been conducted. With the development of the offshore oil fields, however, it will be necessary to study these effects in the open ocean environment against a background of patchiness, seasonal cycles, and year-to-year variability in fish stocks for which the means of accurate prediction have not yet been established - a challenge that BIO must meet in the immediate future.

Chemical oceanographers of the Atlantic Oceanographic Laboratory are engaged in continuing studies of background levels of contamination from petroleum residues in the oceans. Working in



Roger Belanger 4926-24

Collecting water samples from the winch room platform aboard CSS *Hudson*.

co-operative programs with such international agencies as the Intergovernmental Oceanographic Commission, they have concentrated on the Gulf of St. Lawrence, Scotian Shelf, Grand Banks, Baffin Bay, and the eastern Arctic. Baseline studies of the sources, extent, and fates of other organic, metallic, and radioactive pollutants have also been completed and in the course of this work improved sampling and analytical techniques have been established. The Marine Ecology Laboratory has been active in the study of the responses of marine organisms to low levels of contamination and of the pathways and biological availability of toxic elements and compounds. Three classes of pollutants have been stressed - petroleum hydrocarbons, halogenated hydrocarbons, and toxic heavy metals. The Atlantic Geoscience Centre has become involved as a member of the Seabed Working Group of the International Nuclear Energy Authority in the study of the deep sea sediments and the behaviour of the bottom-water layers over the abyssal plains to determine their feasibility as sites for high-level nuclear solid waste. Additional agencies at BIO closely involved with environmental impact are the Environmental Protection Service Laboratory and the Seabird Research Unit of the Canadian Wildlife Service, both of the Canada Department of the Environment, and the Resource Management Branch of the Canada Department of Energy, Mines and Resources.

LARGE SCALE OCEAN OIL POLLUTION

The Atlantic Oceanographic Laboratory has studied the distribution of petroleum hydrocarbons in the oceans since 1970 when the tanker *Arrow* sank in Chedabucto Bay, N.S., spilling some 16,000 tons of Bunker C oil. These studies fall into two broad categories: investigations of existing background levels of contamination in the Norwest Atlantic and eastern Arctic and chemical identification of the sources of the discovered residues combined with participation in co-operative scientific programs of the Intergovernmental Oceanographic Commission to assess the extent, degree, and impact of oil pollution on a global scale. Surveys of the Scotian Shelf and Gulf of St. Lawrence by the Laboratory have shown the water to contain a few micrograms per litre, which appears to originate with the transportation and consumption of petroleun. A comparatively small component is transported by the atmosphere from products of combustion. Baffin Bay has a petroleum background an order of magnitude lower. In some localities, however, there is a much higher concentration caused by natural seepage from the seabed (see "Focus on the Labrador Sea", chapter 2). International programs have clearly demonstrated that regions of highest contamination by oil in the form of visible slicks and floating tar particles coincide with major shipping and tanker routes in the Atlantic, Pacific, and Indian Oceans. It has also been demonstrated that the seasonal changes in the behaviour of surface currents determine where the stranding of oily residue occurs.

SUBLETHAL CONTAMINATION AND EFFECTS

The Marine Ecology Laboratory is continuing its studies of the responses of marine organisms to contamination from heavy metals and hydrocarbons, and their pathways and biological availability. Laboratory experiments on the effects of polychlorinated biphenyl (PCB) replacements on trout and preliminary field studies have been undertaken to determine the responses of cod and sculpin to natural environmental levels of contamination. Three continuing studies are described below: the induction of the MFO (hepatic "mixed function oxidase") system in fish by pollutants, the biological availability and fate of petroleum hydrocarbons in inshore marine environments, and the final stage of a study of mercury pollution in the Saguenay Fjord, an ongoing project since 1973. Work has also continued on the metabolism of petroleum hydrocarbons in the marine food chain with experiments to determine the responses of phytoplankton to contamination. Results indicate that even brief exposure to a broad range of contaminants undermines their fitness in the environment. The work will be continued in order to better understand the toxicology of a range of chemical contaminants.

Studies of the sublethal indices of stress in fish will be extended from the laboratory into the field to relate results to normal biological variables such as age, sex, reproductive and nutritional states, and actual pollutant residue concentrations present in the environment. Studies of the degradation of pollutants will similarly be extended from closely controlled laboratory conditions to the marine ecosystem where methods of assessing the stability of pollutants by mathematical modelling will be examined.

MFO INDUCTION BY PCB'S AND PCB REPLACEMENTS- Mixed function oxidase (MFO) enzymes catalyze the breakdown of certain kinds of foreign compounds including many environmental contaminants. These enzymes also have the property of being 'inducible' - that is, their activity increases when they are exposed to such compounds. The Marine Ecology Laboratory has been using MFO induction firstly as a laboratory measure of the sublethal stress brought about by PCB replacements, which may be future environmental contaminants, and secondly as a field bioassy of the effects of pollutants on natural populations of fish.

Experiments on trout show that some PCBs are themselves excellent 'inducers' of the MFO system. Certain PCB replacements based on chlorinated diphenyl ethers are not MFO inducers and could serve as acceptable replacements. Experiments on cod to define the extent of MFO induction by AROCLOR 1254 and the less chlorinated AROCLOR 1016, conducted in collaboration with German scientists, showed that only the first PCB induced MFO activity. North Sea cod and Nova Scotia cod are now being compared in an attempt to relate MFO activity to variations in the burdens of environmental contaminants. The sculpin examined during an Arctic cruise had low levels of enzyme activity compared to those from the Halifax area.

BIOAVAILABILITY AND FATE OF PETROLEUM HYDROCARBONS - The bioavailability of petroleum hydrocarbons, sediment bound or dissolved in the water column, to the various levels of the marine food chain has been studied by the Marine Ecology Laboratory in laboratory experiments and correlated with field observations after real oil spills whenever possible. The major investigation during the review period comprised two related facets.

A model was developed for oil interaction with a range of benthic sediments in order to determine dynamic processes of oil stranding and the potential of subsequent reentry in three ecosystems - a salt marsh, a sandy beach, and a tidal estuary. It was found that hydrocarbons are present in soft sediments, particularly in low-energy locations, but their long-term effects are unknown. The value of these studies depends on there being a long-term follow-up study of real spill situations. Over the next two years it is intended to develop a model of self-cleaning and oil persistence over a broad range of low-energy inshore marine systems similar to those found on Canada's east coast.

In collaboration with U.S. colleagues from the National Marine Fisheries Service, the chemical alteration of long-term stranded oil and the bioavailability of such oil to members of the marine food chain were investigated. The relative availability of toxic compounds to marine organisms inhabiting different ecological niches has been noted, together with the biochemical manner in which the compounds are handled by body systems. It has been found that hydrocarbons can be transferred to groundfish and distributed within the tissues of the skin, muscle, and liver but the effects of such actions are yet to be determined. Describing the microbial degradation of stranded oil in microenviromments where it appears to be the only available route is also a current facet of this part of the study. The object is to develop a predictive capability for assessing the impact of oil on inshore and shallow water systems, particularly in low-energy environments.

MERCURY POLLUTION IN THE SAGUENAY FJORD - The Saguenay Fjord joins the St. Lawrence Estuary about 182 km below Quebec City. In 1973, abnormally high levels of mercury were found in the surface sediments after restrictions had been placed on the commercial fishing of certain species because of their high levels. Two aluminium smelters, an aluminium plant, a fluorspar processing plant, and a number of pulp and paper mills are situated along the Saguenay River above the Fjord. The chlor-alkali plant, which provides the caustic soda for the aluminium production process, was considered to be the main source of mercury in the system and consequently the Canadian government had imposed restrictions limiting the discharge of mercury from chlor-alkali plants throughout the country. A number of studies of the sediments and water column were subsequently undertaken by scientists of the Atlantic Oceanographic and Marine Ecology laboratories. The last was completed in 1980 and is described below.

The recent geochronology of mercury pollution in the Saguenay Fjord was determined in a suite of sediment cores using the Pb-210 dating method. Contamination of fjord sediments by anthropogenic mercury began in 1948 ± 3 yrs, a date coinciding with the construction of a chlor-alkali plant at Arvida on the Saguenay River. Mer-

Ray Rantala in his geochemical laboratory.

cury fluxes in the sediments attained maximum values in the 1960s and early 1970s and subsequently decreased throughout the fjord from 1971-1976. Both the timing and magnitude of the decrease in mercury fluxes are consistent with compliance by the chlor-alkali plant to government regulations imposed in 1971, which limited mercury discharges in liquid effluent from all chlor-alkali plants in Canada. A good correlation between the calculated mercury inputs to the fjord and the mercury/organic matter ratio in one core illustrates the importance of organic matter as a scavenging mechanism for deposition of mercury in the sediments. The fast response of changes in the sedimentary mercury flux at the head of the fjord to changes in the mercury input is consistent with a residence time in the water column for mercury of less than a month while a considerably delayed response in the sedimentary mercury flux in the deep inner basin of the fjord indicates a water residence time in the order of 5 to 10 years.

ATLANTIC SEABIRDS AND POLLUTION

Atlantic seabird populations, monitored by the Canadian Wildlife Service through the Seabird Research Unit based at BIO, include all seabirds inhabiting an area north of 40°N and west of 60°W. The Arctic studies such as that of the Thick-billed Murre are described in Chapter 2. Those species having their principal habitat south of 55°N have shown a marked decline over the past 10-20 years with the noticeable exception of the Herring and Great Black Backed Gulls, which have increased alarmingly because of the increased availability of scavenging food. The effect of man's interference in the coastal and open ocean environments has understandably been more apparent in the temperate east coast (particularly in the Gulf of St. Lawrence) than in the Arctic up to now. Historically, the most impor-

Northern Gannets *(Morus bussanus)* nesting at Bonaventure Island, Quebec, the largest of the six colonies in North America.

Above: Common Murres *Uria aalge* on breeding ledge at Great Island, Ferryland, Newfoundland. Right: The Atlantic Puffin *Fratercula arctica* at Great Island, Ferryland, Newfoundland.

tant cause for seabird decline has been man's direct persecution in the nineteenth century. With the passing of the Migratory Bird Convention Treaty with the United States, that danger passed except for a very few areas in the northern Gulf of St. Lawrence where monitoring is difficult to maintain. New threats, however, have arisen because of the increased development of the coastal and open ocean areas. By far the greatest threat to seabird populations is that of oil pollution and spillage for the obvious reasons discussed in Chapter 2. The reduction in their food supply by the development of the fishery and the danger to diving birds from nets is also significant, as is the increased contamination of the coastal regions from toxic chemicals and mineral tailings. A third problem is the increased interference by both tourists and the large gulls mentioned above. Some of the threatened populations in Atlantic Canada are enumerated below, either because of inherent features in the distribution pattern or because of recent observed changes in population.

GANNET - About 70% of the total North American gannet population nest in three colonies in the Gulf of St. Lawrence region and the remaining 30% in three colonies on the Newfoundland east coast. Although the Newfoundland colonies have changed relatively little during the last few years, those in the Gulf - principally on Bonaventure Island, Quebec - have decreased by 16 % since 1969, apparently because of toxic chemical contamination and disturbance by tourists at their breeding sites (Bonaventure Island is now a provincial park). It is therefore necessary to monitor the status of the populations on Bonaventure and Anticosti Islands frequently to determine the effects of tourist activity.

RAZORBILL - This bird nests in relatively small colonies throughout eastern Canada from New Brunswick to Loks Land in southeast Baffin Island. There are an estimated 44 colonies in eastern Canada and Maine with a total population of 38,000 birds. There has been a serious decline in the Gulf in the past 10-20 years (probably over 50%). The reasons are obscure, but are probably the result of chemical pollution as in the case of the gannet. The Gulf was originally the principal nesting area for the bird.

COMMON MURRE - This bird was once extremely numerous throughout Atlantic Canada but has been much reduced as a species (present population is 574,000 pairs) and now is almost entirely restricted to breeding areas off Newfoundland's east coast. There are some small relict colonies outside Newfoundland and Labrador and these account for about 4% of the total population. Sixty-nine per cent of the remainder are concentrated on Funk Island. Newfoundland; as a species they are extremely vulnerable to oil blowouts from developments nearby. A prime cause for concern is the very slight recovery since the bird has been protected after the intensive persecution during the nineteenth century. The reduction in the available food supply in the gulf may be a governing factor.

ATLANTIC PUFFIN - This species is highly aggregated and specialized, and therefore in considerable danger. About 75% of the total North American population (338,300 breeding pairs) occurs in eastern Newfoundland with most of these nesting on Great, Green, and Gull islands in Witless Bay. Its pelagic ecology is poorly known but the extensive development of an international capelin fishery will undoubtedly have an adverse effect on its chances of survival since capelin is puffin's principal summer food. In fact, since initiation of the capelin fishery in 1972, there are 20 to 30% fewer puffins in the Witless Bay colonies.

chapter 7

Instrument Development

Modern oceanographers use increasingly sophisticated instruments and techniques to study previously unexamined phenomena in the ocean. For example, measuring pressure fluctuations, in a turbulent water flow became possible only about ten years ago even though measurements on the flow boundaries had been made for much longer. The problem was that the pressures to be measured were so low that the old instruments modified them in the very act of measurement. A scientist at BIO solved this difficulty by developing a precisely contoured sensor that did not itself modify the pressure field. Today several different types of this sensor exist, and oceanographers regularly use them to study waves.

At BIO, instrument development has been give close attention from the beginning and today oceanographers, hydrographers, and engineers are actively involved in the development of better positioning systems, remote sensing devices, new sampling equipment, and many other instruments and techniques. A few of our current concerns are discussed by discipline below.

PHYSICAL OCEANOGRAPHY

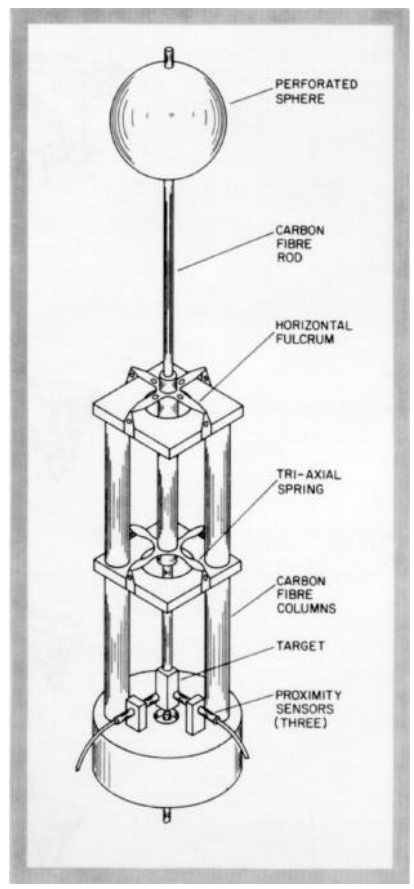
Physical oceanographers use a wide range of instruments from ships to measure and record the physical processes in the ocean. Some instruments are moored in one place and left for extended periods to measure, for example, current speed and direction. Some are retrieved shortly after lowering and measure properties such as temperature, salinity, pressure, and large and small scale water motions. Other instruments are set to drift and can be used to study the patterns of, say, bottom currents over large distances.

The Atlantic Oceanographic Laboratory has been concerned with overcoming two shortcomings of moored instruments and lines: the corrosion of galvanized and stainless steel lines, which reduces the life span of the moorings, and the movement away from the vertical of the mooring lines, which tends to degrade the quality of the data collected by the moored instruments.

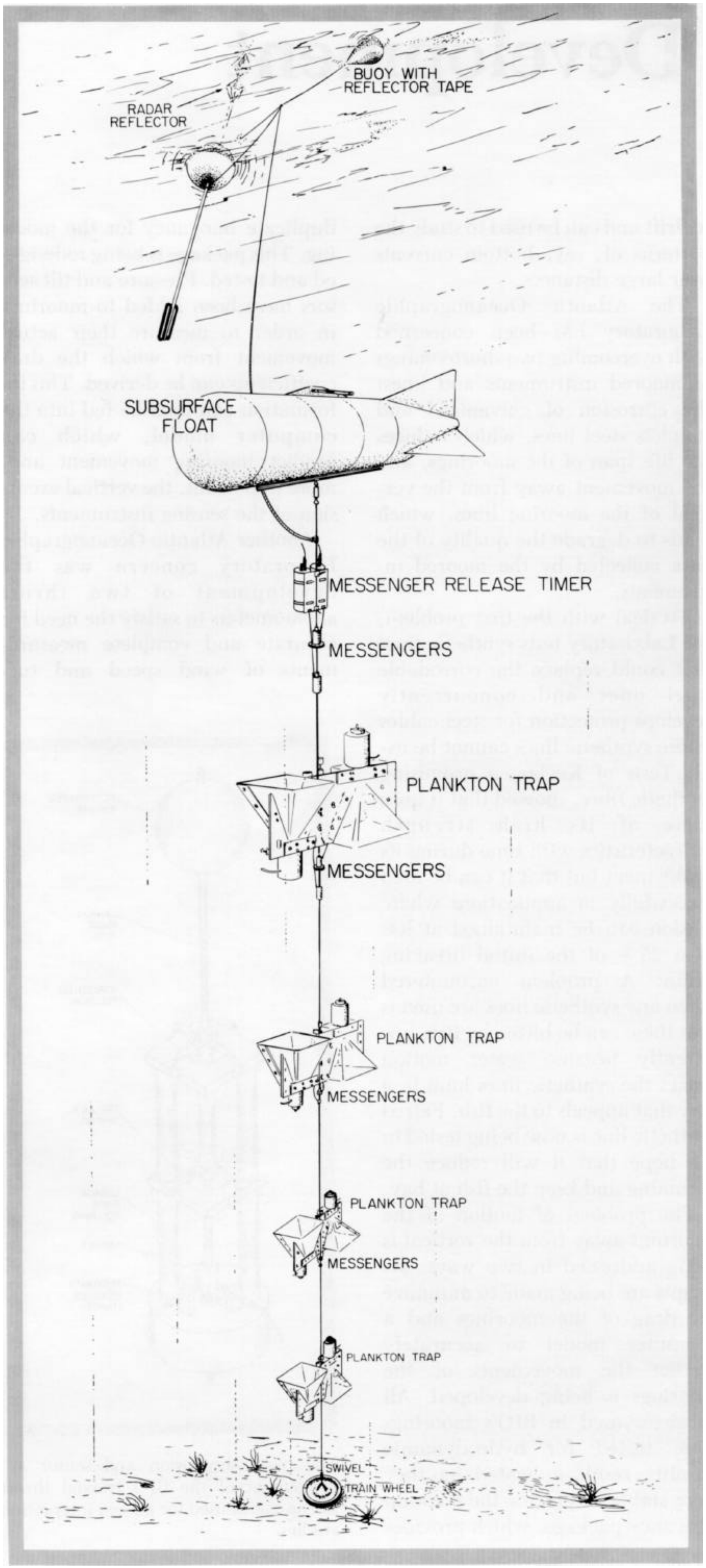
To deal with the first problem, the Laboratory tests synthetic lines that could replace the corrodable steel ones and concurrently develops protection for steel cables where synthetic lines cannot be used. Tests of Kevlar, a promising synthetic fibre, showed that it loses some of its high strength characteristics with time during its deployment but that it can be used successfully in applications where tension can be maintained at less than 25% of the initial breaking strain. A problem encountered when any synthetic lines are used is that these can be bitten by fish, apparently because water motion makes the synthetic lines hum in a way that appeals to the fish. Faired synthetic line is now being tested in the hope that it will reduce the humming and keep the fish at bay.

The problem of motion of the moorings away from the vertical is being addressed in two ways: attempts are being made to minimize the drag of the moorings and a computer model to accurately predict the movements of the moorings is being developed. All packages used in BIO's moorings were tested for hydrodynamic stability; results indicated that they were stable except for the back-up buoyancy package, which provides duplicate buoyancy for the mooring. This package is being redesigned and tested. Pressure and tilt sensors have been added to moorings in order to measure their actual movement from which the drag coefficients can be derived. This information can then be fed into the computer model, which can predict mooring movement and, more important, the vertical excursion of the sensing instruments.

Another Atlantic Oceanographic Laboratory concern was the development of two thrust anemometers to satisfy the need for accurate and complete measurements of wind speed and tur-



The basic suspension and sensor arrangement of the BIO triaxial thrust anemometer used for air-sea interaction studies.



Mooring with four biological traps

Fish sometimes attack instrument mooring lines. This Atlantic Wreckfish took its own picture by biting the compass attached to the trigger line 3 m below our remotely-controlled deep-sea camera.

bulence. One was designed to measure three-components of wind speed (north-south, east-west, and vertical) in support of studies of atmospheric heat flux and carbon dioxide exchange across the air-sea interface, The previous anemometer used was a difficult instrument to construct, its response was not linear, and it had some cross-coupling between wind components. The new design employs a simpler suspension system and uses contactless proximity sensors that eliminate most of the cross-coupling. Other improvements were a more symmetrical sphere on top of the beam and a different arrangement for the thermistor. The result of these changes is an anemometer that can be mounted on a tower and left at sea to telemeter wind data via radio to BIO. An additional feature of this device is a tube that is raised by radio command to cover the beam and sphere. It allows the instrument to be calibrated without wind interference, and prevents damage to the unit in storage. The second thrust anemometer was developed for unattended operation on drifting meteorological buoys that transmit information via satellite. The buoy has a vane and a compass, and the anemometer measures the wind in the axis of the vane only. One feature is that it has no moving parts to wear out. The wind drag on the sphere deflects a diaphragm and the angle is measured by an opto-electronic sensor.

BIOLOGICAL OCEANOGRAPHY

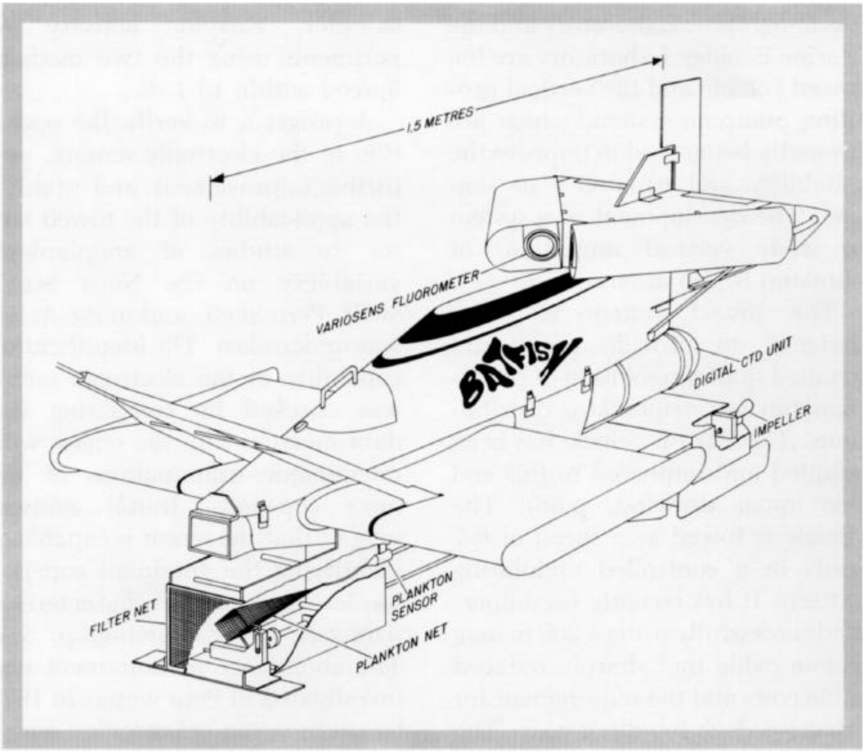
The research interests of the biological oceanographer are in large part concerned with primary and secondary biological production processes and consequently with determining the distributions, abundances, and growth rates of phytoplankton and zooplankton. This type of research is extremely labour intensive and can benefit enormously from the use of biological sensors and sampling devices, Among the varied approaches examined by the Atlantic Oceanographic Laboratory and the Marine Ecology Laboratory are the towed vehicle and the vertical profiling pumping system, which are presently being used to improve the reliability and capability of sensors. The development of a system to study vertical migrations of plankton is also discussed.

The towed system is being designed to provide rapid and detailed spatial resolution of phytoplankton and zooplankton distributions. The Batfish vehicle has been adapted and improved to this end (see upper drawing, p.56). The vehicle is towed at a speed of 6-7 knots in a controlled undulating pattern. It has recently been operated successfully using a 300 m long ribbon cable that sharply reduced cable costs and the requirement for extensive deck handling gear. The achieved depth maximum of 80 m is adequate for studying the euphotic zone. The sensor facilities consist of an electronic zooplankton counter, a fluorometer measuring chlorophyll *a,* and a CTD unit, all mounted on the vehicle. An oscillating mesh sampler has been modified and strengthened so that its average operating time before servicing has been increased from 6 hours to over 50 hours. The electronic counter has been modified to improve the length measurement of copepods, and a new light meter is being installed in the Batfish. These modifications will soon be tested.

The vertical profiling pumping system consists of a variable-depth helical-rotor pump, which sends 50 to 80 L of water per minute through a deck-mounted sampling unit. This system does not have the rapid resolution capability and spatial coverage of the towed system but can provide large samplings of sea water from discrete depths for microscopic examinations and other experiments; it thus permits sensor operation to be monitored and verified. Recent tests showed the captured copepods to be in good condition. The pumped samples were compared with samples obtained from a particular depth with a rosette bottle salmpler. Enzyme activity experiments using the two methods agreed within 10-15%.

A program to verify the operation of the electronic sensors, seek further improvement, and establish the applicability of the towed sensor to studies of zooplankton variability on the Nova Scotia Shelf, Peru Shelf, and in the Arctic was undertaken. The identification capability of the electronic sensor was checked by comparing size data measured by the sensor with microscopic examinations of the same copepods. Initial analyses suggest that the sensor is capable of identifying the dominant copepod species from their characteristic sizes (see lower drawing, p. 56). The abundance measurement was investigated in Peru waters in 1977 by comparing electronic sensor data with estimates from the large volume sampler (BIONESS). The results showed good agreement.

A third development designed to provide quantitative data related to the vertical migrations of planktonic organisms has been successfully tested. Emergence traps have been used for some time to capture migrating benthic and epibenthic organisms and for entomological studies of emerging insects. Such a trap, which captures only migrating organisms at discrete depths, could in theory be used to quantify the rate of vertical migration by providing specific counts over predetermined time periods. Each trap (see drawing p.54) consists of two polycarbonate pyramids - one with its apex facing up, the other down - that funnel the migrating plankters into separate acryllic collection bottles. The system consists of a moored plankton trap array, each trap comprising both upward and downward looking collecting components. These traps are clamped to a single moored cable at predetermined depths and controlled to open and close by preset timing mechanisms. Design of the system evolved around the following points: (1) Collection chambers must be closed during deployment and retrieval. (2) Entrapment funnels must be flushed during the downward movement of the traps (when being deployed); (3) Hardware must be transparent to the greatest extent possible; (4) The opening and closing mechanism of the collection chambers must be operated by a manually set device before deployment; (5) The mooring cable must be kept taut during the deployment; and (6) The whole system must be compact and easily handled from a small deck space. The opening and closing of the traps is controlled by preset timers so that no animals can be captured during deployment or retrieval. and spring-loaded ports in the funnels open while the array is being lowered to ensure that no water is trapped while it is being deployed. The operation of three position valve gates (close/open/close) on each of the collection chambers is controlled by messenger weights released by the start and stop timers, and thence actuated sequentially at each trap level from top to bottom in the array.

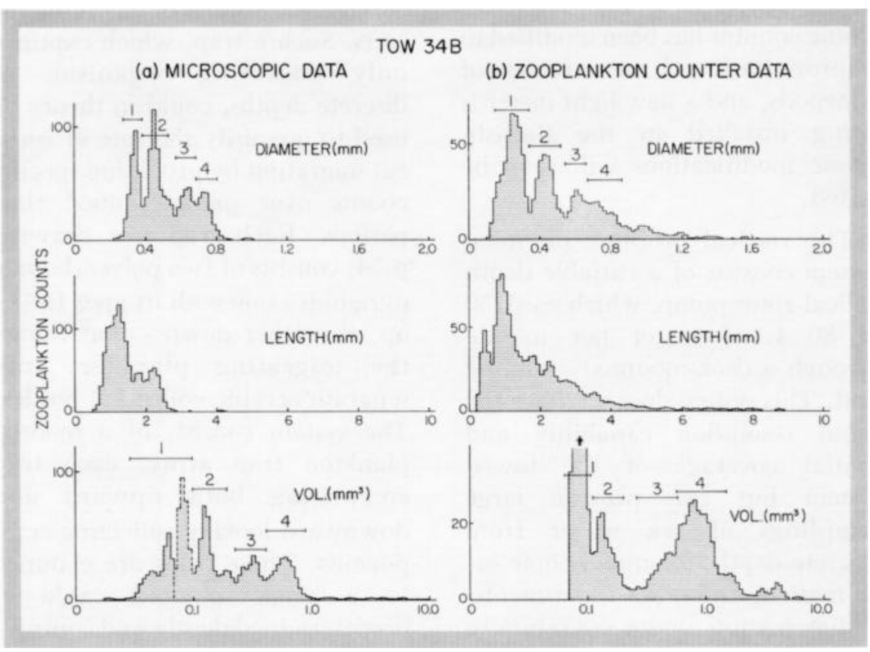


The Batfish system with its complement of biological sensors.

GEOLOGICAL OCEANOGRAPHY

Geologists and geophysicists of the Atlantic Geoscience Centre advise and inform Canadians about the earth beneath the sea and about their shorelines. To carry out that work they use the standard tools of their science such as magnetometers, gravimeters, echo sounders, rock core drills, grab samplers, and sonar, as well as many specialized tools, some of which have been developed at the Institute.

RALPH - An instrument, conceived in the spring of 1978 and affectionately known by the non-acronym Ralph, was designed to monitor the processes that move sediment within the marine environment. Ralph records the current speed and direction, wave state, and, with an optical attenuance meter, the concentration of suspended sediment. In addition, a time lapse camera photographs the

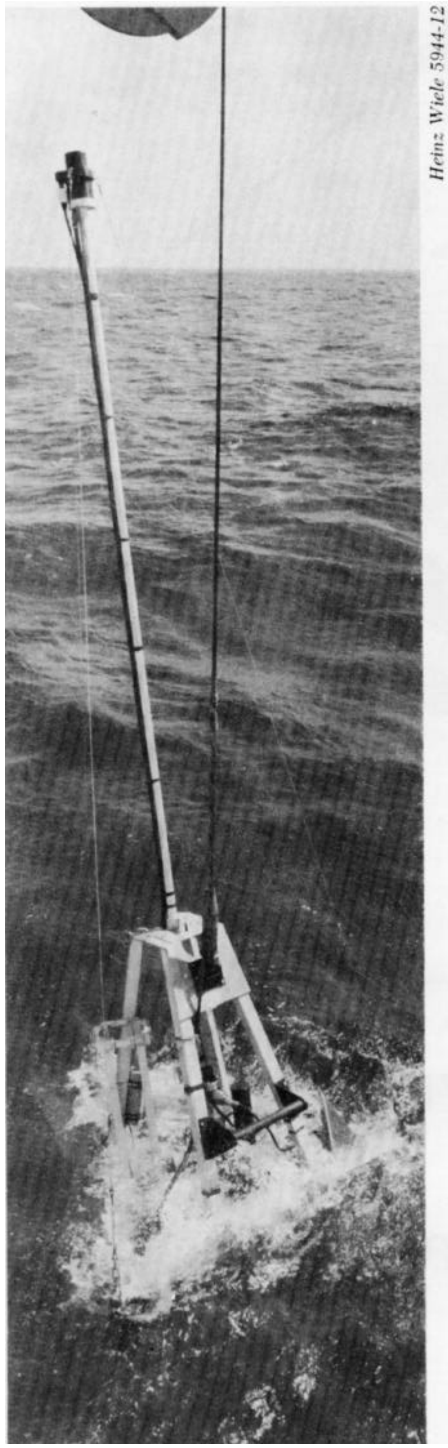


A comparison of zooplankton data measured by the electronic counter (b) and the identical sample measured microscopically (a). Distribution of diameters in both cases is similar in structure with the four peaks corresponding to the following copepods: (1) *Clausocalanus arcuicornis*. (2) *Metridia lucens V*, (3) *Calanus finmarchicus IV*. and (4) *Calanus finmarchicus V*. The data were obtained from a Batfish tow on the Scotian Shelf in 1977.

changes in the seabed. Ralph can monitor estuaries, macrotidal bays, or continental shelf areas for up to 45 days in all weather and can be deployed from small boats. Ralph's operational characteristics were successfully tested during 1979 on the Labrador Shelf, in Lake Melville, in Halifax Harbour, and at the Hibernia oil site. Ralph is now scheduled to participate in his first field project in 1981.

ROCK CORE DRILL - Geological and geophysical surveys have an ongoing need for oriented rock samples from the continental shelf and from greater depths in the open ocean. Deep water drilling has recently received considerable attention under a joint Atlantic Oceanographic Laboratory/Dalhousie University/Atlantic Geoscience Centre program, which enabled drilling to a depth of 1000 m. The electric underwater drill that was used to do this was developed at the Institute several years ago. This drill replaced the hydrostatic one of the later sixties and early seventies. The new drill is connected to the ship by two cables, a buoyant load line, and a buoyant umbilical cable. This system of cables produced two problems at depths over 360 m. Firstly, the cables became entangled and untwisted as the length necessary to reach to sea bottom increased. Secondly, it was difficult to determine where the ship was in relation to the drill on the sea bottorn. The recent success of being able to drill to 1000 m and recover cores from the Mid-Atlantic Ridge area was largely due to the several innovations noted below in acoustic positioning and cable design.

To rectify the problem of knowing the ship's position with respect to the drill, an acoustic positioning system was installed with two points on the ship and one on the drill. The umbilical and load cables were unified into a single high voltage (2400 volts versus the 600 of a normal drill) triaxial cable that carries power and control signals to the drill and engineering data back to the surface. The data telemetry system was constructed under contract by the Nova Scotia Research Foundation. This single cable brought together the load line, power line, and instrument signals. A longer version of this cable will soon be tested to depths of 3500 m. Its successful development will provide more data on the rise and fall of earth plates, age determinations of rocks, and geological information for the offshore survey maps of the continental shelf and Mid-Atlantic Ridge area.



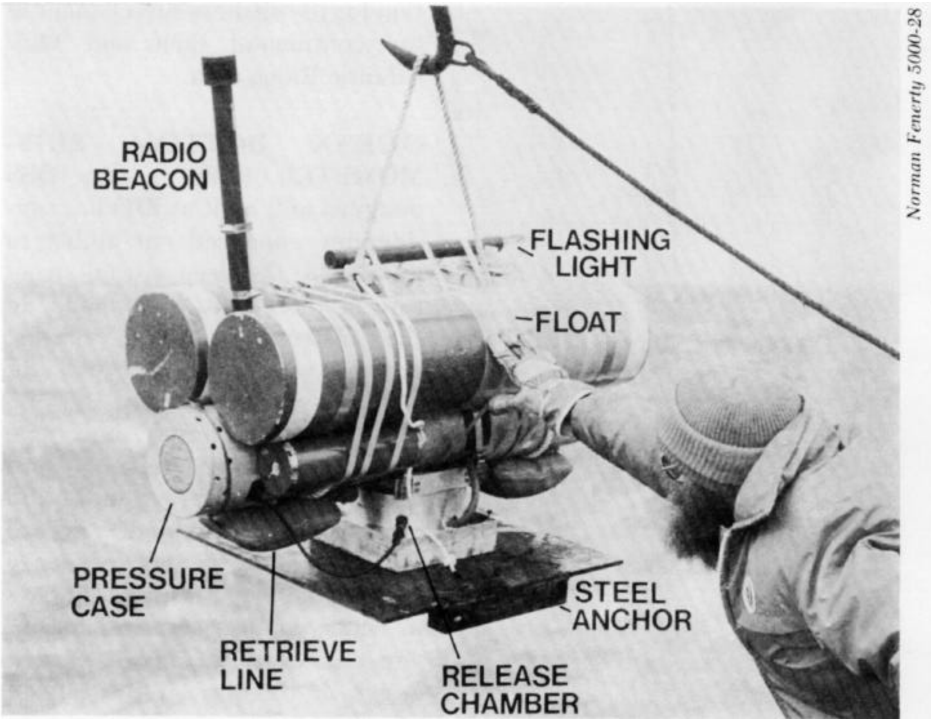
The electric rock core drill.

OCEAN BOTTOM SEISMOMETER (OBS) - An OBS designed and built at BIO has considerably enhanced our ability to investigate the deep crustal structure of the oceans. Geophones in the instrument detect seismic signals, which are recorded for later analysis. Specifically, the OBS uses two geophones and one hydrophone to detect and distinguish compressional and shear wave arrivals and to record seismic waves in the frequency band 4 to 30 Hz for up to ten days in water depths of up to 6000 m. Our OBS evolved from an original design of the Hawaii Institute of Geophysics.

The completely assembled OBS package is shown in the accompanying illustration. It consists of a pressure cylinder that contains the geophones, an electronic package, a tape recorder, a battery pack, an anchor and release mechanism. a floatation sphere, an hydrophone, a pinger, and, for recovery, a flashing light, a radio beacon, and a self-dispensing buoyant line. The line is a novel and convenient accessory for heaving an OBS aboard with little danger of its hitting the ship.

Although earthquakes and microseisms have been successfully recorded with the OBS, the main BIO application of the instrument is to use explosive sound sources to delineate the crustal structure of continental shelves and margins and ocean basins. During 1980, the BIO ocean bottom seismometer was successfully used in a number of major projects including the Lesser Antilles Deep Lithosphere Experiment (LADLE) and the FRAM II experiment. In April 1980 builders and users of OBSs from the U.K., France. Germany, and Japan joined with us in France to intercalibrate the various instruments.

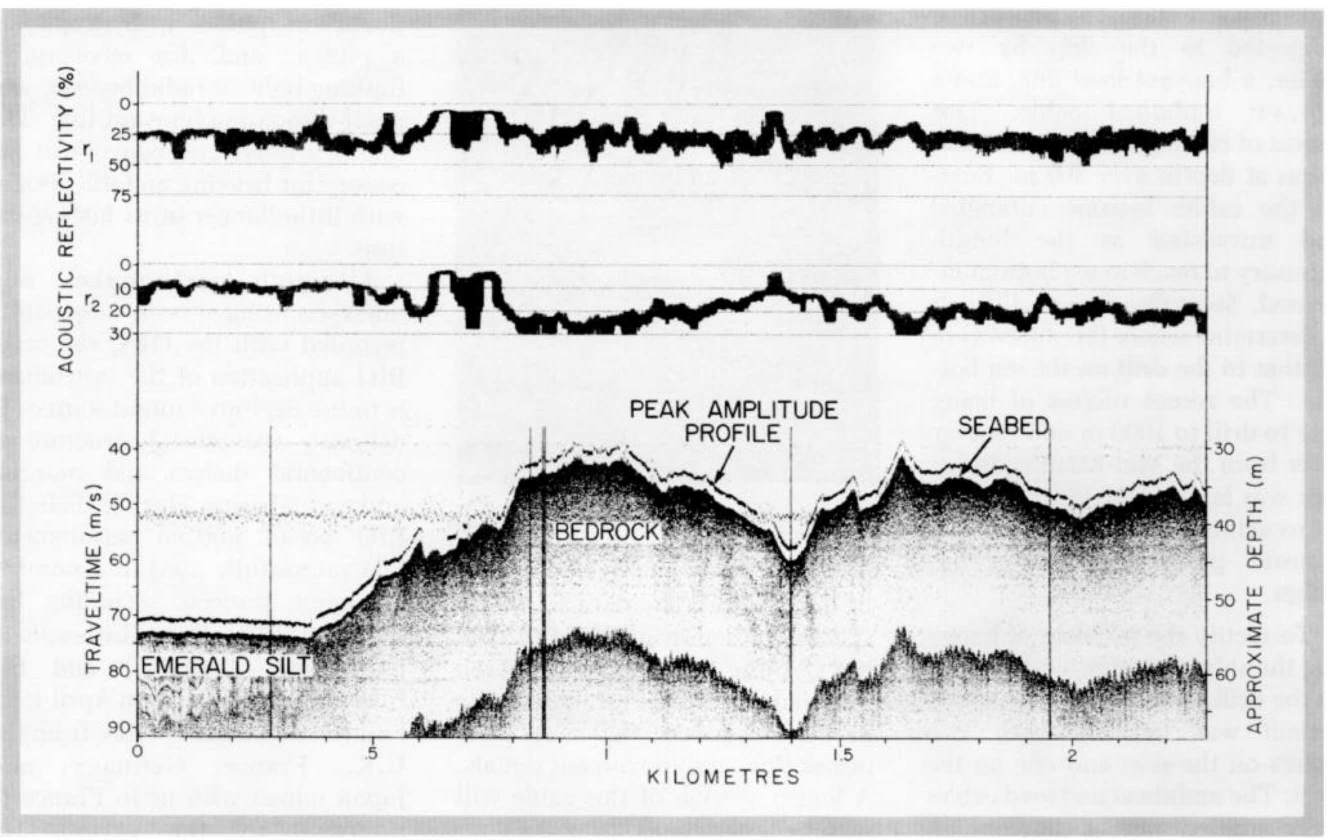
A new release system for BIO's ocean bottom seismometer was successfully used in August 1980 in a



The BIO ocean bottom seismometer.

co-operative project with the Pacific Geoscience Centre of the Canada Department of Energy, Mines and Resources. Six new OBSs are presently under construction and an acoustic command for the new release is being incorporated. The acoustic release will be an essential feature when the OBS is used in the ice infested Beaufort Sea on a project with Dome Petroleum Company scheduled for 1981 to determine the earthquake potential of the area.

HUNTEC DEEP TOWED SEISMIC SYSTEM - The DTS. informally referred to as the "Boomer". was developed specifically for the project SEABED. SEABED is a research project of Huntec ('70) Ltd. of Toronto that is being financed by the federal government to develop a remote method of determining quantitative parameters to characterize the surficial sedimentary units of the sea floor.



A processed seismic reflection profile from the Huntec '70 Ltd. Deep Towed System. The acoustic reflectivities and peak amplitude profile over an outcrop of silt and bedrock are shown. Note that r_1 is a measure of coherently reflected energy from the seabed, r_2 a measure of the scattered energy from the top metre of the seabed.

The equipment has been steadily improved and refined over the review period. The input energy levels have been substantially increased, which significantly improved the acoustic output. Such refinements as moisture detectors, alerting the operator of a possible leak, have improved the reliability on-task; graphic recordings of optimum quality have been produced, and an improved Adaptive Body Motion Compensator that ensures high quality graphics in the heaviest towing weather without operator intervention was introduced.

Work has been completed on an acoustic reflectivity module, which calculates and displays in real time the reflectivity metrics, and yields information about the acoustic hardness and variability of the seabed; this adds measurably to lithologic interpretation. This equipment will soon be tested at sea.

A digital data link has been developed which, by time division multiplexing, permits transmission of up to 16 channels of information from the tow fish to ship via a single coaxial cable or twisted pair. Additional features include the capability to merge the tow fish stream with streams from the ship for positioning and other data as required.

Finally a tow fish positioning system using an ultra-short baseline digital sonar could be fitted to provide precise positioning useful for selecting drilling sites. Such equipment has been designed and a prototype built.

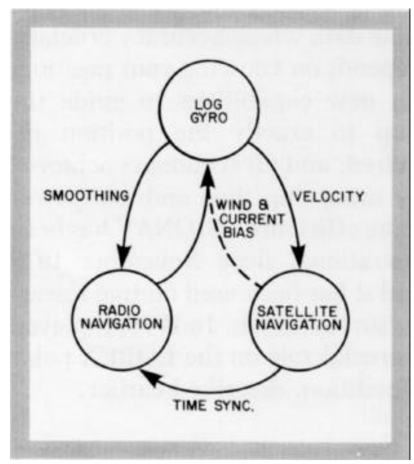
The operational success of the equipment has left open for consideration the possible production of a multidisciplinary platform, which could include sidescan sonar, reflectivity profilers, digital sounders, and the seismic equipment.

HYDROGRAPHY

COMPUTER ASSISTED CARTOGRAPHY - The Canadian Hydrographic Service is actively developing computer applications to make the nautical charts and other service aids that are their responsibility. CHS's four regional offices (of which BIO's hydrography directorate is one) have been directed to establish a computer-assisted cartography function in their region. At BIO, the Graphical On-line Manipulation and Display System (GOMADS) is the key feature of the computer-assisted cartography program. GOMADS enables the cartographer or hydrographer to manipulate a digital chart file in a manner similar to current manual techniques. The system can handle 100,000 soundings, 127 m of curved line, 1000 hydrographic chart symbols, 2000 names, and point-to-point lines. GOMADS users can add, delete, or change features and the corrected information can be redisplayed in seconds. Once the chart information has been digitized and edited in the region, Ottawa headquarters optically plots the final camera-ready artwork preparatory to printing the charts. During 1980, the GOMADS System was successfully used on its first production job - a revision to Chart 4726 covering the Bras d'Or Lakes of Nova Scotia.

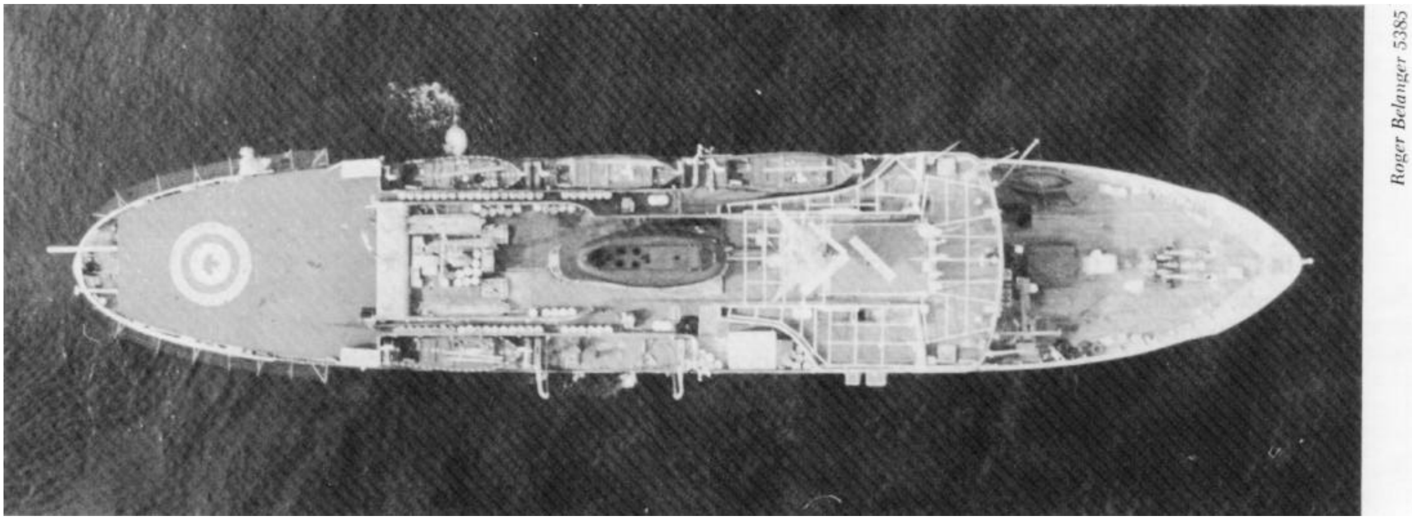
POSITIONING - Before accurate nautical charts can be constructed and before oceanographers can make valid measurements in the ocean, they must know their position at sea. One group in the Canadian Hydrographic Service's Atlantic Region has the job of keeping the Institute on top as far as navigation is concerned. They carry it out, in part, by identifying problem areas and finding solutions and by spotting new developments and bringing them into operation. The Bedford Institute of Oceanography integrated offshore navigation system, or BIONAV, was developed to answer a problem and NAVSTAR is a new satellite navigation tool under development in the U.S. that is of great interest to us.

BIONAV integrates the navigational systems in use at BIO. It was designed to meet BIO's specific needs in navigation as they were defined in a user survey conducted at the start of the BIONAV project. The system is made up of equal parts of computer technology and navigational technology. As a computer software system, BIONAV is about 150 programs, library routines, and procedures totalling about 30,000 lines of code, 95% of which are in the FORTRAN language. These programs operate under the control of the Hewlett Packard Real Time Executive Operating System that has two main functions: to schedule switching from one program to another, a task it performs quickly enough to make it appear to a human as though several programs were running at once, and to communicate between the programs.



To yield optimal positioning of a BIO ship, the BIONAV system combines data from the Transit Satellite Navigation System (Satnav), rho-rho Loran-C, and the ship's speed log and gyro. In BIONAV, the strengths of each system compensate for the weaknesses in the other systems.

As a navigation system. BIONAV accepts inputs from Loran-C in the rho-rho (or range-measuring mode), Transit satellite navigation, speed log, and gyrocompass, and uses the strengths of one system to compensate for the weaknesses of another at any given location. BIONAV can and has easily accepted other inputs such as those from Omega and Decca Navigation Systems and survey positioning systems. BIONAV's advantages in-



CSS *Baffin* is frequently used for hydrographic surveying.

clude, for example: (1) improved capabilities to plot survey data in real time (i.e., while BIONAV is still operating) and to check in real time data whose accuracy crucially depends on knowing your position; (2) new capabilities to guide the ship to exactly the position required; and (3) economies achieved by using ship time and manpower more efficiently. BIONAV has been operational since November 1978 and it has been used on five research/survey vessels. In 1979, it played a crucial role on the LOREX polar expedition, described earlier.

BIO is also evaluating a new satellite navigation system with a view to implementing it between now and 1984. NAVSTAR is being developed by the U.S. to give accuracy to within ten metres for military applications. It will not be fully operational until 1987, and at that time the “precise” code may become classified, leaving civilian users with reduced accuracy on the “clear” mode. But between now and 1987 there will be six out of the eventual 18 satellites in orbit. Normally these give about six hours positioning per day, but we expect that through integration in BIONAV with a cesium clock, and with other lines of position, we should be able to extend accurate, continuous navigation for most of the day for offshore surveys in Baffin Bay, where the alternative of putting in our own Loran-C chain is very expensive. NAVSTAR receivers are still in the development stage, and we will participate in this development, by means of contracts to assess NAVSTAR performance and by developing means of testing NAVSTAR in BIO ships.

chapter 8

Emergencies

BIO stands ready to respond to marine emergencies that may occur in the open northwest Atlantic Ocean, along Canada's Atlantic coast al regions, and in the eastern Canadian Arctic. In all cases, the Institute works hand-in-hand with other federal or local agencies such as the Ministry of Transport who have a direct mandate to deal with emergencies. BIO becomes involved mainly with emergencies that involve spills of oil or chemicals into the ocean and along the shore, and ship founderings or groundings. It would also be called in to assist with any emergency involving the release of radioactive substances in the marine environment. Action taken includes advice given in response to requests for information, or research conducted for the better understanding of the scientific aspects of marine environmental contamination.

The Institute has been involved in such emergencies as the sinking of the tanker *Arrow* in 1970 in Chedabucto Bay, N.S., when some 2.5 million gallons of Bunker-C were spilled; the spill of the *Argo Merchant* off Nantucket in 1977; and the large *Amoco Cadiz* spill off the coast of France in 1978. Though this review period did not include large-scale emergencies such as these above, several incidents that required Institute support were handled as described below.

THE BELLEDUNE PROJECT

In April 1980, it was reported that the concentrations of cadmium in lobsters in the vicinity of Belledune Harbour, N.B., were becoming dangerous to the public's health. As the lobster season was due to start May lst, the Canada Department of Fisheries and Oceans decided to take action; lobster fishing within Belledune Harbour was banned and intensive studies in the Belledune area were begun on the effects of cadmium on lobster. The field program had to be mounted at very short notice.

Several Department laboratories took part; these included the St. Andrews Biological Station, the Atlantic Oceanographic Laboratory, and the Marine Ecology Laboratory. Research was conducted to determine the geographic extent of cadmium contamination in the lobster stocks, gather the data necessary for establishing a safe level, determine the role of currents and ocean circulation in the contamination of the sediments, and evaluate the effects of cadmium on other marine life in the area.

To achieve the objectives, 11 different studies were carried out. These examined the industrial discharge of cadmium from the smelter at Brunswick Smelting, the presence of cadmium in the biota (particularly in the American lobster) in the vicinity, of Belledune Harbour, and the circulation of cadmium in the sediment of the area. The BIO team worked on physical oceanographic (circulation) aspects and the contamination of sediments, water, and suspended matter. The conclusions were that the baghouse dust, which is a by-product of the smelting process, was the largest source of cadmium as it was readily leached by seawater; that the concentration of the contamination decreases seaward and reaches acceptable levels outside the harbour; and that better effluent treatment facilities should lead to an improved marine environment for all biota.

This work is typical of the Institute's ability to respond to emergency situations quickly, and produce data that account for both industrial and environmental concerns.

THE KURDISTAN INCIDENT

The British tanker *Kurdistan*. bound for Sept Isles, Quebec, encountered heavy ice in Cabot Strait on 15 March 1979. Shortly after maneuvering free into heavy seas that night she broke up, spilling about 7,000 tons of bunker-C into the ice infested waters close by the Cape Breton shoreline. The bow and stern sections remained afloat with their tanks intact, although the bow section was without heating to maintain the oil in a liquid state.

Immediately on learning of the tanker disaster, the Bedford Institute of Oceanography mobilized a small group of scientists with experience in oil spill studies and representing a broad range of oceanographic disciplines. Their task was threefold: to provide expert assistance and advice to the Canadian Coast Guard (lead-agency for the *Kurdistan* incident), to act as liaison with the broad range of oceanographic expertise and facilities of the Bedford Institute of Oceanography, and to coordinate any scientific studies or investigations that could be made.

The crew was safely removed by the Coast Guard early on from the stricken tanker, and the two tanker sections more-or-less drifted out of Cabot Strait into the Laurentian Channel. Winter storms persisted for several days, which made towing very difficult. With improvement in the weather, the stern section, still containing the intact part of the cargo, was towed to Port

Roger Belanger 5231-5

Above: *Kurdistan* bow section adrift in Cabot Strait, 17 March, 1979. Below: *Kurdistan* stern section, 17 March, 1979.

Roger Belanger 5231-4

Hawkesbury through Chedabucto Bay where her cargo was offloaded. The bow section, lacking the necessary heating systems to maintain her oil cargo in liquid form and now floating in a vertical position, was ordered sunk. Two possible disposal sites were identified, one at the mouth of the Laurentian Channel and the other south of Sable Island. She was towed across the Scotian Shelf, passing between the Nova Scotia mainland and Sable Island, and was eventually scuttled by naval gunfire off the Scotian Shelf, southeast of Sable Island, in over 2,000 m of water.

The CSS *Hudson*, returning from a survey cruise, was diverted to Chedabucto Bay in preparation for possible more extensive surveys in the area. BIO scientists and support staff were flown aboard by coast guard helicopter and the ship was deployed for a three-day survey following reports of oil along the southeast shore of Cape Breton. This was followed by helicopter assisted oil-in-ice surveys, which confirmed the presence of oil staining. These surveys were later expanded into a hydrocarbon monitoring program for the Scotian Shelf that was carried out in collaboration with the coast guard throughout 1979 and into 1980.

From March 16 until April 2, the BIO response group met on an almost daily basis, including meetings with representatives from the Canadian Coast Guard, Atmospheric Envirornment Service, Fisheries Management, Canadian Wildlife Service, Environmental Protection Service, and Province of Nova Scotia. The BIO response group initiated a number of field studies, including assessment of potential drift trajectories and oil-in-ice interactions; in co-operation with C-CORE (Memorial University of Newfoundland), they organized a scientific workshop to discuss findings and observations made during the *Kurdistan* incident. The activities of the BIO group broadened considerably when the spilled *Kurdistan* oil, which was initially lost from view, began to arrive in significant amounts on the shores of Cape Breton Island and mainland Nova Scotia. Further sampling and field studies were initiated, some of which were eventually grouped into a more formal Scotian Shelf Monitoring Program. Two reports have been published that describe the scientific studies undertaken (see Chapter 9, BIO Technical Reports, Vandermeulen 1980 and Vandermeulen and Buckley 1980).

chapter 9

Charts and Publications of 1979 and 1980

CHART PRODUCTION

The Atlantic Region of the Canadian Hydrographic Service has a staff of 25 cartographers to meet its responsibility for 436 navigational charts covering the region from the Bay of Fundy to the Northwest Passage. Fourteen new charts were under production at December 1980. In addition, 110 of the 120 charts of the Newfoundland area have been updated under the chart maintenance program. The drafting of the new Loran-C lattices for the charts of the Nova Scotia Atlantic coast, the Magdalens, Northumberland Strait, and the Newfoundland and Labrador coasts has been contracted and will be completed in 1981. Apart from the new editions listed below, over 100 reprintings were required during 1979 and 1980 to meet the demand for navigation and fishery charts.

New Charts 1979/80

8015 Funk Island and approaches, Newfoundland
7935 Crozier Strait and Pullen Strait, Little Cornwallis Island

New Editions 1979

4001 Gulf of Maine to Strait of Belle Isle including Gulf of St. Lawrence (Loran-A)
4001 Approaches to Bay of Fundy (Loran-C)
4012 Yarmouth to Halifax (Loran-C plus Decca)
4319 St. John Harbour and Approaches
4622 Cape St. Mary's to Argentia Harbour and Jude Island (Decca)
5001 Labrador Sea - Strait of Belle Isle to Davis Strait (Loran-A plus C)
7010 Davis Strait and Baffin Bay
7011 Hudson Strait to Greenland (Loran-A Plus C)
7220 Lancaster Sound Eastern Approaches
8005 Georges Bank (Loran-C plus Decca)
8006 Scotian Shelf: Browns Bank to Emerald Bank (Loran-C)
8007 Halifax to Sable Island including Emerald Bank and Sable (Loran-C)

New Editions 1980

4001 Gulf of Maine to Strait of Belle Isle including Gulf of St. Lawrence (Loran-C)
4013 Halifax to Sydney (Loran-C)
Halifax to Sydney (Loran-A)
Halifax to Sydney (Decca)
4310 Bedford Basin
4425 Harbours on North Shore - Prince Edward Island
4652 Humber Arm Meadows Pt. to Humber River Newfoundland
5232 Makkalik Bay and Approaches - Labrador
8005 Georges Bank (Loran-C)
8010 Grand Banks Southern Portion (Loran-C)

Large Corrections 1979 (Patches)

4418 Cape Tormentine to Borden - Northumberland Strait
4573 Colliers Bay to Holyroad Bay - Newfoundland
4581 Long Pond - Newfoundland
4665 St. Margarets Bay and Approaches - Newfoundland
4606 St. Barbe Point to Old Ferolle Harbour - Newfoundland
4680 Hawke Bay to Ste. Genevieve Bay including St. John's Bay - Newfoundland
5002 Hudson Strait and Bay

Large Corrections 1980 (Patches)

4015 Sydney to St. Pierre (Decca)
Sydney to St. Pierre (Loran-A)
Sydney to St. Pierre (Loran-C)
4016 St. Pierre to St. John's (Loran-A)
St. Pierre to St. John's (Loran-C)
St. Pierre to St. John's (Decca)
4316 Halifax Harbour
4320 Egg Island to West Iron Bound Island (Decca)
4331 Passamaquoddy Bay and St. Croix River
4614 Argentia Harbour - Newfoundland
4622 Cape St. Mary's to Argentia Harbour and Jude Island (Decca)
4624 Long Island to St. Lawrence Harbours - Newfoundland (Decca)
4625 Burin Peninsula to St. Pierre (Decca)
4626 St. Pierre and Miquelon (Decca)
4722 Terrington Basin - Labrador
7533 Resolute Bay

BIO CONTRIBUTIONS

Contributions by staff of the Atlantic Oceanographic Laboratory, Marine Ecology Laboratory, and Atlantic Geoscience Centre during 1979 and 1980 are included below. A contribution is essentially a scientific article by a staff member that has been published in a journal or other medium with a peer review system. Contribution numbers are given in brackets at the end of each reference.

ADDISON, R.F., ZINCK, M.E., WILLIS, D.E., and DARROW, D.C. 1979. Induction of hepatic mixed function oxidases in trout by polychlorinated biphenyls and butylated monochlorodiphenyl ethers. Toxicology *and Applied Pharmacology 49:* 245-248. (921)

BANKE, E.G., SMITH, S.D., and ANDERSON, R.J. 1979. Drag coefficients at AIDJEX from sonic anemometer measurements. *In* Sea Ice Processes and Models. Proceedings of the Arctic Ice Dynamics Joint Experiment International Commission on Snow and Ice Symposium, *ed.* R.S. Pritchard. University of Washington Press, Seattle, Washington: 430-442. (853)

BARSS, M.S., BUJAK, J.P., and WILLIAMS, G.L. 1979. Palynological zonation and correlation of sixty-seven wells, eastern Canada. *Geological Survey of Canada, Paper 78-24:* 117 pp. (920)

BEAMISH, P. 1979. Behavior and significance of entrapped baleen whales. *Behavior of Marine* Animals 3: 291-309. (843)

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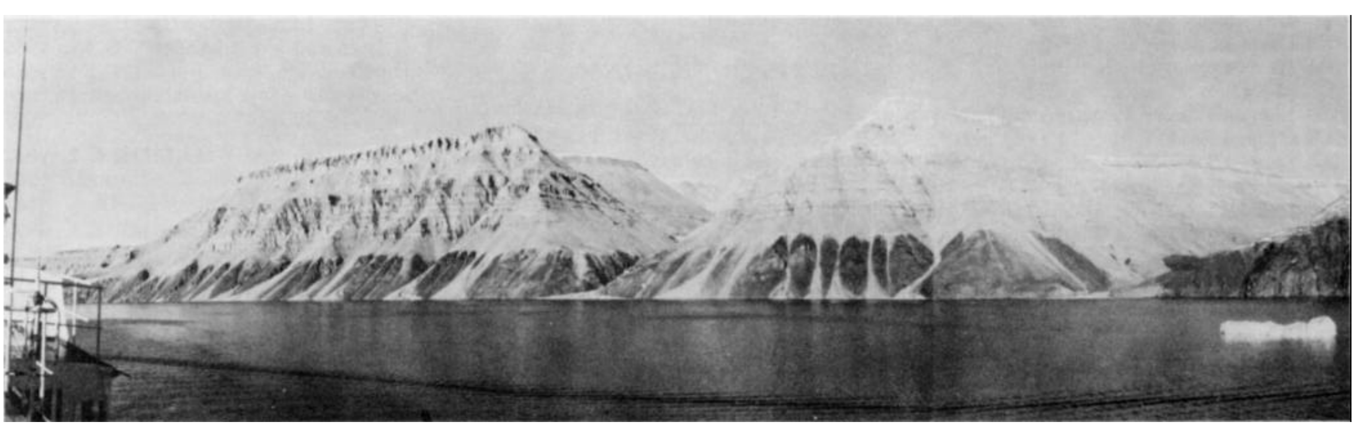

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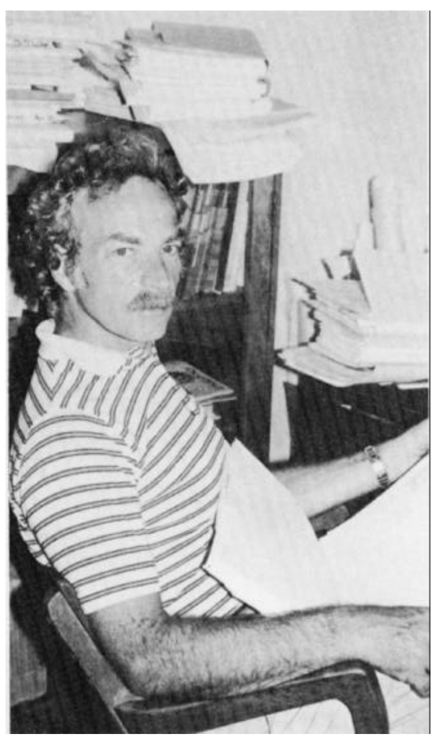

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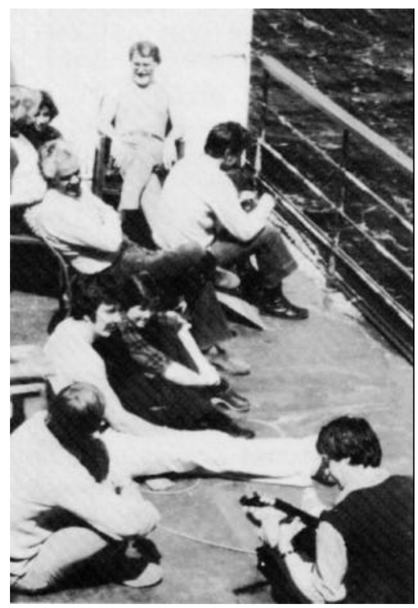

Alan Longhurst

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chapter 10

Cruises of 1979 and 1980*

CSS HUDSON

- The CSS *Hudson* is a diesel-electric driven ship equipped and used for multidisciplinary research projects.

- Vital Statistics - Lloyds Ice Class I hull . . . built in 1963 . . . 90.4 m long (LOA) . . . 15.3 m beam . . . 6.3 m maximum draft . . . 4,870 tonne displacement . . . 3,721 gross registered tons . . . speed full of 17 knots . . , 13 knot cruising speed . . . 15,000 n. mile (50 day) endurance . . . scientific complement of 25 . . . 204 m^2 space in four laboratories . . . two HP 2100 and one PDP 8E computers . . . helipad and hangar.

- 224 days away from BIO in 1979, 226 in 1980.

- 21,214 n. miles steamed in 1979, 37,180 in 1980.

Roger Belanger 4926-C-28

CRUISE YEAR - NUMBER	CRUISE DATES	OFFICER IN CHARGE	AREA OF OPERATION	CRUISE OBJECTIVES
79-00 1	Jan 8 to Feb 3	C.K. Ross, AOL	Flemish Cap	Set subsurface moorings; run CTD survey
79-001	Feb 5 to Mar 31	B.A. Paul, DFO, St. John's, Nfld.	Hamilton Bank southward	Fisheries surveillance
79-006	Apr 18 to May 3	R.J. Conover, MEL	Coastal Shelf & Slope Water, south of Halifax	Study plankton production processes during spring phytoplankton bloom
79-011	May 14 to 24	D.L. McKeown, AOL	Gulf Stream, Scotian Shelf, Grand Banks	Various equipment trials
79-011	May 24 to Jun 8	L.H. King, AGC	Southern Grand Banks, Scotian Shelf	Bedrock sampling, profiling, sidescan testing, etc.
79-013	Jun 18 to Jul 10	S.P. Srivastava, AGC	Off Greenland Coast	Seismic refraction surveying
79-017	Jun 13 to Jul 31	C.T. Schafer, AGC	West of Orphan Knoll, Nfld.	Marine geological process studies
79-018	Jul 22 to Aug 6	G. Vilks, AGC	Off Hamilton Inlet, Labrador	Marine geological process studies
79-019	Aug 9 to 22	R.H. Fillon, AGC	Saglek Bank, Labrador	Marine geological process studies
79-020	Aug 27 to 31	J.R.N. Lazier, AOL	Hamilton Bank	Physical oceanographic studies
79-025	Sep 7 to Oct 5	R. Reiniger, AOL	Gulf Stream, Azores	Recovery/placement of moorings; run CTD lines; engineering evaluations
80-010	Apr 21 to May 20	G.B. Fader, AGC	Scotian Shelf, Grand Banks, NE Nfld. Shelf	Geological/geophysical surveys

*Some of the abbreviations used in this chapter are: AGC - Atlantic Geoscience Centre, AOL - Atlantic Oceanographic Laboratory, Hydrography - Atlantic Region of Canadian Hydrographic Service, MFD - Marine Fish Division, MEL - Marine Ecology Laboratory, NB - New Brunswick, Nfld. - Newfoundland, NS - Nova Scotia, NSRF - Nova Scotia Research Foundation, U - University, and UQAR - Universite de Quebec a Rimouski.

80-016	May 26 to Jun 27	D.L. McKeown, AOL	Sohm Abyssal Plain, Mid-Atlantic Ridge	Co-operative AOL-AGC-Dalhousie University studies & equipment trials
80-026	Jul 14 to 24	J.R.N. Lazier, AOL	Hamilton Bank, Labrador Sea	Continuation of long-term mooring program
80-027	Jul 24 to Sep 2	T.C. Platt, MEL	Various eastern Arctic sites	Arctic ecological/biological studies
80-028	Aug 29 to Oct 10	B. MacLean, AGC	Baffin Bay & Davis Strait	Various geological-geophysical-chemical oceanographic studies
80-035	Oct 10 to 26	G. W. Henderson, Hydrography	Davis Strait, Labrador Sea	Multidisciplinary hydrographic-geophysical surveys
80-037	Oct 26 to Nov 2	J.R.N. Lazier, AOL	Hamilton Bank, Labrador Sea	Continuation of long-term mooring program

CSS BAFFIN

Roger Belanger

- The CSS *Baffin* is a diesel-driven ship equipped for hydrographic surveying but also used for general oceanography.

- Vital Statistics - Lloyds Ice Class I hull . . . built in 1956 . . . 87 m long (LOA) . . . 15 m beam . . . 5.7 m maximum draft . . . 4,011 tonne maximum displacement . . . 3,460 gross registered tons . . . speed full of 15.5 knots . . . 13 knot cruising speed . . . 14,000 n. mile (45 day) endurance . . . scientific complement of 29 . . . drafting, plotting, computing, and laboratory spaces provided . . . helipad and hangar.

- 133 days away from BIO in 1979, 176 in 1980.

- 15,232 n. miles steamed in 1979, 18,312 in 1980.

CRUISE YEAR - NUMBER	CRUISE DATES	OFFICER IN CHARGE	AREA OF OPERATION	CRUISE OBJECTIVES
79-015	Jun 29 to Jul 23	D.D. LeLievre, Hydrography	Labrador Coast	Hydrographic surveying & miscellaneous work
79-015	Jul 24 to Sep 7	M.G. Swim, Hydrography	Ungava Bay	Hydrographic surveying & miscellaneous work
79-015	Sep 8 to Oct 26	G. W. Henderson, Hydrography	Davis Strait	Hydrographic-geophysical surveys
80-014	May 5 to Sep 29	V.J. Gaudet, Hydrography	Ungava Bay, Labrador Coast	Hydrographic surveying-charting, multidisciplinary surveys
80-031	Oct 2 to Nov 6	G, W. Henderson, Hydrography	Labrador Sea, Davis Strait	Hydrographic survey program

Roger Belanger 6121-2

Adam Kerr.

Charles Ross 6069-9

Jim Galliott aboard *Pandora II.*

Roger Belanger 60.1

Charles Stirling.

Roger Belanger 3394-7

CSS DAWSON

- The CSS *Dawson* is a diesel-driven ship equipped and used for multipurpose oceanographic research especialiy over the continental shelf.
- Vital Statistics - built in 1967 . . . 64.5 m long (LOA) . . . 12 m beam . . . 4.9 m maximum draft . . . 2,006 tonne displacement . . . 1,311 gross registered tons . . . speed full of 15.5 knots . . . 13 knot cruising speed . . . 12,000 n. mile (45 day) endurance . . . scientific complement of 13 . . . 87.3 m^2 space in four laboratories . . . computer suite provided.
- 215 days away from BIO in 1979, 248 in 1980.
- 27,875 n. miles steamed in 1979, 30,905 in 1980.

CRUISE YEAR - NUMBER	CRUISE DATES	OFFICER IN CHARGE	AREA OF OPERATION	CRUISE OBJECTIVES
79-002	Mar 5 to 14	D.E.T. Bidgood, NSRF	Scotian Shelf, Slope	Seismic surveys, piston coring
79-003	Mar 19 to 24	B.T. Hargrave, MEL	Emerald Bank, Scotian Shelf and Slope	Water column variable measurements, gas and nutrient exchange in sediment studies
79-004	Mar 29 to Apr 21	C.L. Amos, AGC	Bay of Fundy, Chignecto Bay	Study of seasonal variations in various parameters
79-005	Apr 8 to 21	R.O. Fournier, Dalhousie University	Scotian Shelf, South of Sable Island	Plankton studies
79-007	Apr 24 to May 1	P.C. Smith, AOL	Cape Sable area, N.S.	Cape Sable experiment
79-007	May 1 to 6	J.N. Smith, AOL	Bay of Fundy	Establish baseline radionuclide and trace metal levels near Pt. Lepreau, NB
79-010	May 14 to 18	G. Bugden, AOL	Gulf of St. Lawrence north coast	Various physical oceanographic and biological studies
79-010	May 19 to 27	M.I. El Sabh, UQAR	As above	As above
79-010	May 27 to Jun 8	J.B. Lewis, McGill U.	As above	As above
79-012	Jun 18 to 29	C. Boyd, Dalhousie U.	Scotian Shelf, Sargasso Sea	Studies of marine zooplankton grazing
79-016	Jul 5 to 22	C.K. Ross, AOL	Flemish Cap	Mooring recovery and setting; conduct CTD survey; other studies
79-021	Jul 23 to 29	R.O. Fournier, Dalhousie University	Laurentian Channel, Scotian Shelf area	CTD measurements, bottle sampling, and net towing
79-022	Aug 6 to 10	P.C. Smith, AOL	Cape Sable area, NS	Cape Sable experiment
79-023	Aug 11 to 19	D.C. Gordon, MEL	Bay of Fundy	Multidisciplinary studies of upper reaches of Bay
79-024	Aug 24 to Sep 9	P.A. Yeats, AOL	Gulf of St. Lawrence area	Studies of trace metals and organic carbon
79-026	Sep 22 to Oct 1	G.H. Seibert, AOL	Saguenay fjord and estuary	Physical oceanographic studies
79-027	Oct 15 to 24	P.C. Smith, AOL	Cape Sable area, NS	Cape Sable experiment
79-028	Oct 24 to 28	J.N. Smith, AOL	Bay of Fundy	Establish baseline radionuclide and trace metal levels near Pt. Lepreau, NB
79-029	Nov 5 to 9	R.O. Fournier, Dalhousie University	Cape Sable, Bay of Fundy	Plankton tows, bottle casts, CTD surveys
79-030	Nov 26 to 30	T.R. Foote, AOL	Gulf of St. Lawrence	Annual ice forecasting
79-030	Dec 6 to 11	T.R. Foote, AOL	As above	Recovery/setting of current meter moorings

79-031	Nov 14 to 22	N.S. Oakey, AOL	Shelf east of Emerald Basin	Study near surface temperature and velocity variability
79-032	Nov 30 to Dec 7	R. de Ladurantaye, Hydrography (Quebec)	St. Lawrence Estuary	Miscellaneous hydrographic/biological studies
79-034	Oct 28 to Nov 10	D.C. Cordon, MEL	Bay of Fundy area	Multidisciplinary studies of upper reaches
80-001	Jan 2 to Feb 7	C.E. Keen, AGC	Western Atlantic south of Bermuda	Carry out LADLE project with RRS *Discovery*
80-003	Feb 15 to 22	C.L. Amos, AGC	Bay of Fundy	Study of seasonal variations of various parameters
80-004	Feb 25 to Mar 7	D.E.T. Bidgood, NSRF	Scotian Shelf	Miscellaneous studies
80-005	Mar 11 to 17	R.O. Fournier, Dalhousie University	Scotian Shelf	Miscellaneous studies
80-005	Mar 18 to 23	G.C.H. Harding, MEL	Shelf & slope water, SE of Halifax	Various biological studies
80-006	Mar 25 to Apr 3	P.C. Smith, AOL	Cape Sable area, NS	Cape Sable experiment
80-007	Apr 9 to 17	C.L. Tang, AOL	NW Gulf of St. Lawrence	Physical oceanographic studies
80-008	Apr 17 to 21	G. Bugden, AOL	Gulf of St. Lawrence	Physical oceanographic studies
80-012	Apr 26 to May 6	R.F. Reiniger, AOL	Eastern Gulf Stream	Recover/set moorings; miscellaneous tests
80-015	May 22 to 29	P. Kingston, AOL	Placentia Bay, Nfld.	Testing of new electric rock core drill
80-017	Jun 2 to 9	C.L. Amos, AGC	Bay of Fundy	Miscellaneous geological studies
80-018	Jun 9 to 14	J.N. Smith, AOL	Bay of Fundy	Establish baseline radionuclide and trace metal levels near Pt. Lepreau, NB
80-019	Jun 18 to Jul 3	B. Petrie, C.K. Ross, AOL	Avalon Channel, Flemish Cap	Physical oceanographic & hydrographic studies
80-020	Jul 7 to 21	R.O. Fournier, Dalhousie University	Scotian Shelf	Miscellaneous studies
80-021	Jul 23 to Aug 1	B. Petrie, AOL	Strait of Belle Isle	Set moorings; conduct CTD survey; track surface drogues
80-022	Aug 21 to 29	P.C. Smith, AOL	Cape Sable area, NS	Cape Sable experiment
80-029	Sep 4 to 22	R.A. Clarke, AOL	South and east of Grand Banks	Recover/set moorings; conduct CTD survey
80-030	Sep 23 to Oct 3	M.J. Keen, AGC	Nfld. Coast	Various geological/geophysical studies
80-032	Oct 7 to 14	G. W. Henderson, Hydrography	Labrador Sea, Davis Strait	Multidisciplinary hydrographic/geophysical surveys
80-033	Oct 15 to 23	B. Petrie, AOL	Strait of Belle Isle	Recover moorings; conduct hydrological survey of Strait & Avalon Channel
80-034	Oct 24 to 30	B. Petrie, AOL	As above	As above
80-038	Nov 3 to 8	T.R. Foote, AOL	Shelf Edge, Cape Sable, NS	Set moorings, service guard buoys
80-039	Nov 13 to 22	J.A. Elliott, AOL	Scotian Shelf edge	Study internal tides and turbulent mixing
80-04 1	Nov. 26 to Dec. 3	T.R. Foote, AOL	Gulf of St. Lawrence	Recover/set moorings

Roger Belanger 6112

Lifeboat drill for CSS Dawson off BIO jetty.

CSS MAXWELL

- The CSS *Maxwell* is a diesel-driven ship equipped and used for inshore hyrdrographic surveys.
- Vital Statistics - built in 1962 . . . 35 m long (LOA) . , . 7.6 m beam . . . 2.4 m maximum draft . . . 280 tonne displacement , . . 262 gross registered tons . . . speed full of 12.6 knots . . . 10 knot cruising speed . . . 2,700 n. mile (10) day) endurance . . . scientific complement of 7 . . . drafting and plotting facilities.
- 171 days away from BIO in 1979. 194 in 1980.
- 7,908 n. miles steamed in 1979, 14,597 in 1980.

Roger Belanger 2637-2

CRUISE YEAR - NUMBER	CRUISE DATES	OFFICER IN CHARGE	AREA OF OPERATION	CRUISE OBJECTIVES
79-008	Apr 30 to Oct 25	V.J. Gaudet, M.G. Swim, Hydrography	Bay of Fundy, Labrador Coast, Fortune Bay, Nfld.	Hydrographic surveying and charting
79-035	Oct 31 to Nov 7	R.M. Eaton, Hydrography	Coastal NS	Loran-C calibrations in coastal waters
80-009	Apr 17 to May 1	R.M. Eaton, Hydrography	Bay of Fundy, Nfld. & NS Shores	Standard charting and Loran-C calibration
80-013	Apr 30 to Nov 2	R.M. Cameron, Hydrography	Bay of Fundy (NB), Notre Dame Bay (Nfld.)	Standard charting
80-025	Jul 7 to 15	R.M. Eaton, Hydrography	Nfld. & Cape Breton, NS	Standard charting and Loran-C calibration

OTHER BIO CRUISES

CRUISE YEAR - NUMBER + VESSEL	CRUISE DATES	OFFICER IN CHARGE	AREA OF OPERATION	CRUISE OBJECTIVES
79-09 *Meta*	May 9 to Oct 22	E.J. Comeau, Hydrography	Northumberland Strait, Nfld.	Hydrographic charting
79-014	Jul 19 to Sep 23	V.J. Gaudet, Hydrography	Eastern Arctic	As above
79-051 *Navicula*	Apr 23 to Nov 2	R.W. Sheldon, MEL	St. Georges Bay, NS	Ecological studies
79-052 *Hart*	May 3 to 13	D. Conrad, J. Moffat, AOL	Chedabucto Bay and area	Study oil in water column from *Kurdistan* spill
79-053 *Alert*	May 7 to 12	C.C. Cunningham, AOL	Scotian Shelf	Establish extent of pollution from *Kurdistan* spill
79-054 *Daring*	Jun 1 to 7	E.M. Levy, AOL	Sable Island Bank	Investigate fate of oil from *Kurdistan*
79-055 *Alert*	Jun 4 to 12	E.M. Levy, D.J. Lawrence, AOL	Scotian Shelf	As above
79-058 *Lacuna*	Dec 5 to Jan 15	E.M. Levy, AOL	NS Coast - Halifax to Sydney	As above
79-059 *Alert*	Dec. 14 to 21	E.M. Levy, AOL	Scotian Shelf	As above
80-011 *Gulf Star*	Jul 22 to Oct 18	G. Rockwell, Hydrography	Notre Dame, Bay, Nfld.	Standard hydrographic charting
80-036 *Pandora II*	Oct 19 to 29	R.M. Eaton, Hydrography	Canso area, NS	Calibrate Loran-C
80-040 *Pundora II*	Oct 8 to 16	F. Medioli, Dalhousie University	Scotian Shelf area	Geological studies

80-051 *Navicula*	May 2 to 12	J. Butters, AOL	Belledune, NB	Bottom sampling, CTD profiling, setting moorings
80-052 *Alert*	May 30 to Jun 1	E.M. Levy, D.J. Lawrence, AOL	Scotian Shelf, Halifax to *Kurdistan* Bow Site	Oil sampling
80-053 *Various Vessels*	Jul 10 to Sep 27	D.D. LeLievre, Hydrography	Eastern Arctic	Hydrographic charting

LADY HAMMOND

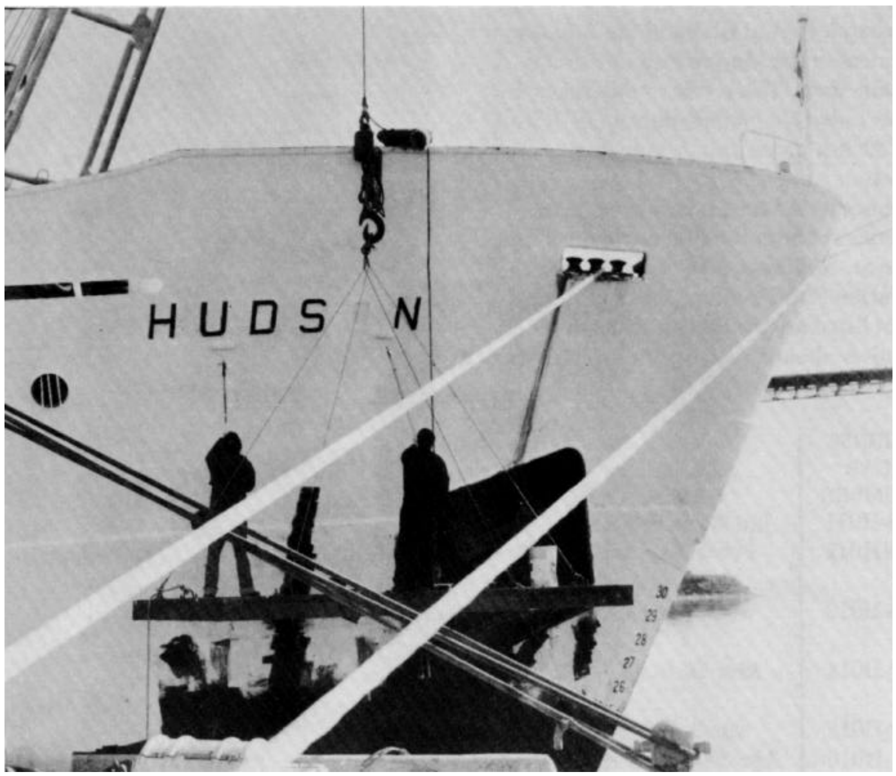
The *Lady Hammond* is a converted fishing trawler with an overall length of 58 m and a gross tonnage of 897 tonnes. The vessel has become part of the research fleet at BIO and the BIO component of the Marine Fish Division is its main user. The cruises undertaken by the *Lady Hammond* during 1979 and 1980 are given below and in the next section the Division's co-operative cruises with USSR vessels are presented. Cruises of both the BIO component and the St. Andrew's, NB, component of the Marine Fish Division (MFD) are listed. Not listed are the Marine Fish Division's cruises aboard vessels that are only irregularly berthed at BIO.

Heinz Wiele 6119-3,8

CRUISE YEAR - NUMBER	CRUISE DATES	OFFICER IN CHARGE	AREA OF OPERATION	CRUISE OBJECTIVES
79-H011	Jan 23 to Feb 2	R. Mohn	Emerald Bank	Standard ichthyoplankton survey
79-H012	Feb 12 to 19	R. O'Boyle	Chebucto Head and Emerald Basin	Batfish gear tests
79-H013	Mar 5 to 13	R. Dufour	Bay of Fundy - Scotian Shelf	Spring groundfish inventory
79-H014	Mar 20 to 29	J.S. Scott	Scotian Shelf - Sydney Bight	Spring groundfish inventory
79-H015	Apr 2 to 25	S. Bonnyman	Scotian Shelf	Standard ichthyoplankton survey
79-H016	Apr 30 to May 4	J. Carrothers	Emerald Bank	Gear tests
79-H017	May 7 to 9	D. Waldron	Chebucto Head	Observer training
79-H018	May 14 to Jun 1	J. Reid	Scotian Shelf	Standard ichthyoplankton survey
79-H020	Jul 6 to 14	R.G. Halliday	Bay of Fundy - Scotian Shelf	Comparative fishing experiment with A.T. *Cameron*
79-H021 to H023	July 17 to Sep 6	-	Scotian Shelf	Scheduled programs aborted for extensive emergency repairs to the main trawl winch. Cruises 21, 22, and 23 were essentially winch trials.
79-H024	Sep 11 to 21	W.D. Smith	Southern Gulf of St. Lawrence	Cod migration study
79-H025	Sep 24 to Oct 12	R. O'Boyle	Scotian Shelf	Standard ichthyoplankton survey
79-H026	Oct 15 to 26	P. Koeller	Scotian Shelf	Autumn groundfish inventory
79-H027	Oct 29 to Nov 8	K. Waiwood	Scotian Shelf	Autumn groundfish inventory
79-H028	Nov 13 to Dec 5	J. Maguire	Scotian Shelf	Standard ichthyoplankton survey
80-H030	Jan 14 to 23	T. Kenchington	Roseway Basin	Redfish survey
80-H031	Jan 29 to 31	P. Koeller	Bedford Basin	Boris trawl gear tests
80-H033	Mar 5 to 14	J.S. Scott	Scotian Shelf (Sambro Bank - Sydney Bight)	Spring groundfish survey
80-H034	Mar 17 to 27	N.J. McFarlane	Scotian Shelf (Western Bank - Bay of Fundy)	Spring groundfish survey
80-H035	May 5 to 30	J. Reid	Scotian Shelf	Standard ichthyoplankton survey
80-H036	Jun 2 to 13	M. Sinclair	Scotian Shelf	Standard ichthyoplankton survey
80-H037	Jul 7 to 15	P. Koeller	Bay of Fundy - Scotian Shelf	Comparative fishing experiment with A.T. *Cameron*

80-H038	Jul 17 to 27	J. Hunt	Scotian Shelf - Sydney Bight	Same
80-H039	Aug 1 to 25	Joint cruise MFD-MEL	Southwestern Nova Scotia	Herring acoustical survey methodology
80-H041	Sep 2 to 28	R. O'Boyle	Emerald Bank	Silver hake patch study
80-H042	Sep 30 to Oct 10	J.S. Scott	Bay of Fundy - Scotian Shelf	Autumn groundfish inventory
80-H043	Oct 16 to 24	D.N. Fitzgerald	Scotian Shelf - Scotian Bight	Same
80-H044	Oct 28 to Nov 11	J.J. Hunt	Scotian Shelf	International young gadoid pelagic trawl gear tests
80-H045	Nov 17 to Dec 19	G. Young	Scotian Shelf	Standard ichthyoplankton survey

Ships need constant maintenance.



Roger Belanger 5918-3

CO-OPERATIVE CRUISES

The Marine Fish Division participated in co-operative cruises during 1979 and 1980 aboard the following USSR research vessels: *Viandra* (VN), *Argus* (AR), 60 *Let* (LE), and *Antares* (AN).

CRUISE YEAR - NUMBER	CRUISE DATES	OFFICER IN CHARGE	AREA OF OPERATION	CRUISE OBJECTIVES
79-VN01	Aug 3 to 19	J. Reid	Scotian Shelf	Standard ichthyoplankton survey
79-VN02	Aug 22 to Sep 11	B. Wood	As above	As above
79-VN03	Sep 12 to Oct 1	G . Donaldson	As above	Silver hake feeding study
79-VN04	Oct 2 to 29	A. Sinclair, B. Wood	As above	Juvenile silver hake survey
80-AR01	Aug 22 to Sep 2	J. Reid	As above	Standard ichthyoplankton survey
80-AR02	Sep 3 to 29	Y. de Lafontaine	As above	As above
80-AR03	Sep 30 to Oct 14	K. Zwanenburg	As above	As above
80-AR04	Dec 2 to 7	B. Wood	Emerald Basin	Silver hake late season survey
80-LE01	Aug 12 to Sep 2	As above	Scotian Shelf	Standard ichthyoplankton survey
80-LE02	Sep 3 to 24	As above	As above	As above
80-LE03	Sep 26 to Nov 3	P. Koeller, B. Wood	As above	Juvenile silver hake survey
80-AN01	Oct 1 to Nov 26	R. Sciocchetti, J. Spry	As above	Saury research and exploratory fishing

chapter 11

Organization and Staff

BIO is a research institute of the Government of Canada operated by the Department of Fisheries and Oceans (DFO), both on its own behalf and for the other federal departments that maintain laboratories and groups at BIO. Research, facilities, and services at BIO are co-ordinated by a series of special and general committees.

BIO also houses the offices of the Northwest Atlantic Fisheries Organization (Executive Secretary - Captain J.C.E. Cardoso); the analytical laboratories of the Department of the Environment's (DOE) Environmental Protection Service (Dr. H.S. Samant); and the Atlantic regional office of the Resource Management Branch of the Department of Energy, Mines and Resources (DEMR) (Mr. T.W. Dexter). In leased accommodation at BIO are the following marine-science related private companies: Huntec Ltd., Wycove Systems Ltd., and Franklin Computers Ltd.

We present below a partial list of the 801 staff employed at BIO (as at December 1980), along with the organizational structure of the Institute and telephone numbers for the various components. (NOTE: Nova Scotia's area code is 902, the BIO exchange 426). Also included is a list of some of the work undertaken by BIO staff during 1979 and 1980 on behalf of national and international committees and organizations.

OCEAN SCIENCE AND
SURVEYS, ATLANTIC (DFO)

A.R. Longhurst
Director-General 3492

J. Brooke (BIOMAIL) 3698
C.E. Murray (P.R.) 3251
H.B. Nicholls
Program Anal. & Co-ord 3246

Management Services
G.C. Bowdridgc, Manager 6166

Admimistrative Services
M. C. Bond. Head
Q.V. Ackcr

Financial Services
E. E. McMullin, Head
E. Pottie

Materiel Management Services
A.R. Mason, Head
B. V. Anderson
B.G. Martin

Personnel Services 2366
J.G. Feetham, Manager
R.R. Edwards
F.G. MacLaren
G. Joly

Atlantic Oceanographic Laboratory
G.T. Needler, Director 2366

Chemical Oceanography
J.M. Bewers, Head 2371
J.L. Barron
A.R. Coote
C.C. Cunningham
K. Ellis
T. Fu
R.S. Hiltz
E.P. Jones
J.D. Leonard
E.M. Levy
G. Lord
J. Pempkowiak
R. Pocklington
J.N.B. Smith
M. Stoffyn
P.M. Strain
F.C. Tan
P.A. Yeats

Coastal Oceanography
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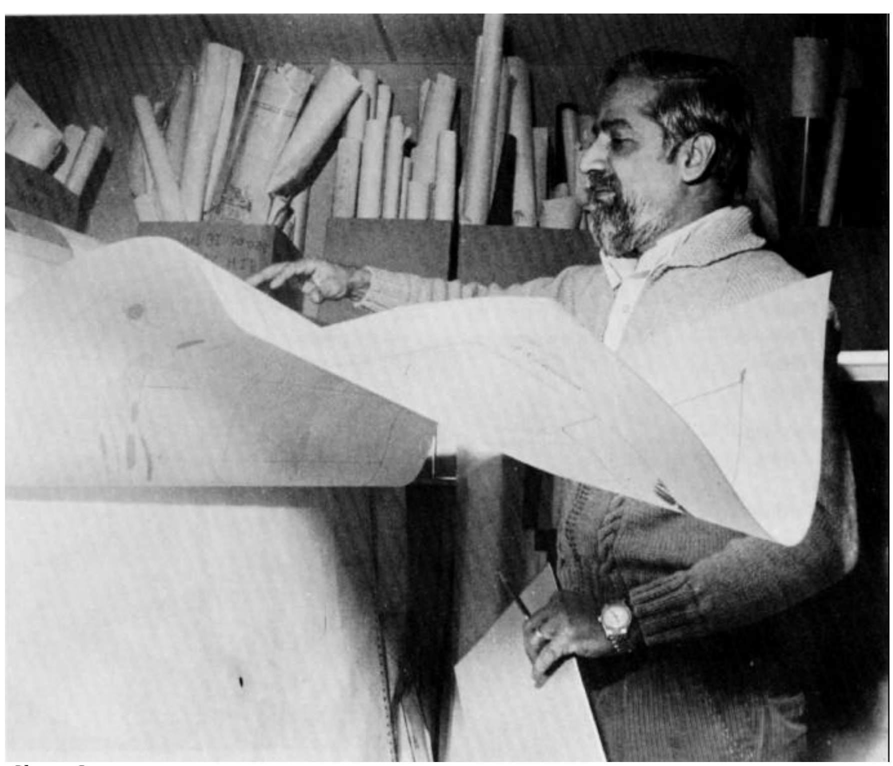
G. Bugden
P. d'Entremont
D. Dobson
T.R. Foote
D. Greenberg
D.N. Gregory
F. Jordan
K. Kranck
D.J. Lawrence
R. Lively
H.J.A. Neu
A.J. Hartling
B.D. Petrie
J.W. Pritchard
W. Richard
G.H. Seibert
P.C. Smith
C.L. Tang

Metrology
D.L. McKeown, Head 3489
A.S. Bennett
J.J. Betlem
R. Cassivi
N.A. Cochrane
G.F. Connolly
J.-G. Dessureault
G.A. Fowler
D.R. Harvey
A.W. Herman
K.D. Hill
P.F. Kingston
D.F. Knox
M. Mitchell
M. Stepanczak
W.J. Whiteway
S.W. Young

Ocean Circulation
J.A. Elliott, Head 2502
R.J. Anderson
R. Branton
D. Lefaivre
N.S. Oakey



Roger Belanger 5861-12

Shiri Srivastava.

B.D. Carson
R.A. Clarke
F.W. Dobson
S.J. Glazebrook
W.B. Greifeneder
R.M. Hendry
J.R.N. Lazier
P. Pozdnekoff
C. Quon
R.F. Reiniger
C.K. Ross
H. Sandstrom
S.D. Smith
K.T. Tee

Atlantic Region
Canadian Hydrographic Service
A. Kerr, Director 3497

Field Surveys
T.B. Smith, Head 2432

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S.S. Dunbrack
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V.J. Gaudet
J.E. Goodyear
R.P. Haase
M.A. Hemphill
C.W. Henderson
D.D. LeLievrc
P.L. McCarthy
R.D. Mehlman
G. Rockwell
G. Rodgcr
C.S. Stirling
M.G. Swim
R.L. Tracey
H.P. Varma

Chart Production
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E.N. Lischenski
B.E. McCorriston
F.S. Miller
S.L. Weston

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S.R. Forbes
K.T. White

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S.T. Grant
N.H.J. Stuifbergen

Planning and Records
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G.H. King

Tidal
D.I. DeWolfe, Head 3846

C.T. O'Reilly

Marine Ecology Laboratory
K.H. Mann, Director 3696

Biological Oceanography
T.C. Platt, Head 3793

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J.J. Cullen
S.R.V. Durvasula
W.B. Fraser
W.G. Harrison
E.J.H. Head
M. Hodgson
E.P.W. Horne
B.D. Irwin
W.K. Li
M.A. Paranjape
D.D. Sameoto
J.C. Smith

Environmental Quality
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P.G. Wells
J.J. Wrench
D.E. Willis
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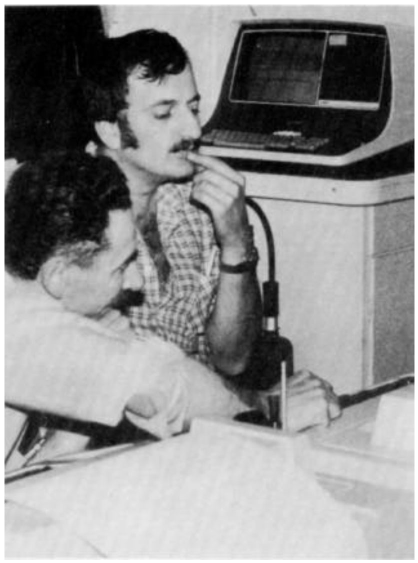
Fisheries Oceanography
R.W. Sheldon, Head 3270

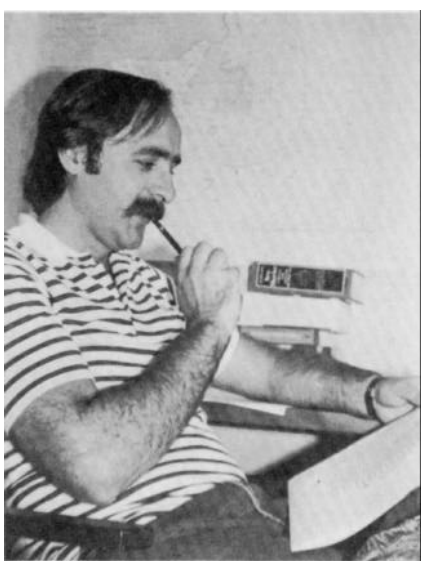


Charles Ross 6069-16

Peter Pozdnekoff and Larry Bellefontaine aboard *Pandora II.*

Tim Lambert 6068-19

Peter Vass.



Roger Belanger 6085-13

J.J. Maguire.

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R.G. Dowd
K.F. Drinkwater
R.C. Edmonds
K.R. Freeman
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T.C. Lambert
J. McRuer
R. Shotton
W.L. Silvert
W.H. Sutcliffe
C.B. Taylor
R.W. Trites
D.M. Ware

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R.L.G. Gilbert, Manager

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D. F. Dinn, Head 3700

G.E. Await, C.R. Caldwell, M. Chin-Ye, T. Clarke, C. Cooke, J.R. Cournoyer, G. Dcase, R.E. Delong, D. Eisener, J. Etter, R. Gallant, D.N. Gilroy, W.W. Goodwin, G.J. MacDonald, C.R. MacHattie, F.J. Muise, A.D. Parsons, C. Peterson, C.E. Poison, S.F.W. Spencer, G.D. Steeves, A.C. Stuart, H.B. Sutherland, J.C. Vezina, R.N. Vine, R.D. Wardrope, S.J.F. Winter, H.C.L. Woodhams

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ATLANTIC FISHERIES
SERVICE. MARITIMES
(DFO)

Marine Fish Division
R.C. Halliday. Chief 8390

Canadian Atlantic Fisheries Scientific Advisory Committee -- Secretariat
D. Geddes 8390

Co-ordinator, BIO Component 8390
W.T. Stobo

Computer Services
B. Leverman
M. Milligan

International Research and Samplng
A. Sinclair
D. Waldron

National Sampling and Statistics
B. Smith
K. Zwanenburg

Population Dynamics

B. Beck	K. Metuzals
D. Clay	R. O'Boyle
Y. DeLafontaine	M. Sinclair
J.J. Maguire	S. Smith
J. McGlade	G. White
S. Messieh	

CANADIAN WILDLIFE SERVICE (DOE)

Seabird Research Unit 3274

T.R. Birkhcad	A. Grcen
R.G.H. Brown	A.R. Lock
D.S. Currie	R. Milton
A.J. Gaston	D.N. Ncttleship

GEOLOGICAL SURVEY OF CANADA (DEMR)

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M.J. Keen. Director 2367

Administration
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Eastern Petroleum Geology
G.L. Williams, Head 2730

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S. Barss	R.D. Howie
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E.H. Davies	L.F. Jansa
F.M. Gradstein	C. J. Mitchcll
A.C. Grant	D.C. Umpleby
G.M. Grant	J.A. Wade

Environmental Marine Geology
D.J.W. Piper, Head 7730

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M. Lewis	Y. Wang
M.A. Rashid	G.V. Winters
K.R. Robertson	

Program Support
K.S. Manchester, Head 3411

V.F. Coady	B.L. Johnston
F.D. Ewing	D.R. Locke
A. Frickcr	J.A. Nielson
M.E. Gorveatt	A.G. Sherin
D.E. Heffler	R. Sparkes
M.D. Hughes	M. Walkcr

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R.T. Haworth, Head 3448

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R.H. Fillon	J.B. MacIntyre
I.D. Hardy	B. MacLean
H.R. Jackson	R.F. Macnab
W.H. Josenhans	K.G. Shih
C.E. Keen	S.P. Srivastava
L.H. King	J.M. Woodside


Roger Belanger 5851-3

Iris Hardy


Roger Belanger 6080

Bob Miller


Roger Belanger 5863-1

Mike Hughes.

BIO staff are actively involved in various ways with scientific journals, international and national scientific organizations, and academic institutions. We present below about one-quarter of these. Abbreviations used in the listing include:
AGC Atlantic Geoscience Centre; *AOL* Atlantic Oceanographic Laboratory; CCCO Committee on Climatic Changes and the Ocean; CMOS Canadian Meteorological and Oceanographic Society; *Comm.* Committee; *EAMES* Eastern Arctic Marine Environmental Studies; *GAC* Geological Association of Canada; *GESAMP* Group of Experts on the Scientific Aspects of Marine Pollution; *GIPME* Global Investigations of Pollution of the Marine Environment (program of the IOC); Hydrography Atlantic Region, Canadian Hydrographic Service; IAEA International Atomic Energy Agency; *IAGA* International Association of Geomagnetism and Aeronomy; IAPSO International Association for the Physical Sciences of the Ocean; *ICES* International Council for the Exploration of the Sea; ICSU International Council of Scientific Unions; *IF* Institute Facilities of BIO; *IGCP* International Geological Correlation Program; IOC Intergovernmental Oceanographic Commission; *MEL* Marine Ecology Laboratory; *MARPOLMON* Marine Pollution Monitoring (program of the IOC); *NATO* North Atlantic Treaty Organization; *NEA* Nuclear Energy Agency; NRC National Research Council; *NSERC* Natural Sciences and Engineering Research Council; OSS Atlantic Ocean Science and Surveys (Atlantic); SCOR Scientific Committee on Oceanic Research; *UNESCO* United Nations Educational, Scientific, and Cultural Organization; WG Working Group; and *WMO* World Meteorological Organization.

EDITORIAL BOARDS

R.F. Addison, MEL - Member, Editorial Advisory Board, Canadian Journal of Fisheries and Aquatic Sciences
J.P. Bujak, AGC - Newsletter Editor, Canadian Association of Palynologists
A.C. Grant, AGC - Associate Editor, Bulletin of Canadian Petroleum Geology
M.J. Keen, AGC - Associate Editor, Marine Geology
S.R. Kerr, MEL - Member, Editorial Advisory Board, Canadian Journal of Fisheries and Aquatic Sciences
B.D. Loncarevic, AGC - Editor-in-Chief, Marine Geophysical Researches
A.R. Longhurst, OSS Atlantic - Member, Scientific Board, Oceanologica Acta; Member, Editorial Board, Journal of Plankton Research
T.C. Platt, MEL - Member, Editorial Board, Journal of Plankton Research; Member, Editorial Advisory Board, Marine Ecology
W.L. Silvert, MEL - Member, Editorial Board, Biological Oceanography Journal
G.L. Williams, AGC - Associate Editor, Marine Micropaleontology; Editor, Geolog

INTERNATIONAL ORGANIZATIONS

R.F. **Addison,** MEL - Member, ICES Environmental Quality Comm.

P.F. **Brodie,** MEL - Member. International Whaling Commission, Cambridge 1980

J.P. **Bujak,** AGC - Councillor, American Association of Stratigraphic Palynologists

R.A. **Cranston,** AGC - Chairman, Deep Ocean Sediment Symposium, 11th International Congress on Sedimentology (1982)

F.W. **Dobson,** AOL - Member, NATO Science Comm. Special program panel on air/sea interaction

S.R. **Durvasula,** MEL - Member, SCOR-UNESCO Comm., Biological research in coastal, estuarine, and lagoon waters

D.C. **Gordon,** MEL - Chairman, Symposium on dynamics of turbid coastal environments (1981)

P.A. **Hacquebard,** AGC - Member, International Commission on Coal Petrology

W.G. **Harrison,** MEL - Canadian representative, NATO Advanced Study Institute, Physiological ecology of phytoplankton (1980)

C.E. **Keen,** AGC - Member, Commission on Marine Geology

M.J. **Keen,** AGC - Member, Executive Comm., Joint Oceanographic Institutions Deep Earth Sampling (JOIDES)

A.J. **Kerr,** Hydrography - Chairman. International Cartographic Association. Commission on Marine Cartography: Member, International Hydrographic Organization/Federation Internationale des Géomètres, Advisory Board on Standards of Competence

L.H. **King,** AGC - Member, North American Commission on Stratigraphic Nomenclature

M.P. **Latremouille,** IF - President (1981). Association of Earth Science Editors

E.M. **Levy,** AOL - Canadian delegate, IOC MARPOLMON program

B.D. **Loncarevic,** AGC - Member, Scientific Advisory Comm., IGCP

A.R. **Longhurst,** OSS Atlantic - Secretary, SCOR; Chairman, Biology Panel, SCOR Comm. on Climatic changes and the ocean; Canadian delegate, ICES; Honorary member. Comité de Perfectionnement, Institut Océanographique, Paris

K.H. **Mann,** MEL - Adviser, Swedish Natural Science Research Council; Director, American Society for Limnology and Oceanography

G.T. **Needler,** AOL - Member, GESAMP

M.A. **Paranjape,** MEL - Member, NATO Advanced Research Institute, Ecology of marine planktonic protozoa

T.C. **Platt,** MEL - Director, NATO Advanced Study Institute, Physiological ecology of phytoplankton; Organizer, ICES International symposium on shelf ecosystems: Chairman, ICES Comm. on biological oceanography

C.K. **Ross,** AOL - Member, UNESCO-SCOR-IAPSO Joint Panel on Oceanographic tables and standards

P.C. **Smith,** AOL - Member, Hydrography Comm., ICES

J.H. **Vandermeulen,** MEL - Member, National Academy of Sciences (USA) Steering Comm. to organize and prepare updated report on “Petroleum in the Marine Environment”

INTERNATIONAL WORKING GROUPS

P. **Ascoli,** AGC - Member, WG 9, IGCP Subgroup on smaller benthonic foraminifera; Member, WG 58, IGCP Mid-Cretaceous Events Project

J.M. **Bewers,** AOL - Chairman, IAEA Technical Group 337, Revision of IAEA Series 5; Canadian delegate, IAEA WG on definition of *de minimis* levels of radioactivity for the purposes of the London Convention (1968); Co-ordinator, ICES Intercalibration for trace metals in seawater; Canadian delegate, Executive Group, NEA Surveillance program for the northeast Atlantic dumpsite

D.E. **Buckley,** AGC - Member, NEA Seabed WG to evaluate seabed disposal of high-level radioactive waste

R.A. **Clarke,** AOL - Member, SCOR-ICES WG 68 on North Atlantic Circulation

R.A. **Cranston,** AGC - Canadian delegate, NEA Seabed WG to evaluate seabed disposal of high-level radioactive waste

F.W. **Dobson,** AOL - Chairman, WG for feasibility of climate scale meridional heat flux experiment (CAGE) - WG appointed by Joint Scientific Committee Liaison Panel of WMO/ICSU/CCCO; Chairman, NAPOMS Ship-of-Opportunity WG (sponsored by CCCO)

F.M. **Gradstein,** AGC - Member, IGCP WG 158, Mid-Cretaceous Events Project: Member, IGCP WG 148, Quantitative Stratigraphic Correlation Techniques Project

R.T. **Haworth,** AGC - Member, Canadian WG and International Special Study Group on Geophysics and Geologic Correlation of IGCP Project 27; Member, Continental Margin Transect WG of the Canadian and USA Geodynamics Comm.; Tectonic Map of North America WG for the American Association of Petroleum Geologists

E.M. **Levy,** AOL - IOC Task Team on petroleum hydrocarbon measurements procedures: Member, IOC Task Team on surface microlayer sampling for the purposes of GIPME

K.H. **Mann,** MEL - Chairman, SCOR WG 59 on mathematical models in biological oceanography

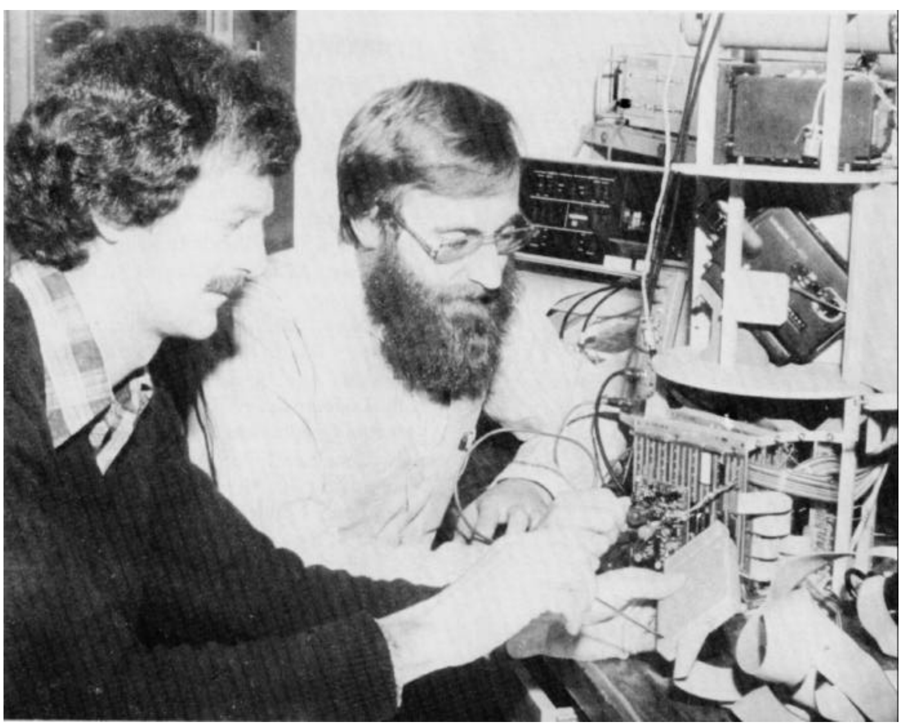
G.T. **Needler,** AOL - Member, SCOR WG 34; Member, GESAMP WG on the health of the oceans: Chairman, GESAMP WG on an oceanographic model for the dispersion of wastes disposed of in the deep sea

T.C. **Platt,** MEL- Member, ICES WG on measuring primary production; Member, SCOR WG 59 on mathematical models in biological oceanography

C.K. **Ross,** AOL - Member, ICES WG on oceanic hydrography

D.D. **Sameoto,** MEL - Member, SCOR WG 52 on methods for the sampling of micronekton; Member, SCOR *ad hoc* group on krill survey design for the BIOMASS FIBEX acoustic survey for Antarctic krill

S.P. **Srivastava,** AGC - Member. IAGA WG I-4 on magnetic anomalies; Member, IAGA WG I-4 on the international geomatnetic reference field



Roger Belanger 3861-5

Don Locke and Dave Heffler.

NATIONAL COMMITTEES AND WORKING GROUPS

M.S. **Barss,** AGC - Geological Survey of Canada representative, Steering Comm., Kremp palynological computer research project

J.M. **Bewers,** AOL - Member, Canadian National Comm. for SCOR; Member, Canadian Marine Analytical Standards Comm.

S.M. **Blascoe,** AGC - Chairman, Industry-Government Beaufort Sea synthesis group

J. **Brooke,** OSS Atlantic - Vice-President for 1981, Marine Applications Council

D.E. **Buckley,** AGC - Member, NRC Associate Comm. on shoreline erosion and sedimentation

L.M. **Dickie,** MEL - Fellow of the Royal Society of Canada

R.H. **Fillon,** AGC - Member, Atlantic Provinces Subgroup of the Canadian W G on Quaternary glaciations in the northern hemisphere

D.C. **Gordon,** MEL - Member, Strategic grants advisory panel on oceans, NSERC: Executive member, Atlantic Provinces Council on the Sciences

P.A. **Hacquebard,** AGC - Vice-President, Mining Society of Nova Scotia; Fellow of the Royal Society of Canada

R.D. **Howie,** AGC - Member, the Canadian-New Brunswick minerals and fuels comm.

C.E. **Keen,** AGC - Chairman, Canadian Lithosphere Project; Councillor, GAC; Fellow of the Royal Society of Canada

M.J. **Keen,** AGC - Member, Interdisciplinary advisory panel on strategic grants on oceans, NSERC; Fellow of the Royal Society of Canada

A.J. **Kerr,** Hydrography - Member, National Commission for Cartography

S.R. **Kerr,** MEL - Chairman, 1980 Program Comm., Canadian Conference for Fisheries Research

D.J. **Lawrence,** AOL - Chairman, Interdepartmental-Industry W G on oil spill trajectory modelling

C.F.M. **Lewis,** AGC - Government co-chairman, Joint industry-government W G on ice scour research

A.R. **Longhurst,** OSS Atlantic - Member, Baffin Island Oil Spill Project Management Comm.

K.H. **Mann,** MEL - Fellow of the Royal Society of Canada

C.S. **Mason,** AOL - Member, EAMES Management Comm.

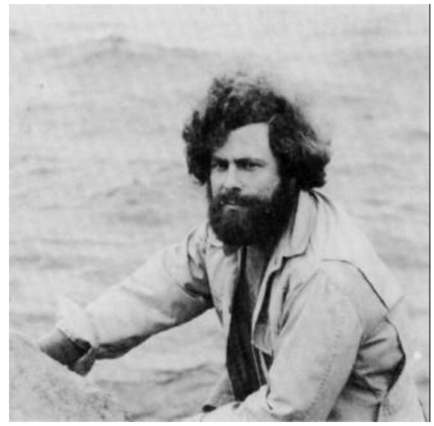
H.B. **Nicholls,** OSS Atlantic - Member, National Steering Comm. for 1982 Joint Oceanographic Assembly

P.C. **Smith,** AOL - Member, Scientific Comm., CMOS

D.C. **Umpleby,** AGC - Member, Hydrocarbon Potential Assessment Comm.

J.A. **Wade,** AGC - Member, Hydrocarbon Potential Assessment Comm.

G.L. **Williams,** AGC - Chairman, GAC Paleontology Division; Member, Canadian National Comm.. IGCP



Roger Belanger 6070-9

David Nettleship.

Heinz Wiele 6056-1

Hartie Champion and Ron Myers of the Northwest Atlantic Fisheries Organization.

chapter 12

Project Listing

We present below a listing of the projects (A, B, C, etc.) and individual investigations (1, 2, 3, etc.) being undertaken by staff of the three major research laboratories at BIO: this listing was current at December 1980. For more information on these and the projects of other BIO component laboratories, feel free to write to the directors of the laboratories or to the BIOMAIL address given on the last page of this report.

ATLANTIC OCEANOGRAPHIC LABORATORY

A. SURFACE- AND MIXED-LAYER OCEANOGRAPHY

1. Sea surface wind stress, heat flux, and evaporation *(S.D. Smith, F.W. Dobson)*
2. CO_2 exchange at the air-sea interface *(E.P. Jones. S.D. Smith)*
3. Pressure measurements in the atmospheric boundary layer (J.A. *Elliott)*
4. Surface heat flux at OWS Bravo *(S.D. Smith, J.R.N. Lazier)*
5. Beaufort Sea heat budget *(E.G. Banke, S.D. Smith)*
6. Wave growth studies *(F.W. Dobson)*
7. Wave climate studies *(H.J.A. Neu)*
8. Oil trajectory analysis (D.J. *Lawrence, J.A. Elliott, D. Greenberg)*
9. Surface drifters *(D. Bezanson)*
10. Iceberg drift track prediction *(E.G. Banke, S.D. Smith)*
11. Microstructure in the surface layers *(N.S. Oakey, J.A. Elliott)*
12. Arctic polynya experiment *(S.D. Smith. F.* W. *Dobson)*

B. LARGE-SCALE DEEP-SEA OCEANOGRAPHY

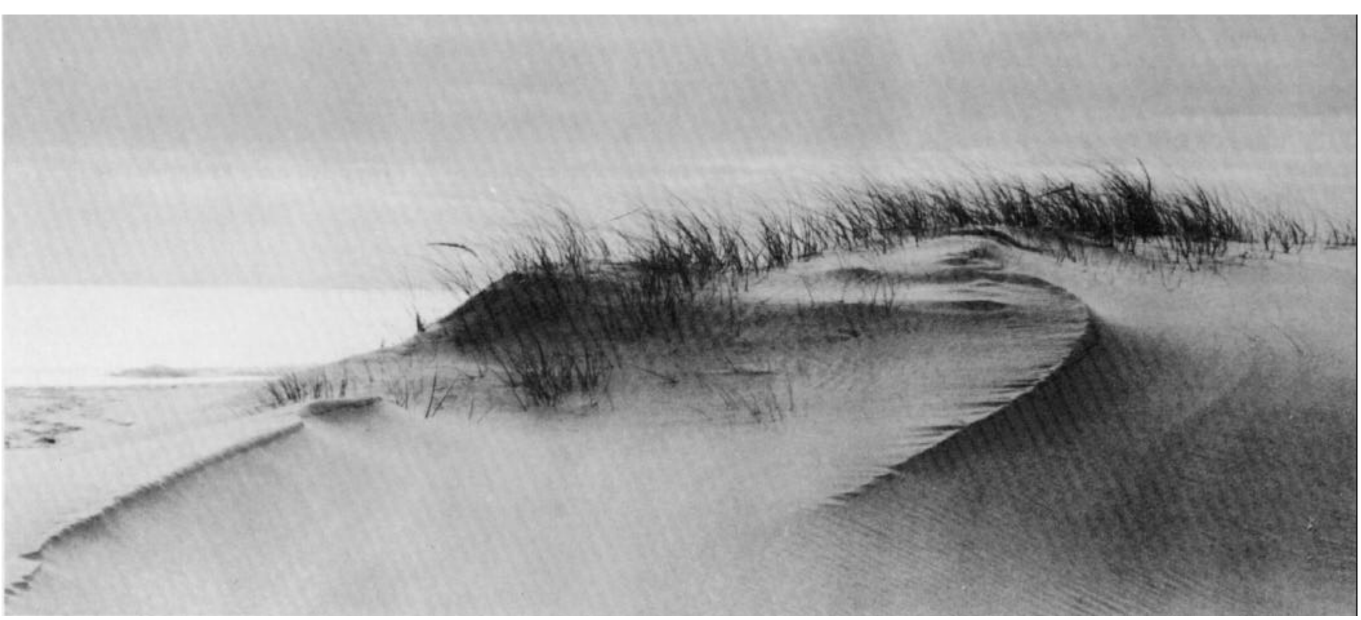
1. Labrador Sea Water formation (R.A. *Clarke and others)*
2. Oceanographic conditions at Station Bravo 1963-1974 *(J.R.N. Lazier)*
3. Dynamics of the Labrador Sea (C. *Quon)*
4. Labrador Current variability (A. *Allen, R.A. Clarke)*
5. Age determinations in Baffin Bay bottom water *(E.P. Jones)*
6. Tail of the Grand Banks *(R.A. Clarke, R. F. Reiniger)*
7. Local-scale Gulf Stream structure *(R.M. Hendry, R.F. Reiniger)*
8. Gulf Stream extension studies *(R.M. Hendry, R.F. Reiniger)*
9. Newfoundland Basin experiment *(R.A. Clarke and others)*
10. Topographic experiment *(R.M. Hendry)*
11. Nonlinear dynamics of long waves in the ocean *(H. Sandstrom)*
12. Stability problems in GFD flows *(C. Quon)*
13. Northwest Atlantic atlases *(R.F. Reiniger and others)*

C. CONTINENTAL SHELF DYNAMICS

1. Cape Sable experiment *(P.C. Smith and others)*
2. Shelf Break experiment *(P.C. Smith and others)*
3. Strait of Belle Isle *(B. Petrie, C. Garrett)*
4. Shelf dynamics - Avalon Channel experiment *(B. Petrie, H. Sandstrom)*
5. Tidally induced mixing *(J.A. Elliott, H. Sandstrom)*
6. Batfish internal waves *(A.S. Bennett)*

D. CONTINENTAL SHELF AND PASSAGE WATER MASS AND TRANSPORT STUDIES

1. Labrador Shelf and Slope studies *(I. R. N. Lazier)*
2. Flemish Cap experiment *(C.K. Ross)*
3. Impact of fresh water on the water masses of Davis Strait and the Labrador Sea *(H.J.A. Neu)*
4. Water mass analysis using nutrients in the Canadian Archipelago *(E.P. Jones. A. Coote)*



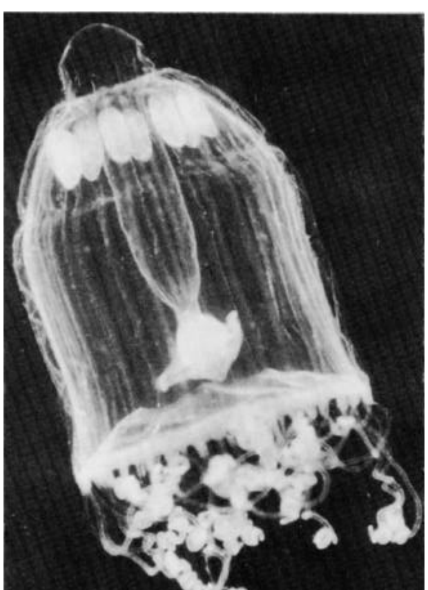
Roger Belanger 5050-103

Dunes on Sable Island.

5. Long-term monitoring of the Labrador Current at Hamilton Bank *(J.R.N. Lazier)*
6. Long-term temperature monitoring *(B. Petrie, P.C. Smith)*
7. Applied studies - EAMES data archiving *(G.H. Seibert)*
8. Long-term surface velocity patterns in Baffin Bay and Davis Strait *(H.J.A. Neu)*

E. OCEANOGRAPHY OF ESTUARIES AND EMBAYMENTS

1. Saguenay fjord study *(G.H. Seibert)*
2. Northwestem Gulf of St. Lawrence oceanography *(C. Tang. A.S. Bennett)*
3. Gaspe current studies *(C. Tang)*
4. Gulf of St. Lawrence frontal study *(C. Tang, A.S. Bennett)*
5. Seasonal and interannual variability in the Gulf of St. Lawrence *(G. Bugden. H.J.A. Neu)*
6. Laurentian Channel current measurements *(G. Bugden)*
7. Time-dependent estuary models *(K. Tee, T. Lim)*
8. Gulf of St. Lawrence - Normal mode studies *(G. H. Seibcrt)*
9. Topographic effects on tidal currents *(R. Tee)*
10. Bay of Fundy - Gulf of Maine modelling studies *(D. Greenberg)*
11. Forced flows in the Strait of Canso *(D.I. Lawrence, D. Greenberg)*
12. General characteristics of particle distributions *(K. Kranck)*
13. Laboratory studies of particulate matter (K. *Kranck)*
14. Particulate matter in the Bay of Fundy and Saint John Harbour *(K. Kranck, D. Bezanson)*
15. Bottom drifters *(D. Bezanson)*



Peter Vass

The jelly fish *Aglantha digitales.*

F. SENSOR DEVELOPMENT

1. Anemometers *(J.-G. Dessureault. D.F. Knox)*
2. CTDs and associated sensors *(A.S. Bennett)*
3. Thermistor chains on drifting buoys *(G.A. Fowler and others)*
4. Towed biological sensors *(A. W. Hcrman and others)*
5. High productivity and frontal dynamics at the Scotian Shelf Break *(A.W. Herman)*
6. Vertical profiling biological sensors *(A.* W. *Herman and others)*
7. Zooplankton grazing at the productivity maximum *(A.W. Herman, A.R. Longhurst)*
8. Measurement of zooplankton spatial variability *(A.W. Herman, D.D. Sameoto)*
9. Real-time data acquisition *(A.S. Bennett)*
10. Optical instrumentation for suspended-solid measurements *(A.S. Bennett)*

G. SURVEY AND POSITION SYSTEM DEVELOPMENT

1. Acoustic current profiler *(D.L. McKeown, R.M. Hendry)*
2. Bottom-referenced acoustic positioning systems *(D.L. McKeown)*
3. Ship-referenced acoustic positioning systems *(D.L. McKeown, K.R. George)*
4. BIONAV *(D.E. Wells, S.T. Grant)*
5. Satellite positioning in the Arctic *(D.E. Wells)*
6. Sea surface topography of Hudson Bay *(D.E. Wells)*

H. OCEANOGRAPHIC INSTRUMENT DEPLOYMENT

1. Engineering studies of the stable platform *(S.D. Smith and others)*
2. Yacht hull buoy *(J.-G. Dessureault, J.A. Elliott)*
3. Mooring systems development *(R.F. Reiniger and others)*
4. Handling and operational techniques for instrument/cable systems *(G.A. Fowler and others)*

I. NEARSHORE AND ESTUARINE GEOCHEMISTRY

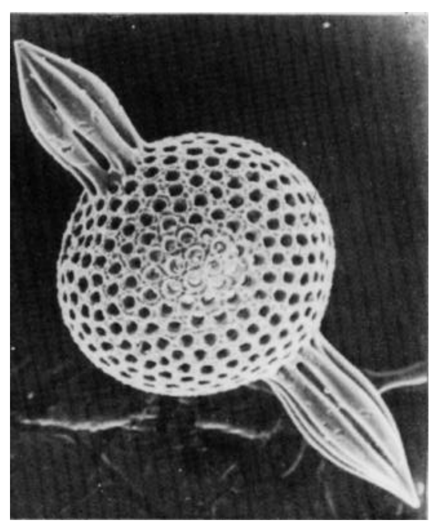
1. Nutrients on the Grand Banks and *Scotian* Shelf *(A.R. Coote)*
2. Estuarine and coastal trace metal geochemistry *(P.A. Yeats. J.M. Bewers)*
3. Atmospheric deposition of metals into the coastal zone *(P.A. Yeats)*
4. St. Lawrence River compositional studies *(P.A. Yeats. J.M. Bewers)*
5. Sediment geochronology and cl geochcmistry in the Saguenay fjord *(J.N. Smith and others)*
6. Sediment transport and bioturbation studies in the Bay of Fundy *(J.N. Smith and others)*
7. Organic matter in estuarines of the St. Lawrence *(F.C. Tan and others)*
8. Organic chemicals in atmospheric phases *(G. Lord and others)*
9. Organic carbon in the eastern Canadian Arctic *(F.C. Tan, P.M. Strain)*
10. Sources of organic carbon in the Peck's Cove ecosystem *(F.C. Tan, D.C. Gordon)*
11. Composition of organic matter in marginal seas *(R. Pocklington)*

J. DEEP-OCEAN MARINE CHEMISTRY

1. Nutrient regeneration processes *(A.R. Coote. E.P. Jones)*
2. CO_2 in the ocean *(E.P. Jones, E.M. Levy)*
3. Distribution of sea-ice meltwater in Baffin Bay *(F.C. Tan, P.M. Strain)*
4. Trace metal geochemistry in the North Atlantic *(P.A. Yeats)*
5. Trace meal biochemistry *(M. Stoffyn. P.A. Yeats)*
6. Sediment transport, deposition, and bioturbation studies on the Newfoundland Slope *(J.N.B. Smith and others)*
7. Upwelling and living resources *(R. Pocklington)*
8. Natural marine organic constituents *(R. Pocklington. J. D. Leonard)*
9. Particulate organic matter in the North Atlantic *(F.C. Tan. P.M. Strain)*
10. Paleoclimatic studies *(F.C. Tan and others)*

K. MARINE POLLUTION CHEMISTRY

1. Chlorinated hydrocarbons *(R. Pocklington, J. D. Leonard)*
2. Dissolved low molecular weight hydrocarbons *(E.M. Levy. E.P. Jones)*
3. Petroleum hydrocarbon components *(E.M. Levy)*
4. Seabird preen gland chemistry *(E.M. Levy, P.M. Strain)*
5. Petroleum residues in the eastern Canadian Arctic *(E.M. Levy)*
6. Large scale oil pollution of the oceans *(E.M. Levy)*



A fossil radiolaria from a Deep-Sea Drilling Project site in the Atlantic Ocean.

7. ICES quality control program for organic compounds *(E.M. Levy)*
8. Point Lepreau Environmental Monitoring Program *(J.M. Bewers and others)*
9. ICES quality control program for trace metals *(J.M. Bewers, P.A. Yeats)*
10. IOC GIPME Pilot Project sampling workshop *(J.M. Bewers and others)*
11. Canadian marine analytical standards program *(P.A. Yeats, J.M. Bewers)*
12. Belledune project *(D. Loring and! others)*

L. TECHNOLOGY TRANSFER

1. Seabed mosaics *(J.-C. Dessureault)*
2. Ocean data systems *(J. Brooke, J.A. Elliott)*
3. Papa *(J. Brooke, J.A. Elliott)*

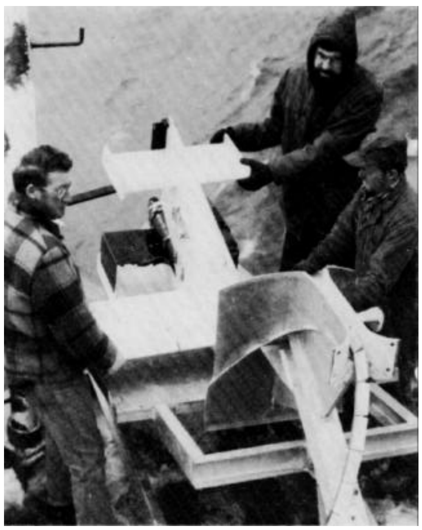
MARINE ECOLOGY LABORATORY

A. PRIMARY PRODUCTION PROCESSES: PHYTOPLANKTON PHYSIOLOGY AND BIOENERGETICS

1. Mathematical representation and parameterization of phytosynthetic response to changes in light intensity *(T.C. Platt. W.G. Harrison)*
2. Dependence of photosynthesis - light parameters on environmental conditions *(T.C. Platt and others)*
3. Significance and nature of aggregation and dispersion in phytoplankton production processes. *(T.C. Platt)*
4. Photosynthetic and respiratory enzymes in phytoplankton assemblages dynamics and significance for understanding and predicting variations in rate of primary production (J.C. *Smith. T.C.Platt)*
5. Dynamics of adaptation and acclimation of phytoplankton photosynthesis and respiration in response to changes in light intensity and temperature *(J.C. Smith and others)*
6. Size-fraction of phytoplankton in photosynthesis - light experiments and relative contribution of diatoms to total phytoplankton production *(D.V.* Subba *Rao)*
7. Effects of nutrient and trace element enrichment on size spectrum and production of phytoplankton populations *(D.V. Subba Rao)*
8. Primary production rates of individual phytoplankton species *(Harrison)*
9. Growth rates and protein synthesis by phytoplankton in relation to light intensity *(T.C. Platt and others)*
10. Respiration, nutrient dynamics, and regeneration in natural plankton populations *(W.G. Harrison, J.C. Smith)*
11. Physical oceanography of selected features in connection with marine ecological studies *(W.H. Horne, T.C. Platt)*
12. Physiology of marine micro-organisms *(W. Li. T.C. Platt)*

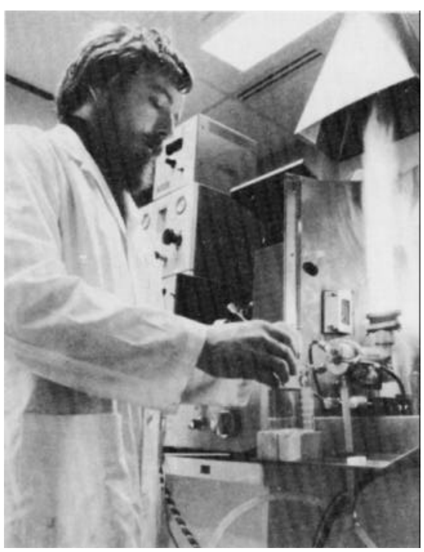
John Lazier

Paul d'Entremont & Bruno Greifeneder



Heinz Wiele 3946-12

L to R: Joe Avery, Bjorn Sundby, and Tommy Richards recovering the Batfish aboard CSS *Hudson*.



Roger Belanger 5793-8

Gary Winters.

B. SECONDARY PRODUCTION PROCESSES: TRANSFORMATION OF ORGANIC MATERIAL IN SECONDARY PRODUCTION

1. Carbon and nitrogen utilization and factors controlling secondary production by zooplankton *(R.J. Conover)*
2. Distribution of digestive enzymes in zooplankton in relation to substrate concentrations in their food supply *(R.J. Conover)*
3. Nutrition, metabolism, and overwintering strategies of microzooplankton *(M.A. Paranjape)*
4. Vertical distribution of microzooplankton *(M.A. Paranjape)*
5. Development of profiling equipment for plankton and micronekton *(D.D. Sameoto)*
6. Use of acoustic techniques to measure distribution of plankton and ichthyoplankton *(D.D. Sameoto)*
7. Analysis of microdistribution of ichthyoplankton and zooplankton in upwelling ecosystems *(D.D. Sameoto)*
8. Nature and significance of vertical variability in zooplankton profiles *(A.R. Longhurst)*
9. The polysaccharide components of particulate organic matter in relation to digestion of zooplankton *(E. Head)*
10. Digestive enzymes of zooplankton in relation to food supply *(E. Head)*
11. BIOSTAT *(D.D. Sameoto)*

C. ATLANTIC CONSHELF ECOLOGY: STUDIES OF THE SCOTIAN SHELF AND ADJACENT REGIONS

1. Scotian Shelf resources, ecological component of CEP/SSIP analysis: data acquisition over large spatial and long temporal scales *(R.J. Conover and others)*
2. Seasonal cycles of abundance and distribution of microzooplankton *(M.A. Paranjape)*
3. Methods of calculation of secondary production estimates from zooplankton population data *(R.J. Conover)*
4. Significance of Yarmouth upwelling plankton production to general productivity of Scotian Shelf fish stocks *(D.D. Sameoto)*
5. Pelagic ecosystem structure. Scotian Shelf *(D.D. Sameoto)*
6. Comparative studies of functional structure of pelagic ecosystems *(A.R. Longhurst)*
7. Vertical flux of living and nonliving particles in the water column and nutrient-gas exchange across the seawater-sediment boundary on the Scotian Shelf *(B.T. Hargrave. G.C.H. Harding)*
8. Georges Bank zooplankton and ichthyoplankton study *(D.D. Sameoto)*

D. EASTERN ARCTIC ECOLOGICAL STUDIES

1. Physiology, production. and distribution of marine phytoplankton *(T.C. Platt and others)*

2. Enzyme studies, phytosynthesis-light relationships *(J.C. Smith)*
3. Phytosynthesis-light studies and nutrient dynamics of phytoplankton *(T.C. Platt and others)*
4. Distribution, growth, and production, and the role of diapause in Arctic zooplankton communities *(R.J. Conover)*
5. Biological effects of natural oil seep at Scott Inlet *(J. H. Vandermeulen)*
6. Heavy metals in the eastern Arctic *(D.H. Loring)*
7. Bioenergetics and management of marine mammals *(P.F. Brodie)*
8. Zooplankton and macronekton of the eastern Arctic *(D.D. Sameoto)*
9. Arctic surface water zooplankton *(D.D. Sameoto)*
10. Arctic microzooplankton *(D.D. Sameoto)*
11. Distribution and abundance of microzooplankton in the eastern Arctic *(M.A. Paranjape)*

E. POPULATION AND TROPHYDYNAMICS: ECOLOGICAL THEORY AND STRUCTURE OF ECOSYSTEMS

1. Acoustic analyses of fish populations and development of survey methods *(L.M. Dickie and others)*
2. Genetic and environmental control of production parameters *(L.M. Dickie, K. R. Freeman)*
3. Geographic variation of production parameters *(L.M. Dickie, K. R. Freeman)*
4. Development of biochemical indicators of metabolism and growth for fish (J.C. *Smith, L.M. Dickie)*
5. Metabolism and growth of fishes *(S.R. Kerr)*
6. Mathematical analysis of fish population interactions (S.R. *Kerr, W.L. Silvert)*
7. Parameter estimation and the theory of predation *(W. I,. Silvert)*
8. Generalized stock-recruitment interaction models *(W.L. Silvert)*
9. Dynamics of energy and material flow through ecosystems *(W. L. Silvert)*
10. Interaction of ecological and economic factors in fisheries management (W. *L. Silvert)*
11. Size-structure spectrum of fish production *(W. L. Silvert and others)*
12. Optimal foraging and reproductive strategies *(D.M. Ware, W.L. Silvert)*
13. Growth rate in relation to size and temperature *(R. W. Sheldon)*
14. Bioenergetics management of marine mammals *(P. Brodie)*
15. Feeding, growth, and mortality of larval fish *(D.M. Ware)*

F. ENVIRONMENTAL VARIABILITY EFFECTS: CLIMATE CONTROL OF FISH POPULATION ABUNDANCE

1. Residual current patterns on the Canadian Atlantic continental shelf as revealed by drift bottles and seabed drifters *(R.W. Trites)*
2. Water type analyses for the NAFO areas *(R. W. Trites)*
3. Mesoscale variability in current patterns in the southern Gulf of St. Lawrence *(R.W. Trites)*
4. Scotian Shelf plankton variability from analysis of CPR data *(W.H. Sutcliffe)*
5. Effects of Hudson Bay outflow on the Labrador Shelf *(W.H. Sutcliffe)*
6. Effects of St. Lawrence River outflow on the populations of fish and invertebrates in the Gulf of St. Lawrence and on the Scotian Shelf *(W.H. Sutcliffe)*
7. Larval herring transport and diffusion studies *(R.W. Trites, D.M. Ware)*
8. Currents and transport in Georges Bank - southwest Nova Scotia in relation to the inshore-offshore lobster problem *(R.* W. *Trites)*
9. Oil distribution in relation to winds and currents following the break-up of the Kurdistan *(D. J. Lawrence and others)*

G. INSHORE ECOLOGY: ECOLOGICAL STUDIES OF COASTAL FISHERIES

1. Steady state model and transient features of the circulation of Georges Bay *(K.F. Drinkwater)*
2. Lateral diffusion measurements *(R. W. Trites)*
3. Relation between chlorophyll-a and temperature structure *(K.F. Drinkwater)*
4. Distribution of lobster larvae in relation to water movement *(G.C.H. Harding and others)*
5. The distribution, abundance, and recruitment of lobster larvae in St. Georges Bay and the possible effects of the Canso Causeway on the Chedabucto Bay lobster fisheries *(G.C.H. Harding and others)*
6. Seasonal variability of planktonic particle size spectrum *(G.C.H. Harding and others)*
7. Nutrition and growth studies of micro- and macrozooplankton *(R.W. Sheldon and others)*
8. Vertical movement of plankton. suspended matter. and dissolved nutrients in the water columns of coastal embayments *(G.C.H. Harding and others)*
9. Distribution and ecology of ichthyoplankton *(D.M. Ware)*
10. Ecological studies of the Gulf of St. Lawrence herring stocks *(D.M. Ware, T. Lambert)*
11. Spatial relations between demersal fish and sediment parameters *(R.W. Sheldon)*
12. Characterization of water masses by particle spectra *(R.W. Sheldon, R.W. Trites)*
13. Langmuir circulation and small scale distribution of the plankton *(D.M. Ware and others)*

Roger Belanger 5861-8

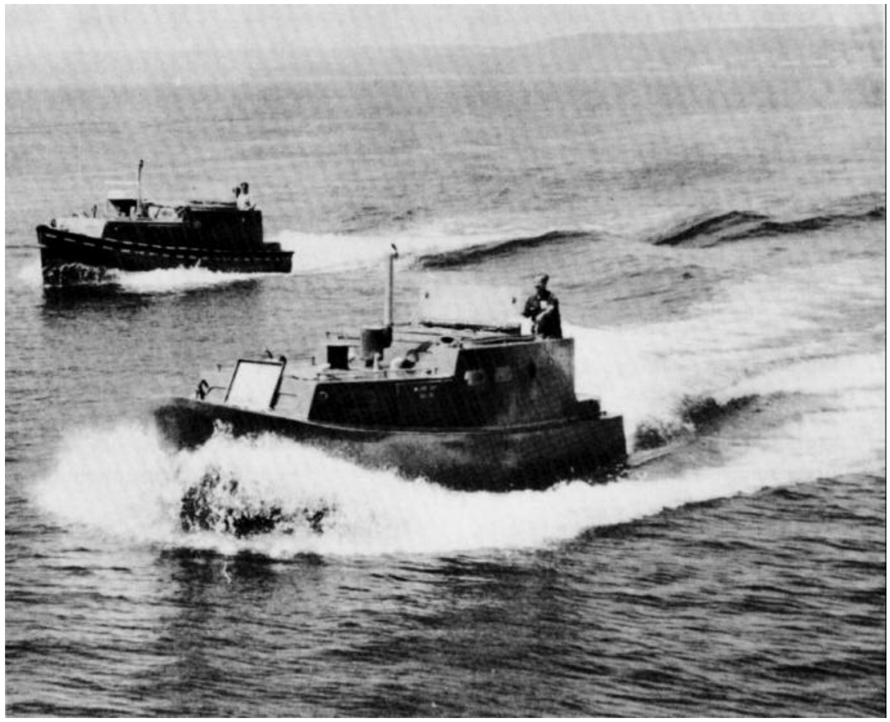
Susan Hubley and Andy Sherin.

H. SUBLETHAL CONTAMINATION AND EFFECTS: LOW-LEVEL RESPONSES AND PHYSIOLOGICAL STRESS

1. MFO induction by PCBs and PCB replacements *(R.F. Addison)*
2. ATPase activity and inhibition in marine biota *(B.F. Addison)*
3. Organochlorines in Arctic seals *(R.F. Addison)*
4. Distribution and fate of petroleum hydrocarbons in marine environments *(J. H. Vandermeulen)*
5. Metabolism of petroleum hydrocarbons in the marine food chain *(J.H. Vandermeulen)*
6. Abundance and regional distribution of potential contaminants in the marine environment *(D.H. Loring)*
7. Geochronology of mercury pollution in the sediments of the Saguenay fjord *(D.H. Loring, J. N. Smith)*
8. Cadmium contamination in the sediments and SPM at Belledune Pte., N.B. *(D.H. Loring)*
9. Potential bioavailability of heavy metals in eastern Canadian coastal sediments *(D.H. Loring)*
10. Potential bioavailability of heavy metals in SPM *(D.H. Loring)*
11. Uptake and clearance of p,p'-DDT by zooplankters through feeding and from the aqueous phase *(G.C. H. Harding and others)*
12. Seasonal cycle of organochlorine content in size-fractionated zooplankters in St. Georges Bay *(G.C.H. Harding, W.P. Vass)*
13. Geochronology of perchlorinated hydrocarbons in a Saguenay fjord core *(R.F.* Addison *and others)*
14. Dynamics of arsenic in marine phytoplankton *(B.F. Addison)*

I. BAY OF FUNDY ECOLOGICAL STUDIES: MACROTIDAL ECOLOGY AND ENVIRONMENTAL MODIFICATION

1. Major and heavy metals in the Bay of Fundy sediments *(D.H. Loring)*
2. Trace metals in SPM in the Bay *(D.H. Loring)*
3. Physical-chemical controls of particulate heavy metal in a turbid tidal estuary *(D.H. Loring)*
4. Concentration, distribution, seasonal variation, and flux of inorganic nutrients, chlorophyll, and organic matter in the water column of the Bay *(D.C. Gordon, P.D. Keizer)*
5. Organic chemistry of subtidal Bay sediments *(D.C. Gordon, B.T. Hargrave)*
6. Descriptive ecology of subtidal benthic communities in the Bay *(D.L. Peer)*
7. Planktonic primary production in the Bay and over the Pecks Cove mudflat *(N. Prouse)*
8. Microbial ecology of the Bay and Pecks Cove mudflat *(J. Walker)*
9. Phytoplankton of the Bay *(University of Moncton)*



Roger Belanger 6050-1-33

Testing hydrographic survey launches in Bedford Basin, N.S.

10. Chemical and biological analysis of Cumberland Basin water and sediments *(D.C. Gordon and others)*
11. Physical and chemical measurements of sediment on the Pecks Cove mudflat *(D.C. Gordon and others)*
12. Sediment-water exchanges on the Pecks Cove mudflat *(D.C. Cordon and others)*
13. Intertidal epibenthic primary production and benthic metabolism at Pecks Cove *(B.T. Hargrave, G. Phillips)*
14. Respiration in the water column and sediments at Pecks Cove *(B.T. Hargrave)*
15. Descriptive ecology and population dynamics of intertidal benthic organisms on the Pecks Cove mudflat *(D.L. Peer and others)*
16. Ecological energetics of *Corophium volutator* at Pecks Cove *(C.M. Hawkins)*
17. Sediment organic matter availability to microbial decomposition and assimilation by invertebrate organisms *(B.T. Hargrave and others)*
18. Spectral analysis of benthic organisms and sediment chemical variables on the Pecks Cove mudflat *(D.L. Peer and others)*
19. Bioturbation of the Pecks Cove mudflat *(D.C. Gordon and others)*
20. Enclosure experiment *(C.M. Hawkins)*
21. Zooplankton at the Pecks Cove mudflat *(C.M. Hawkins)*
22. Stable carbon isotope ratios in the Pecks Cove mudflat food chain *(Schwinghammer and others)*
23. Energetics of fish feeding on the Pecks Cove mudflat *(Dalhousie University)*
24. Formulation of carbon budgets *(Entire group)*

ATLANTIC GEOSCIENCE CENTRE

A. TECHNOLOGY DEVELOPMENT

1. Seabed mosaics *(D.E. Heffler)*
2. Huntec Seabed project *(L.H. King)*
3. Sediment dynanrics monitor - RALPH *(D.E. Heffler)*
4. Ocean bottom seismometers at the Atlantic Geoscience Centre *(D. E. Heffler)*
5. Development of data management system for marine geophysical data (GEOFFREY) *(G. Martin)*
6. Vibracorer updating *(M. Walker)*

B. RESOURCE EVALUATION: HYDROCARBONS

1. Hydrocarbon inventory of the sedimentary basins of eastern Canada *(J.A. Wade)*
2. Geophysical interpretation of geophysical data as an aid to basin synthesis and hydrocarbon inventory (A.C. *Grant)*

C. RESOURCE EVALUATION: COAL

1. Rank and petrographic studies of coal and organic matter dispersed in sediment *(P.A. Hacquebard)*
2. Geological assistance with provincial coal drilling project in Nova Scotia *(P.A. Hacquebard)*
3. Advice to the Cape Breton Development Corporation on coal geology for its operation in the Sydney coal field *(P.A. Hacquebard)*

D. REGIONAL GEOLOGY

1. Compilation of geoscience data in the Paleozoic basins of eastern Canada *(R. D. Howie)*

2. Regional subsurface geology of the Mesozoic and Cenozoic rocks of the Atlantic continental margin *(J.A. Wade)*
3. Regional subsurface geology of the continental shelf and slope, offshore Labrador, Baffin Island, and related areas *(D.C. Umpleby)*

E. BIOSTRATIGRAPHY
1. Identification and biostratigraphic interpretation of referred fossils *(Eastern Petroleum Geology Subdivision staff)*
2. Palynological zonation of the Carboniferous and Permian rocks of the Atlantic Provinces, Gulf of St. Lawrence, and northern Canada *(M.S. Barss)*
3. Biostratigraphic zonation (palynology) of the Mesozoic and Cenozoic rocks of the Atlantic Shelf (G.L. *Williams)*
4. Biostratigraphic zonation (Foraminifera-Ostracoda) of the Mesozoic and Cenozoic rocks of the Atlantic Shelf *(P. Ascoli)*
5. Classification of dinocysts *(G.L. Williams)*
6. Biostratigraphic history of the Mesozoic-Cenozoic sediments of the Grand Banks, northeast Newfoundland, and Labrador Shelves based on Foraminifera and Ostracoda *(F.M. Gradstein)*
7. Biostratigraphy and paleo-ecology (palynology) of the Mesozoic and Cenozoic, Atlantic Shelf *(J.P. Bujak)*
8. Geological Survey of Canada representative on the steering Committee for the Kremp Palynologic Computer Research Project *(M.S. Barss)*
9. Taxonomy, biostratigraphy, paleoecology, and paleobiogeography of agglutinated foraminifera *(F.M. Gradstein)*
10. Dinoflagellates - origin and evolution *(E.H. Davies)*
11. Vitrinite reflectance of dispersed organic matter *(E.H. Davies)*
12. Mesozoic-Cenozoic palynostratigraphy *(E.H. Davie)*

F. LITHOSTRATIGRAPHY
1. Stratigraphy and sedimentology of the Mesozoic and Tertiary rocks of the Atlantic continental margin *(L.F. Jansa)*

G. GEOLOGICAL MAPPING
1. Bedrock and surficial geology, Grand Banks *(L.H. King)*
2. Eastern Baffin Island Shelf bedrock and surficial geology mapping program *(B. MacLean)*
3. East coast offshore surveys *(R. Macnab)*

H. CRUSTAL PROCESSES
1. Geophysical investigation of the submarine extension of geological zonation of Newfoundland *(R.T. Haworth)*
2. FRAM 1 refraction experiment *(H.R. Jackson)*
3. Rift processes and the development of passive continental margins *(C.E. Keen)*

Dick LeLievre 5828-10

CCGS *Labrador* on an Arctic hydrographic survey.

4. Seismic studies of continental margins and ocean basins of the North Atlantic *(C.E. Keen)*
5. Co-crust 1980 *(B.D. Loncarevic)*
6. An earth science atlas of the continental margins of eastern Canada *(S.P. Srivastava)*
7. Comparative studies of the continental margins of the Labrador Sea and of the North Atlantic *(S.P. Srivastava)*

I. OCEAN BASINS
1. Geochemical transformations and reactions of organic compounds in recent marine sediments *(M.A. Rashid)*
2. Environmental geology of the deep ocean *(G. Vilks D.E. Buckley)*

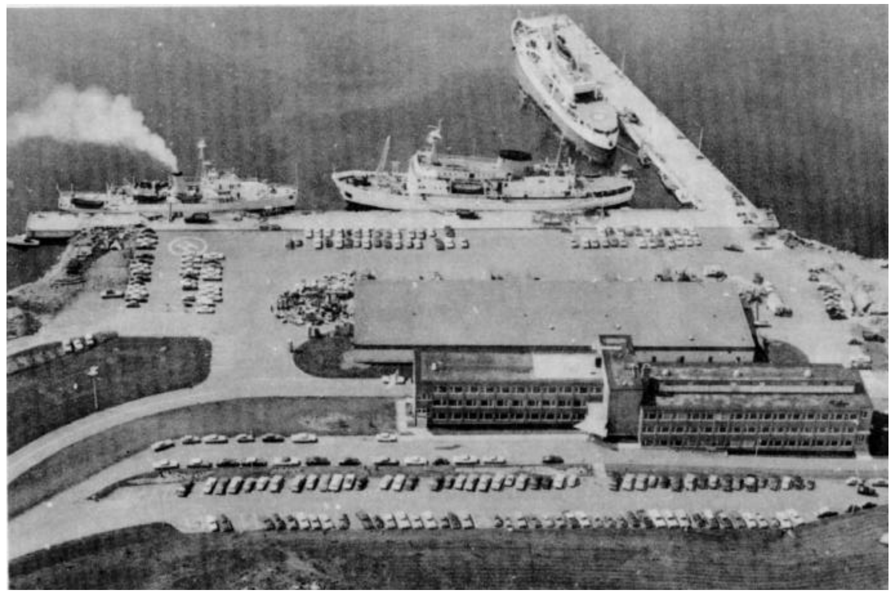
J. COASTAL MORPHOLOGY AND COASTAL PROCESSES
1. Coastal erosion and sedimentation, Northern Somerset Island, N.W.T. *(R.B. Taylor)*
2. Consulting advice on conservation and restoration of coastal environments *(R.B. Taylor)*
3. Ocean dumping consultation and study *(D.E. Buckley)*
4. Landsat calibration for suspended sediment concentration in the marine coastal environment (C.L. *Amos)*
5. Sediment dynamics of the head of the Bay of Fundy *(C.L.* Amos)
6. Coastal reconnaissance of Bylot and Northeast Baffin islands *(R.B. Taylor)*
7. Coastal morphology and sediment dynamics, southeast and east Cape Breton Island, N.S. *(R.B. Taylor)*
8. Multidisciplinary environmental marine geological analysis of the Miramichi estuary and bay *(D.E. Buckley)*
9. Sedimentology of fjord sills *(J. Syvitsky)*
10. Sedimentology of Arctic fjords *(J. Syvitsky)*
11. Sedimentology of west coast fjords *(J. Syvitsky)*
12. The physical behaviour of SPM in eastern Canada *(J. Syvitsky)*

K. SHELF AND SLOPE PROCESSES
1. Surficial geology and geomorphology of MacKenzie Bay/continental shelf *(S.M. Blascoe)*
2. Pleistocene-Holocene marine basin sedimentation *(G. Vilks)*
3. The Newfoundland continental slope at 49°N to 50°N - nature and magnitude of contemporary marine geologic processes *(C. T. Schafer)*
4. Ice scouring *(C.F.M. Lewis)*
5. The recent paleoclimatic and paleoecologic records in fjord sediments *(C.T. Schafcr)*
6. Stability and transport of sediments on continental shelves *(C.L. Amos)*
7. Surficial geology of the Lomonosov Ridge *(S.M. Blascoe)*
8. Regional distribution of marine Mollusca (Gastropoda and Pelecypoda) in eastern Canada *(F.J.E. Wagner)*

chapter 13

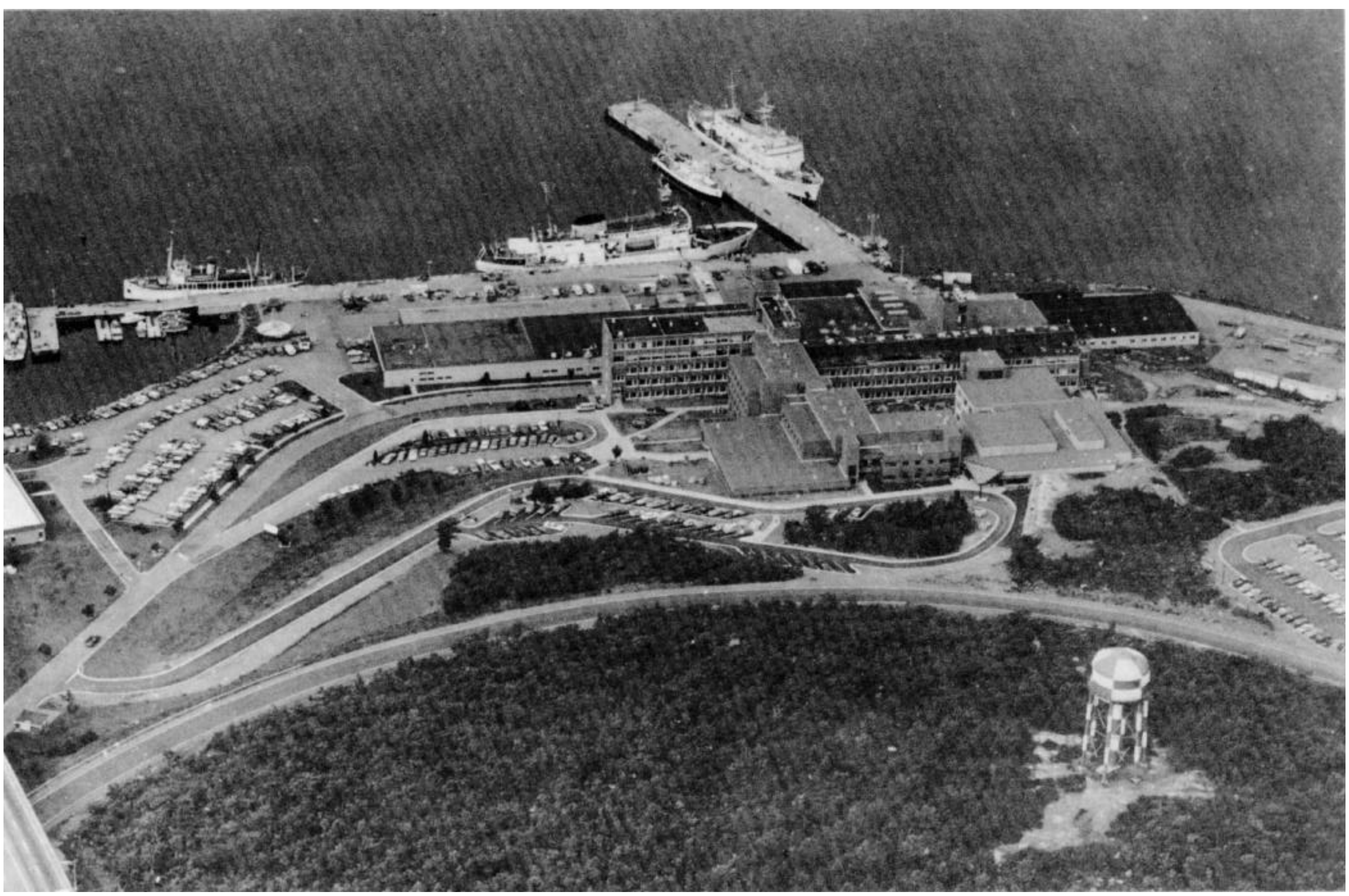
Excerpts from the BIO Log

A research centre like BIO that employs over 800 people and operates a half-dozen research vessels is bound to undergo many changes in two years. Nevertheless, we experienced more than our usual share of major events during 1979 and 1980 as the following partial chronology shows.



Norm Fenerty 670-7

MARCH 1979 . . . the Institute mobilized a group of scientists with experience in oil pollution incidents to help the Canadian Coast Guard to handle the 7,000 ton oil spill from the break-up of the British tanker *Kurdistan* off Nova Scotia. The scientists conducted scientific research on the aftermath of the



Roger Belanger 5704-7

BIO in 1967 (top) and in 1981 (bottom). The recently completed building extension has more than doubled the Institute's laboratory and office space, now about 22,000 m^2.

Roger Belanger 5258-36

Fire destroyed six trailers in April 1979.

spill and later organized a two-day workshop dealing with the incident. BIO hosted this workshop and published its proceedings.

APRIL 1979 . . . an arsonist destroyed six of our trailers, then used as temporary accommodation for about 75 people, but fortunately no lives were lost, the main buildings were not damaged, and virtually no scientific data were permanently lost in the blaze. More heartening news came later that month when our long-awaited and more versatile new CDC Cyber 171 computer arrived. April also marked the beginning on a large scale of the Marine Ecology Laboratory's major research commitment to describe and understand the fundamental ecology of the Bay of Fundy where renewed interest exists for the development of tidal power.

MAY 1979 . . . the LOREX and FRAM expeditions to the Arctic Ocean were in full swing. BIO scientists were major participants in these multidisciplinary and multi-nation investigations. The expeditions had camps set up on the drifting pack ice for up to 60 days to study the nature and history of the Arctic Ocean basins. Further expeditions are being planned to complete the studies by 1983. In the same month, Peter Hacquebard of the Atlantic Geoscience Centre at BIO was awarded the Reinhard Thiessen Medal by the International Committee of Coal Petrology. This was only the first of several awards that Peter won during 1979-80 for his exceptional achievements in coal geology. In November 1979 he received the Gilbert H. Cady Award from the Geological Society of America and in May 1980 Dalhousie University of Halifax conferred upon him the degree of Doctor of Laws. Charlotte Keen of the Atlantic Geoscience Centre was awarded the Past President's Medal of the Geological Association of Canada in May 1979 in recognition of her contributions to the understanding of continental margins.

JULY 1979 . . . many staff of the Marine Ecology Laboratory joined CSS *Hudson* for a one-month cruise to investigate aspects of plankton ecology in the Canadian Arctic. This cruise represented BIO's first major biological expedition in high latitudes. Plans for this effort were largely developed from the limited ecological work done on previous cruises that were devoted chiefly to chemical and physical oceanography and from ecological research conducted by the Marine Ecology Laboratory aboard Coast Guard icebreakers.

AUGUST 1979 . . . physical oceanographer Fred Dobson left BIO for one year to conduct collaborative research with several German meteorological institutes on boundary-layer meteorology and ocean waves . . . and Director-General and physical oceanographer Ced Mann prepared to leave BIO to accept a similar post at our sister institute in Patricia Bay, British Columbia. Marine ecologist Alan Longhurst succeeded Ced as Director-General. At the end of the month, Adam Kerr was appointed Director of the Canadian Hydrographic Service's Atlantic Region at BIO.

NOVEMBER 1979 . . . a group of Canadian oceanographers left for a one-month visit to China at the invitation of the Chinese government. The delegation, led by Gerry Ewing, Assistant Deputy Minister for Ocean Science and Surveys of DFO, visited 14 Chinese oceanographic institutes and discussed possible Canadian-Chinese oceanographic collaboration. BIO participants were Richard Addison, Michael Keen, and Alan Longhurst.

JANUARY 1980 . . . the year began 'with a 37-day cruise to an area south of Bermuda during which BIO's *CSS Dawson* was joined by the British RRS *Discovery*. The purpose was to carry out the Lesser Antilles Deep Lithosphere Experiment (LADLE). The velocity structure of the upper mantle down to 100 km depths was determined from a 1,500 km-long line along which ocean bottom seismometers were used to record seismic refraction events from large explosive shots and earthquakes. Another objective of this cruise was to evaluate the potential of deep sea sediments for the disposal of high level nuclear waste.

MARCH 1980 . . . the Institute

Heinz Wiele 5674-121

Open House gave visitors a close-up look at BIO's work.

Bob Taylor explains how the wave tank is used to study sediment movement underwater to Judy Erola, Minister of State (Mines)

Roger Belanger 5763-1

Sterling silver medals were presented to the 1980 BIO Huntsman Award winners (left to right):
Dan MacKenzie
Ramon Margalef, and
Henry Stommel.

Wamboldt-Waterfield

In addition to several international awards, coal geologist Peter Hacquebard received an honourary degree from Dalhousie University for his outstanding work. The coalified tree trunk at right is a 200-million-year-old Sigillaria from the Sydney Coalfield of Nova Scotia.

The black-hulled RRS Discovery flanked by CSS *Hudson* and CSS *Baffin* at the BIO jetty.

Alan Longhurst

Captain Jacques Cousteau crosses the gangplank to board his *Calypso,* shown departing BIO at right.

Roger Belanger

A light moment during the official ceremonies to open BIO's new buildings.

hosted an ocean and fisheries climate workshop whose aim was to define a climate research program for Canada that would develop our ability to predict climate trends between decades and longer periods. A wide range of topics was covered at the workshop and a framework for the program was developed. Participants were mainly from Canada and the U.S.

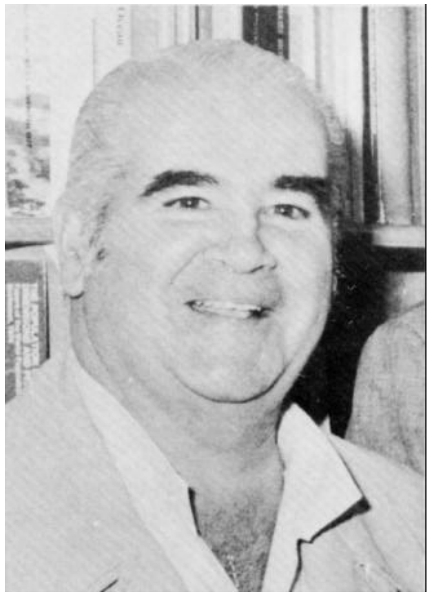
APRIL 1980 . . . the 19th annual conference of the Canadian Hydrographers' Association was held in Halifax. Chief organizers of this event were the staff of the CHS Atlantic Region directorate at BIO.

MAY 1980 . . . a busy month. BIO's five-year building program was completed and our older facilities renovated or rebuilt, all within the initial $18.5 million budget. The three new buildings were officially opened on the 22nd by Romeo LeBlanc, Minister of Fisheries and Oceans, with Judy Erola representing Energy, Mines and Resources. Following the opening, schools and the general public were invited to a three-day open house. Over 25,000 people came to view the 56 manned exhibited areas and to tour our facilities.

The new BIO Huntsman Award for excellence in marine research was presented on the 22nd by R.E. Bell, president of the Royal Society of Canada to Dan MacKenzie, a British geophysicist, for his contributions to our understanding of subcrustal dynamics and processes such a deep-ocean ridge building; to Ramon Margalef, a Spanish marine ecologist, for his significant and lifelong studies of marine plankton; and to Henry Stommel, a U.S. physical oceanographer, for his insights into the properties of major ocean current systems.

Also in May, the 1980 joint annual meeting of the Geological Association of Canada (GAC) and the Mineralogical Association of

Roger Belanger 5759-11



Bobby Fudge, for many years a storesman at BIO, died of cancer on April 26, 1981. We remember Bobby with fondness: his cheerful personality and always helpful contributions are missed.

Canada (MAC) was held in Halifax. Staff of the Atlantic Geoscience Centre played a major role in the organization of this event, which included a visit to BIO.

JUNE 1980 . . . Captain Jacques Yves Cousteau and his vessel *Calypso* visited BIO, and RRS *Discovery* from Britain called in on her way home from the Pacific. Coincidentally, the entire BIO fleet was alongside the jetty then, making for a rather crowded and convivial waterfront. Ken Mann became a Fellow of the Royal Society of Canada in June joining other BIO staff who are fellows such as Lloyd Dickie, Peter Hacquebard, Charlotte Keen, and Michael Keen.

SEPTEMBER 1980 . . . BIO established its BIOMAIL office. The "BIO Marine Advisory and Industrial Liaison" office is intended as a point of entry to the Institute for anyone seeking information on Canadian oceanography and related topics. Its specific functions are described on the facing page. Also that month, Ken Mann became the Marine Ecology Laboratory's new director.

OCTOBER 1980 . . . Trevor Platt directed an Advanced Study Institute on the Physiological Ecology of Phytoplankton, which was held on the Island of Lipari in the Aeolian Archipelago off the coast of Sicily. This was a NATO-sponsored workshop whose aim was an exchange of ideas and results between 70 field ecologists and laboratory physiologists working on phytoplankton. Back in Halifax, BIO hosted the annual meeting of the Association of Earth Science Editors and the International Association of Marine Science Libraries and Information Centers. The chief organizers of these meetings were BIO's editor, Michael Latremouille, and chief librarian, Elizabeth Sutherland.

NOVEMBER 1980 . . . the Institute's first industrial tenant, Huntec Atlantic Ltd., which has been working on a co-operative project with the Atlantic Geoscience Centre for several years, moved in to BIO and shortly thereafter several other firms also leased space on our campus. Felix Gradstein left to join the drilling vessel *Glomar Challenger* on which he was co-chief scientist for leg 76 of the Deep Sea Drilling Project.

DECEMBER 1980 . . . Jacques Cousteau, returning from a Canadian expedition, stopped off at BIO and previewed his latest film for us and CSS *Baffin* again docked at our jetty after the second portion of her mid-life refit had been completed.

As the year came to a close, BIO was preparing for its major role in the organization of the Joint Oceanographic Assembly to be held in Halifax in August 1982.

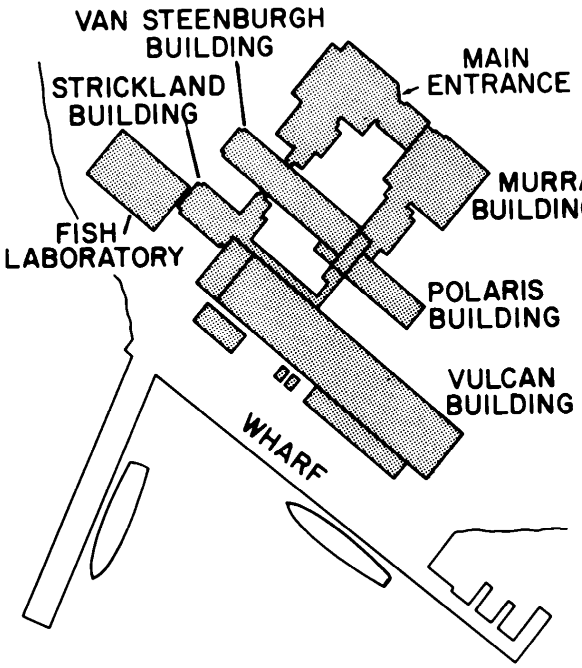
BIOMAIL

BIO's newly established Marine Advisory and Industrial Liaison office, or BIOMAIL for short, is there to:

- assist in obtaining oceanographic infomation for you
- help you solve your problems with any aspect of oceanography
- smooth the transfer of our know-how to your company
- facilitate joint projects with BIO and industry
- bring the right people together for an expansion of oceanographic industry.

BIOMAIL's scope is not limited to local or Canadian aspects; we have access to global ocean information and expertise. The office is here to serve the interests of Canadian industry for the benefit of Canadian citizens.

CONTACT: BIOMAIL
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, Nova Scotia
B2Y 4A2 CANADA
Phone: (902) 426-3698
Telex: 019-31552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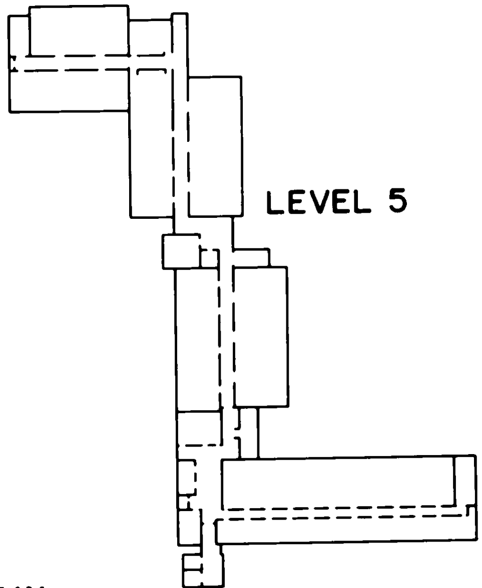
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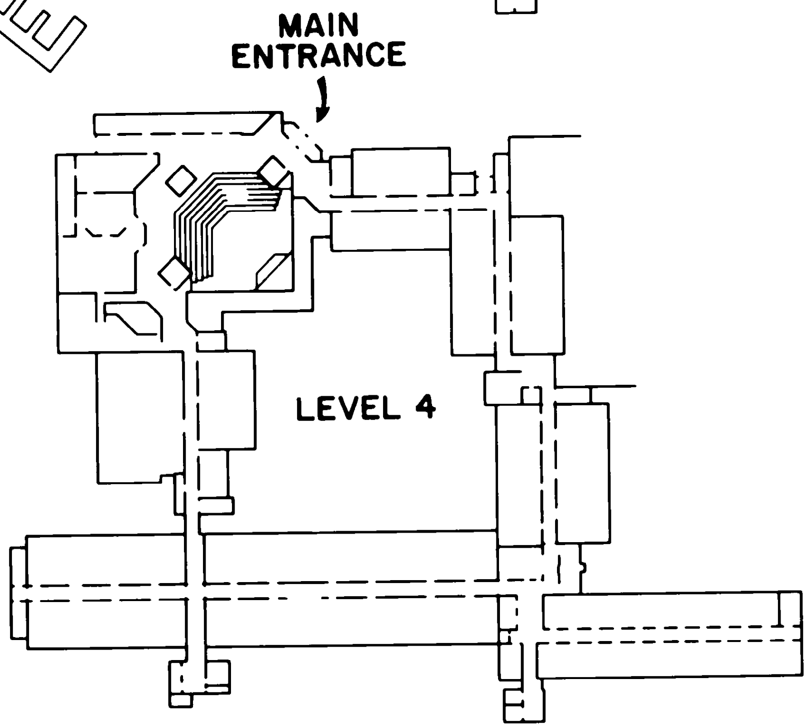
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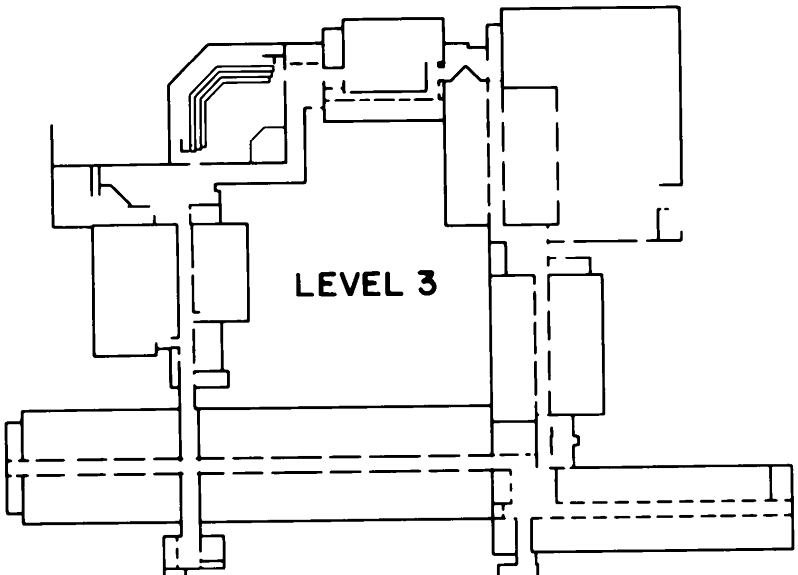
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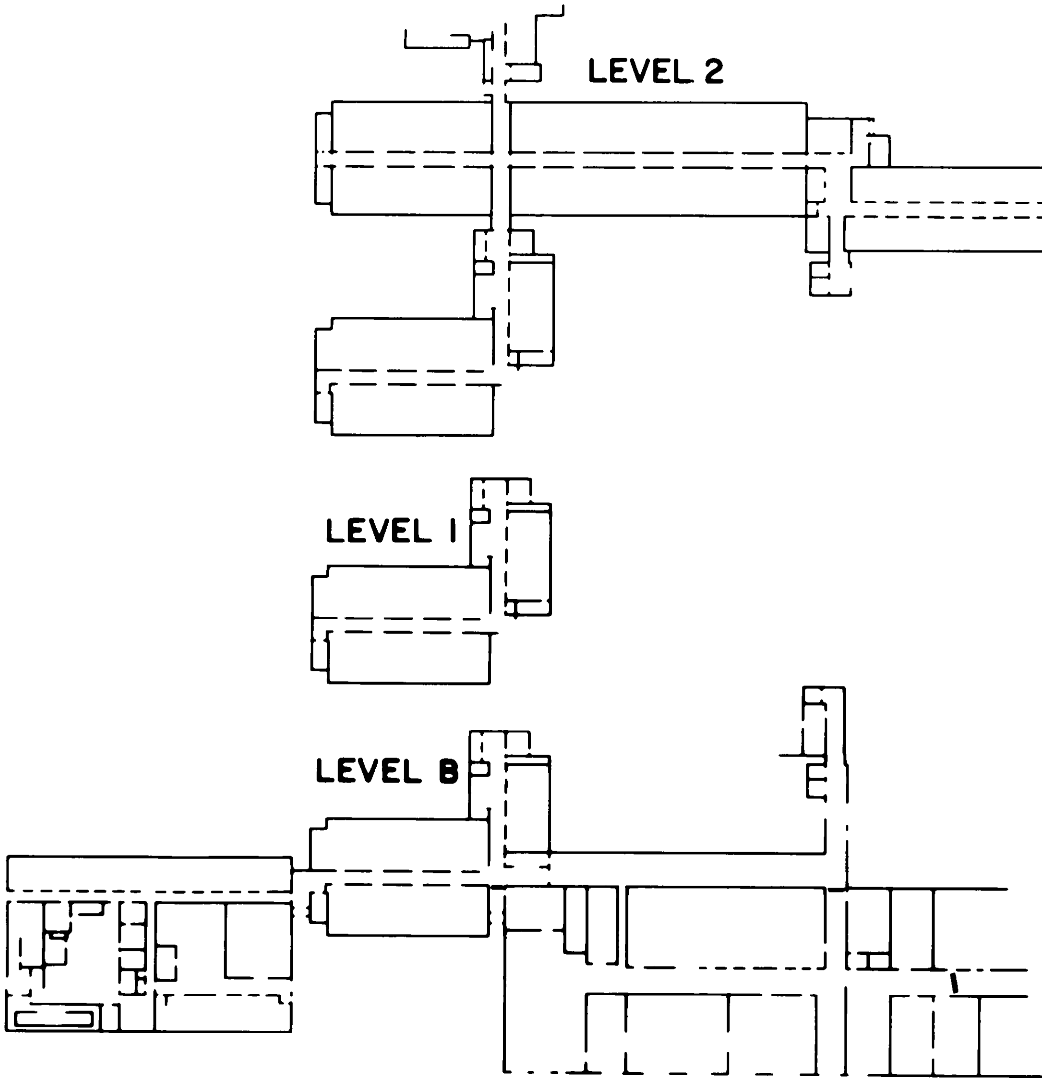

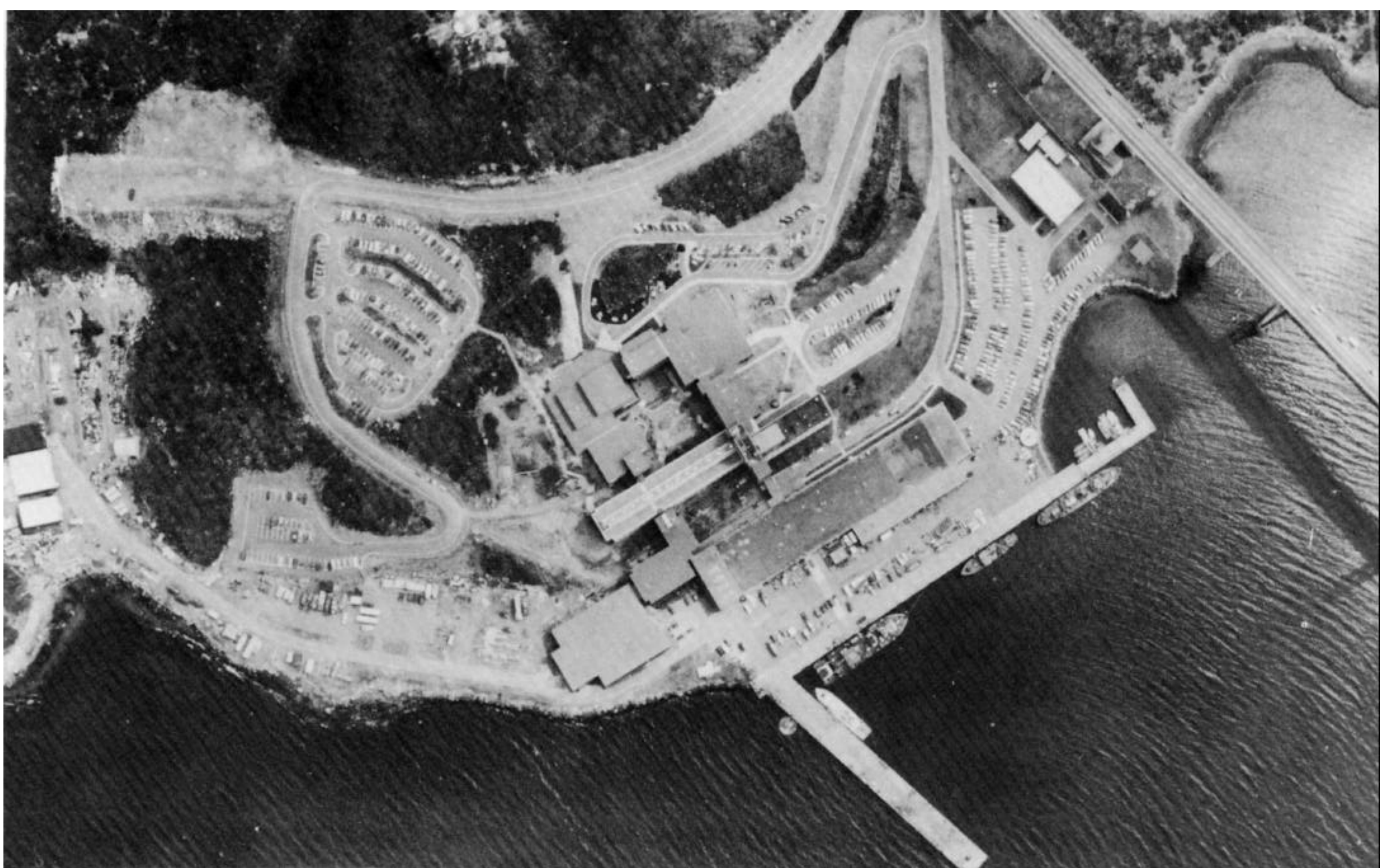

Roger Belanger 3954-3

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